Characterization of small-pitch 3D sensors from CNM

Esteban Currás[1,2], **Gervasio Gómez**[1], **Iván Vila**[1], **Marcos Fernández**[1,2], **Javier González**[1], **Richard Jaramillo**[1], **Andrea García**[1], **Jordi Duarte**[1,2], **David Moya**[1], **Salvador Hidalgo**[3], **Giulio Pellegrini**[3], **David Quirion**[3], **Michael Moll**[2]

[1]IFCA – [2]CERN - [3]CNM

30th RD50 Workshop
Radiation hard semiconductor devices for very high luminosity colliders
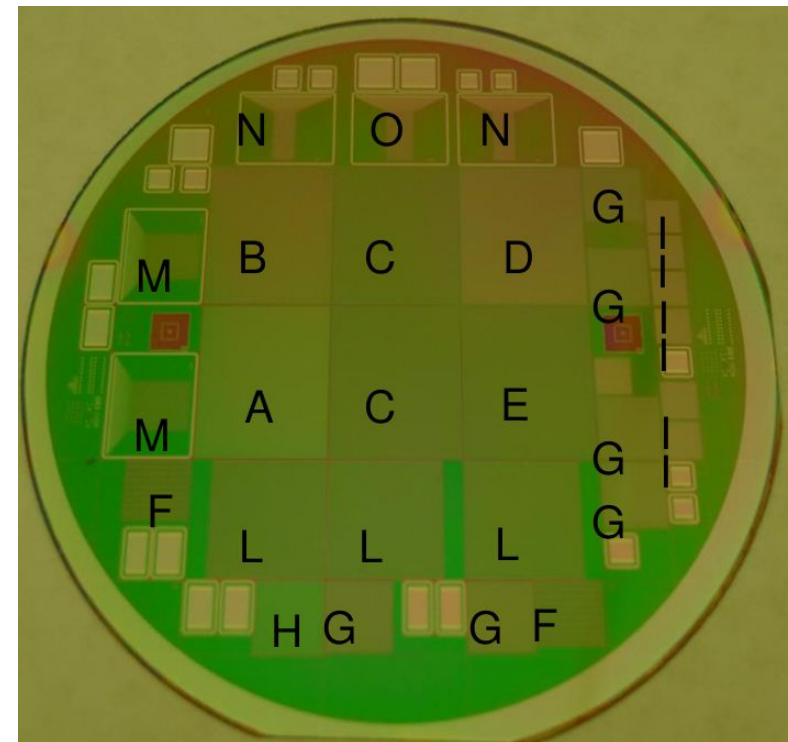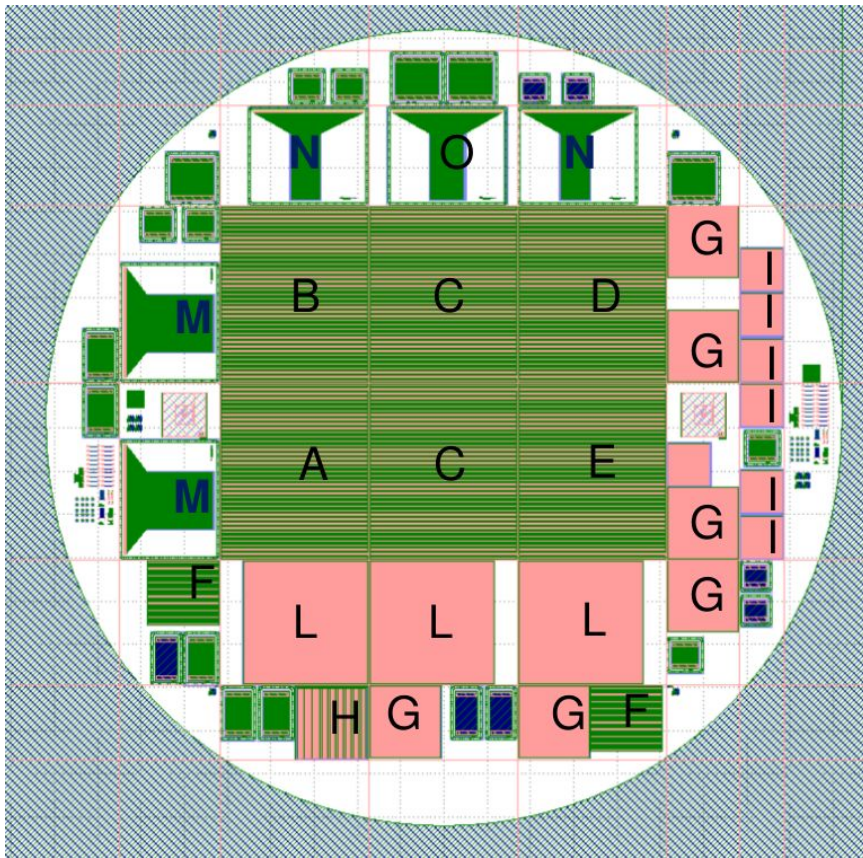Krakow, 5-7 June 2017

CNM small pitch double sided 3D run (7781)

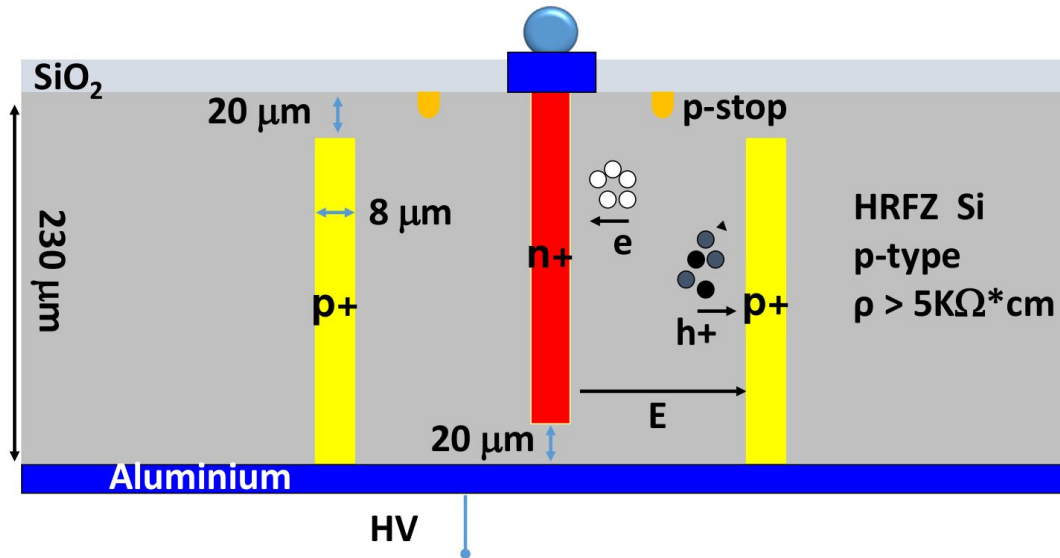This study focuses on strips (M,N) readout using Alibava and pads:

M: Strip 50x50x230 μm^3
N: Strip 25x100x230 μm^3
Pads: 50x50x230 μm^3 and 25x50x230 μm^3

CNM double sided 3D process: cross section and layout

SiO₂

20 μm

230 μm

8 μm

p+

n+

e

p-stop

HRFZ Si
p-type
ρ > 5KΩ*cm

h+
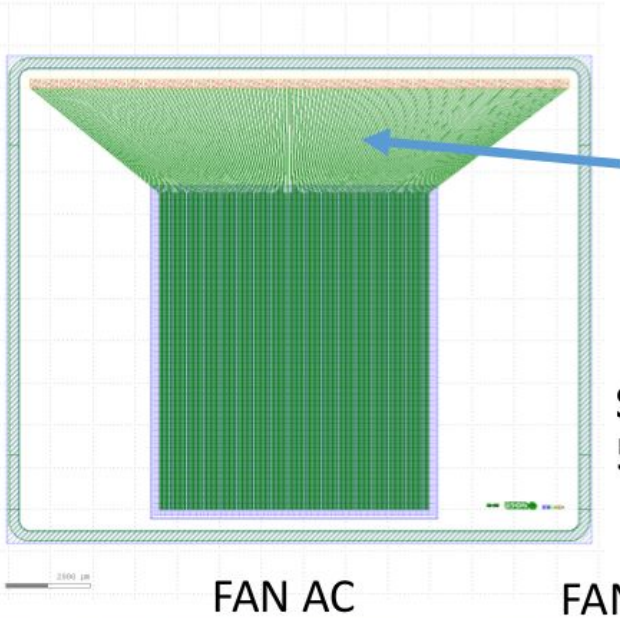
p+

E

20 μm

Aluminium
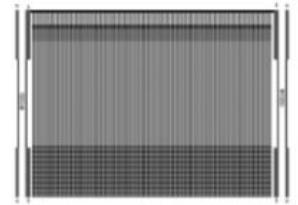
HV

➤ 25x100 (1E) μm²
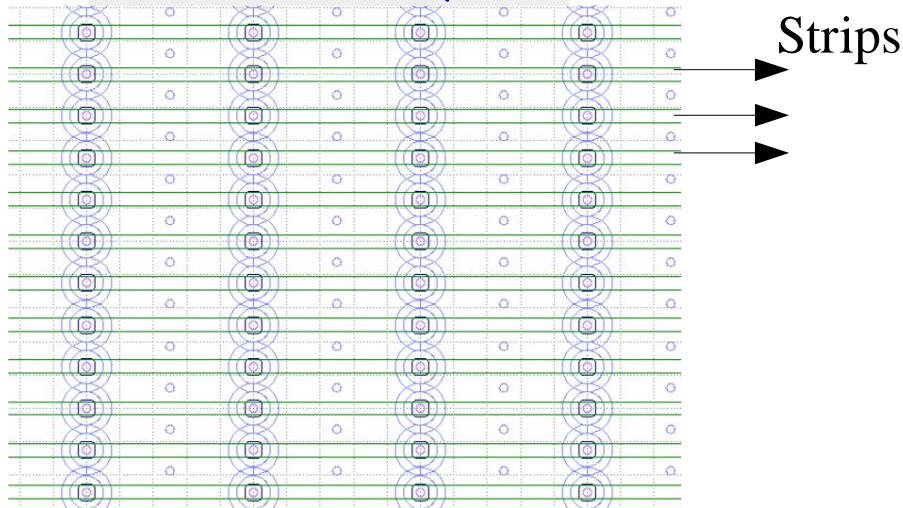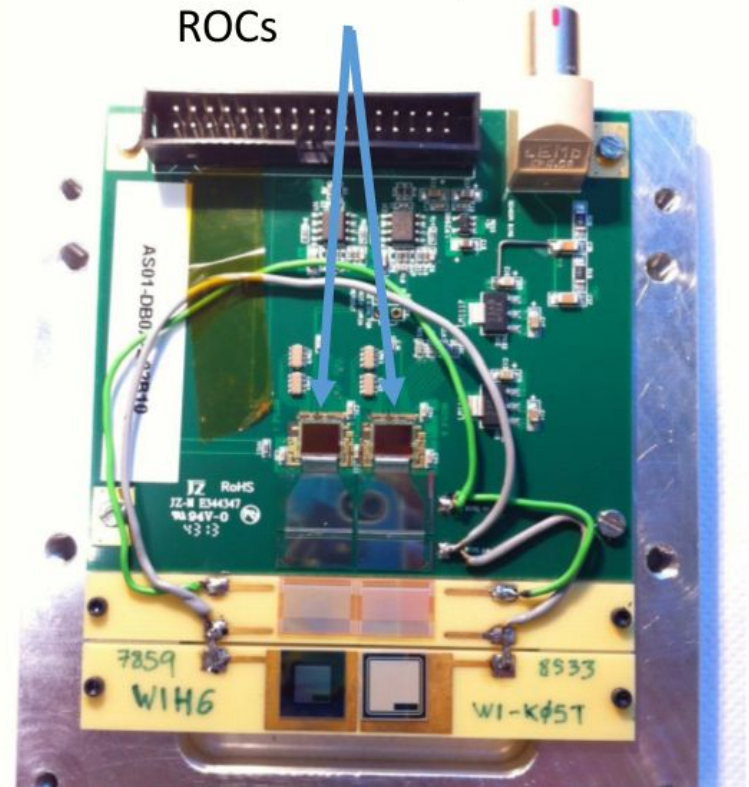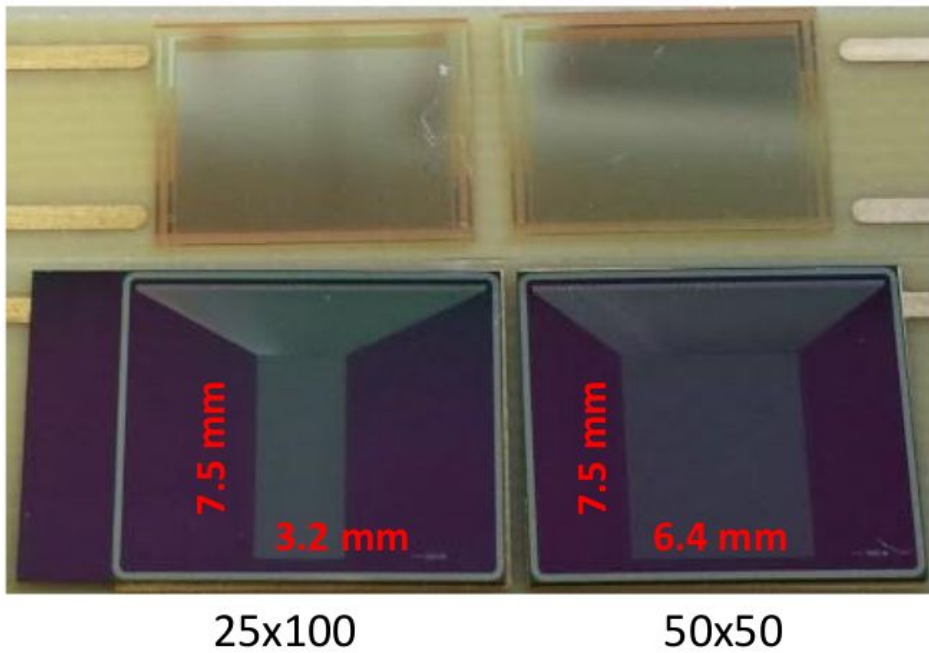
Strips

➤ 50x50 (1E) μm²
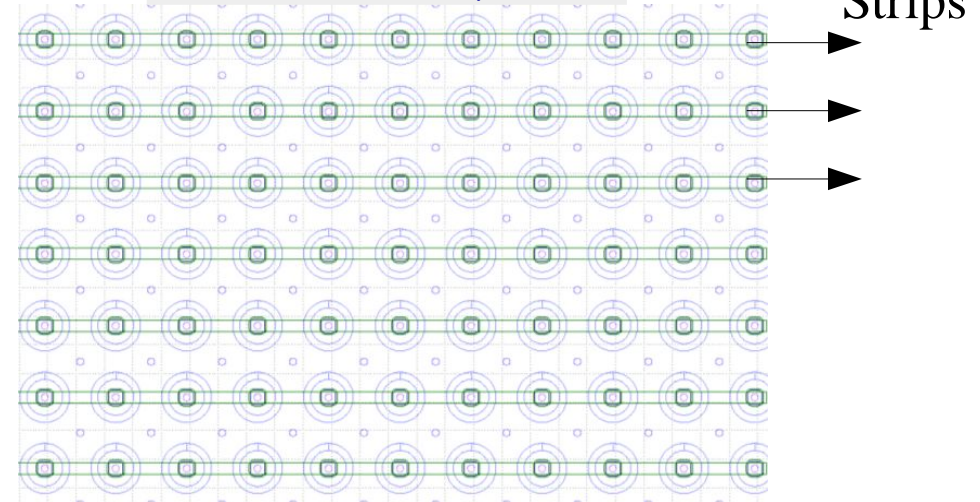
Strips

DUT:3D strips

Metal routing to fit 80 μm pitch electronics (Alibava Systems). Connected through fan AC.

Strip geometries tested: 50x50 μm², 25x100 μm²

Alibava daughter board with 2 beetle (strip) ROCs

FAN AC   FAN AC

7.5 mm   3.2 mm

7.5 mm   6.4 mm

25x100   50x50

Sensors' status and measurements performed:

Strips

- Two unirradiated strip sensors:
  M: 50x50 μm^2 (M1_5) and N: 25x100 μm^2 (N1_3)

- Two irraditated strip sensor → $7x10^{15}$ ±7% p/cm^2 at CERN PS line (24 GeV protons):
  M: 50x50 μm^2 (M1_8) → "bad sensor readout" and N: 25x100 μm^2 (N1_7)

- Two irraditated strip sensor → $1.7x10^{16}$ ±7% p/cm^2 at CERN PS line (24 GeV protons):
  M: 50x50 μm^2 (M2_3) and N: 25x100 μm^2 (N1_8)

➢ Test beam at CERN SPS with Alibava readout:
  1st in July 2016 and 2nd in May 2017

➢ IV/Power studies.

⭐ **Characterization with ^{90}Sr radioactive source → results in this talk.**

Pads

- Ten unirradiated pads sensors:
  Five 50x50 μm^2 and five 25x50 μm^2

⭐ **IV and CV characterization of 3D pads sensors → results in this talk.**

Test beam 2017 schematic → analysis ongoing
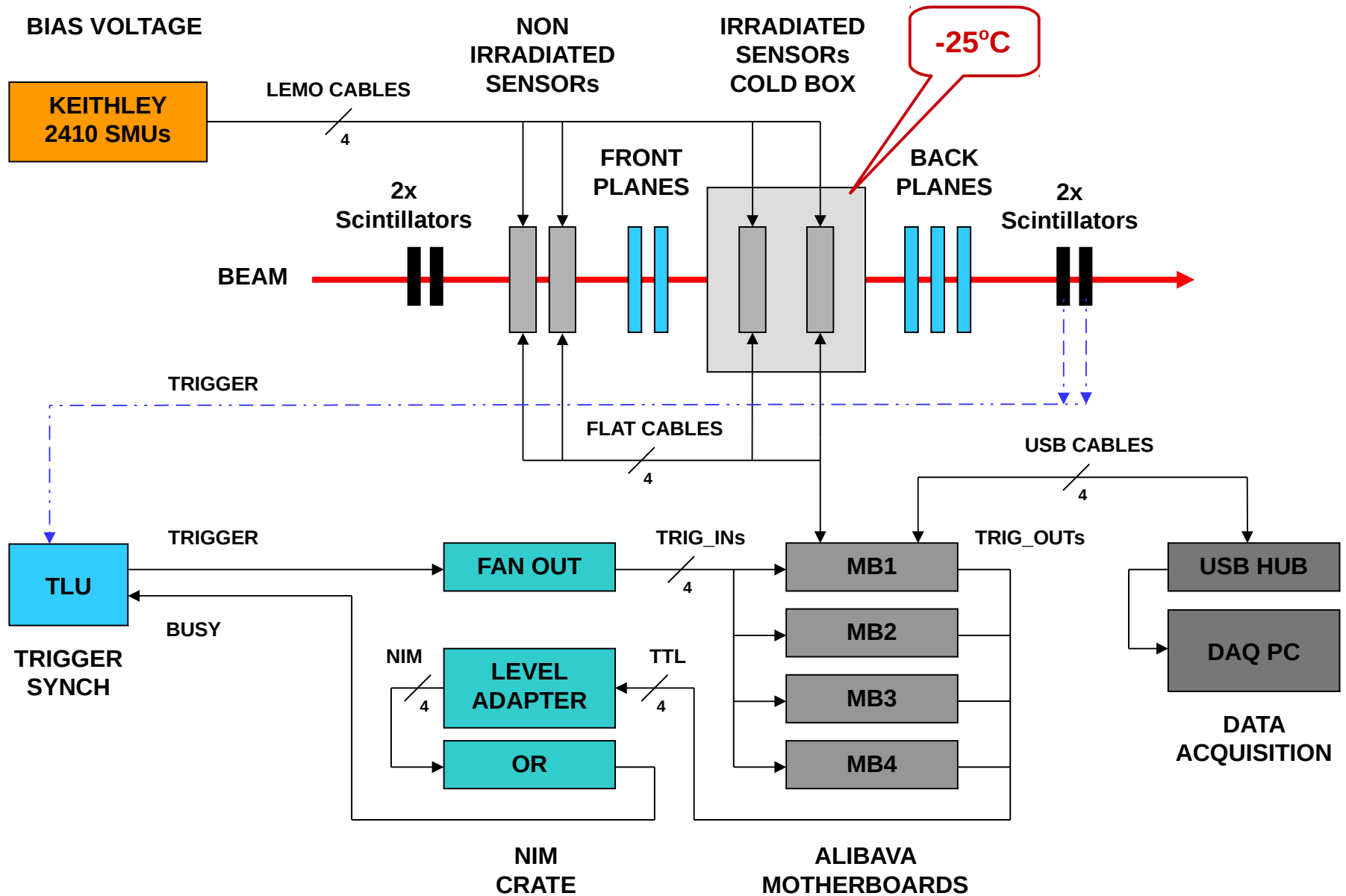
Strips ^{90}Sr Characterization → data analysis summary

- Raw data → subtract common noise (shift per event) → subtract pedestal per strip

- Noise per strip is extracted from the pedestal run

- The Alibava beetle chips are calibrated (ADC → electrons)

Noise per channel beetle 2, ADC
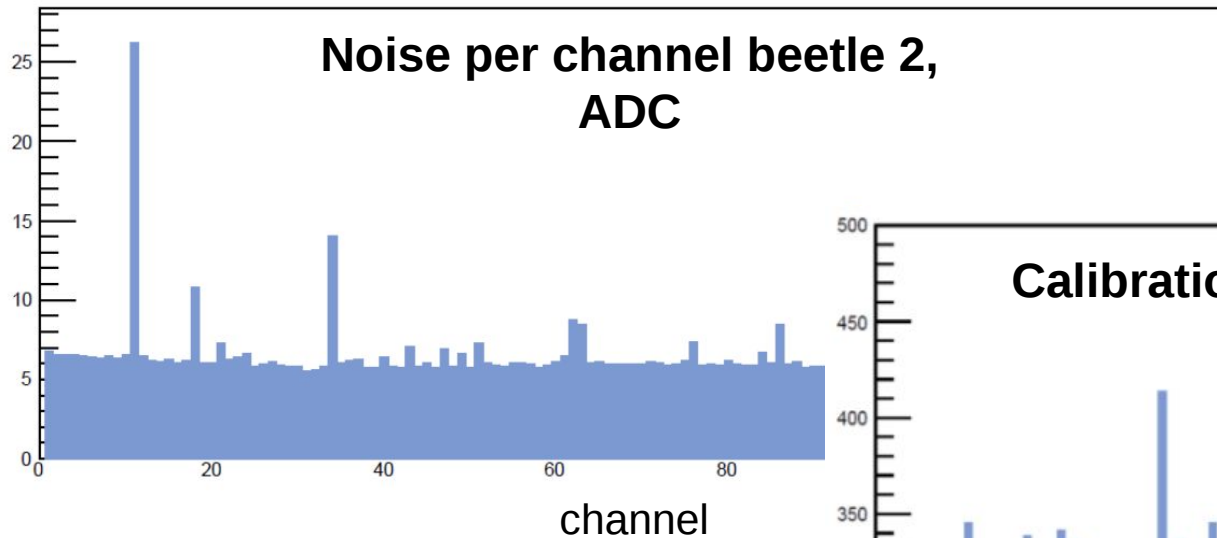
Strong temperature dependence

Insensitive to Vbias

Calibration value per channel beetle 2, electrons/ADC

channel

channel

Noise in the unirradiated strips:

At +22°C → 2400 electrons

At -25°C → 1800 electrons
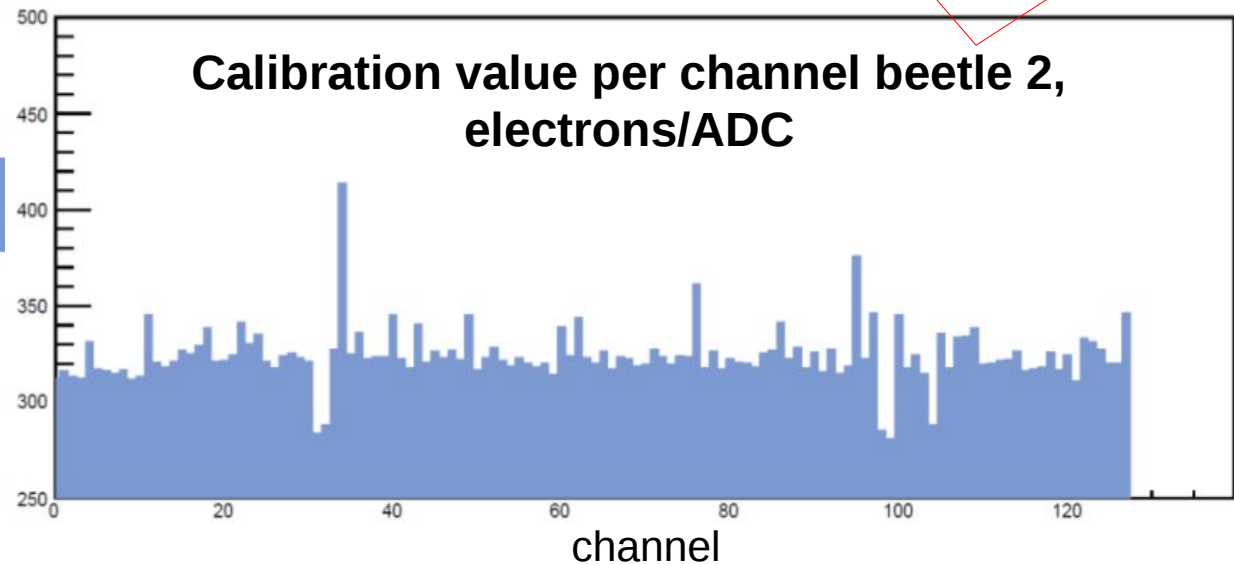
Strips ^{90}Sr Characterization → data analysis summary

- Strips with S/N > 5 are considered a "hit"

- Strips with a "hit" are seeds for clusters → Neighboring strips with S/N > 3 are associated to the cluster

- The final calibrated cluster signal distribution is fitted with a convoluted function → Landau * Gauss
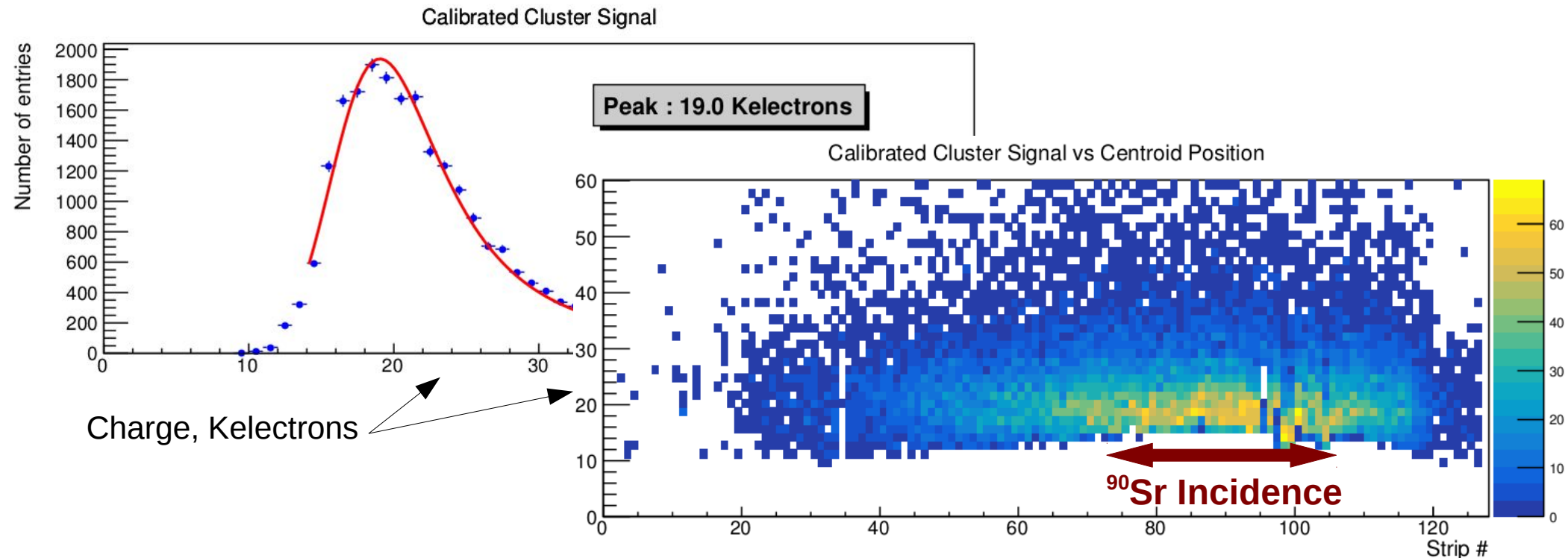
Peak : 19.0 Kelectrons

Charge, Kelectrons

Calibrated Cluster Signal vs Centroid Position

^{90}Sr Incidence

Strips ^{90}Sr Characterization → Charge collected before irradiation

Charge measured with ^{90}Sr at -25°C

M1-5 (50x50) unirradiated ■

ref 230 um   unirradiated ┄

Charge expected using 76 e/µm equivalence in 230 µm of silicon (≈ 17.500 electrons)

Charge higher that expected:
1) energy deposition → ^{90}Sr slightly higher than a MIP.
2) Normal incidence → ionization path higher than 230 um.

High charge collected at 0V!!
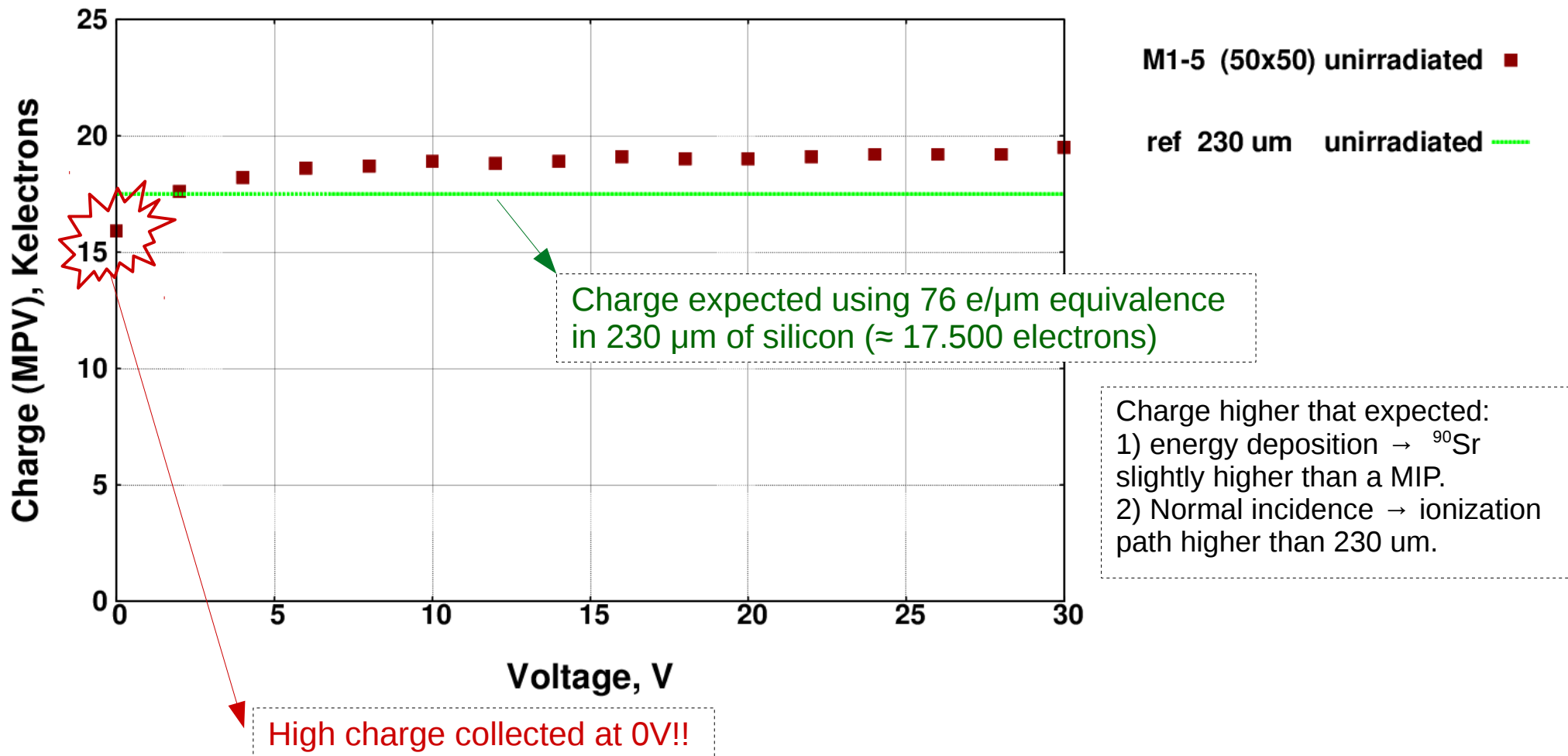
Strips ^{90}Sr Characterization → Charge collected before irradiation

Charge at 0V

3D pixels deplete laterally:
→ Good charge collection even at 0V!!
→ But efficient only near union column

mip
SiO$_2$
p-stop
n+
π bulk   p+   p+
230 μm
HV
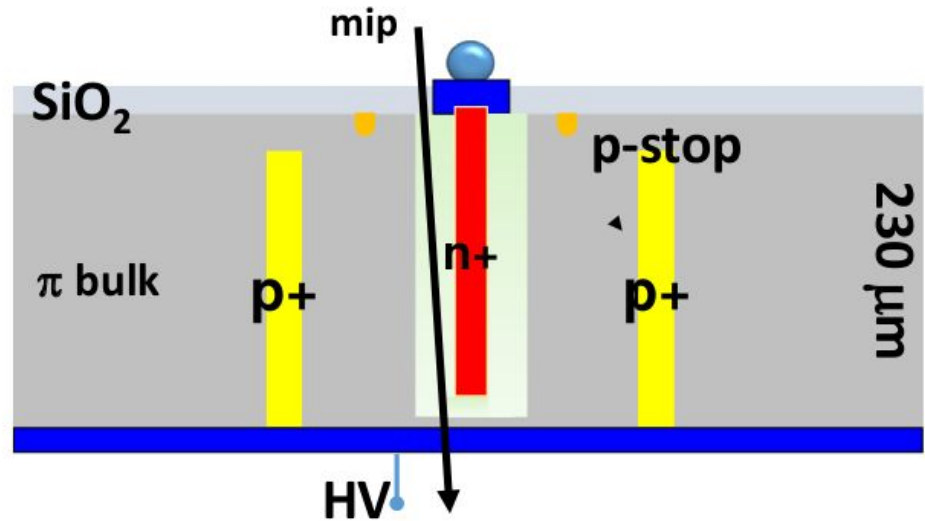
Nice charge distribution

Calibrated Cluster Signal

Number of entries

Peak : 15.9 Kelectrons

50x50 μm^2 unirradiated

Charge (electrons x10^3)
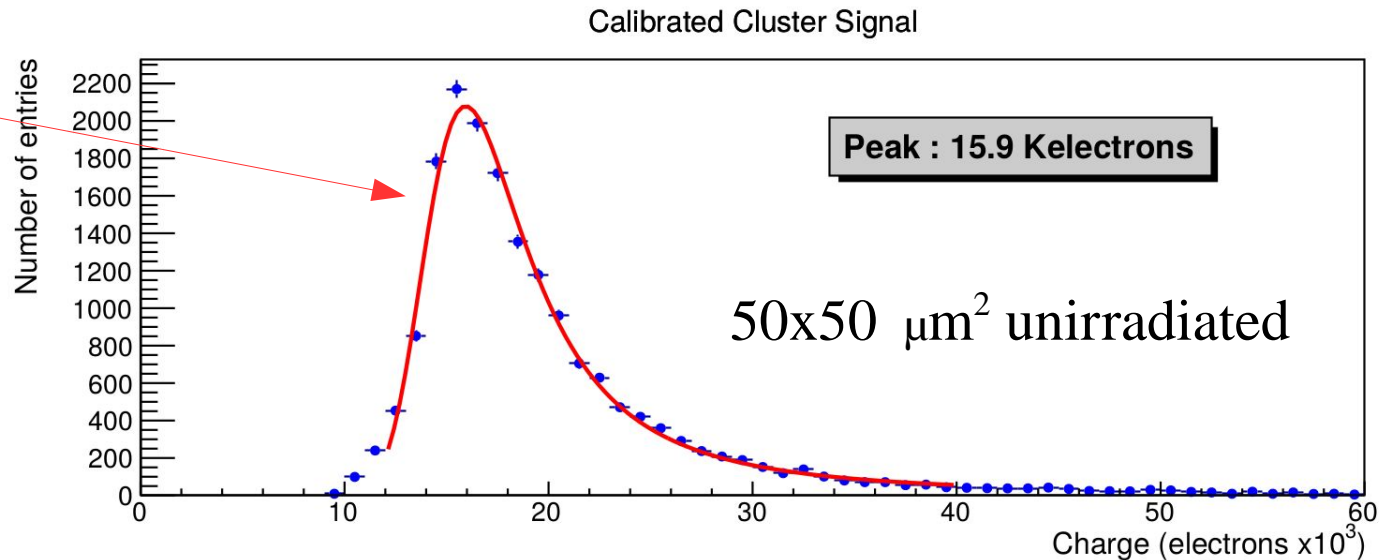
Strips ^{90}Sr Characterization → Charge collected after irradiation

Charge measured with ^{90}Sr at -25°C

We might have charge multiplication at high voltages

M2-3 (50x50) 1.0×10^{16} n_{eq}/cm^2 ■

N1-8 (25x100) 1.0×10^{16} n_{eq}/cm^2 ●

N1-7 (25x100) 5.7×10^{15} n_{eq}/cm^2 ●

M1-5 (50x50)   unirradiated ---

High charge collection at moderate Vbias

Better behavior of the 50x50 µm^2
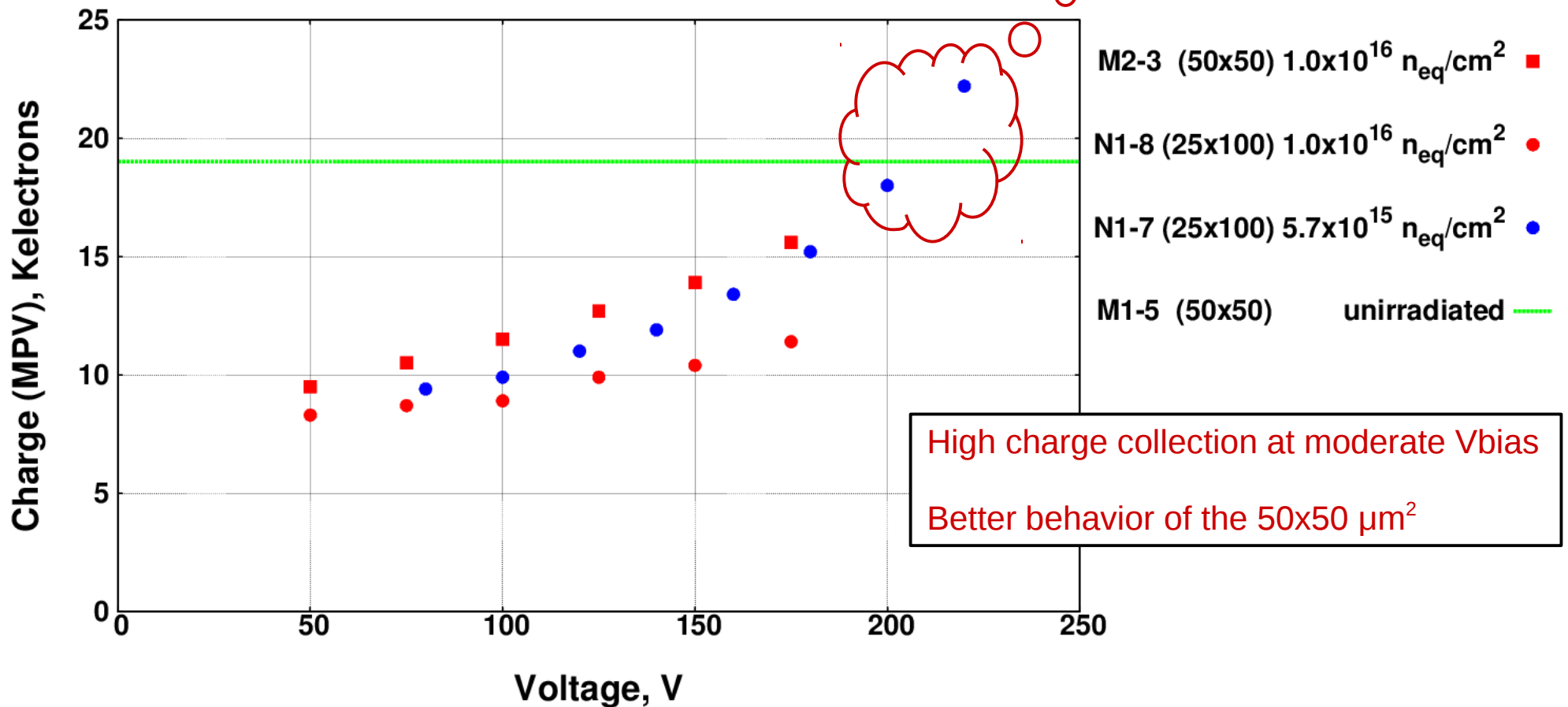
Strips IV measurements after irradiation

IV measurement at -25°C

Current measured is dominated by edge current

A few nA for the unirradiated (up to 25V)

M2-3 (50x50) 1.0×10^{16} n_{eq}/cm^2 ■

N1-8 (25x100) 1.0×10^{16} n_{eq}/cm^2 ●

N1-7 (25x100) 5.7×10^{15} n_{eq}/cm^2 ●

M1-8 (50x50) 5.7×10^{15} n_{eq}/cm^2 ■

Current per pixel, nA

Voltage, V
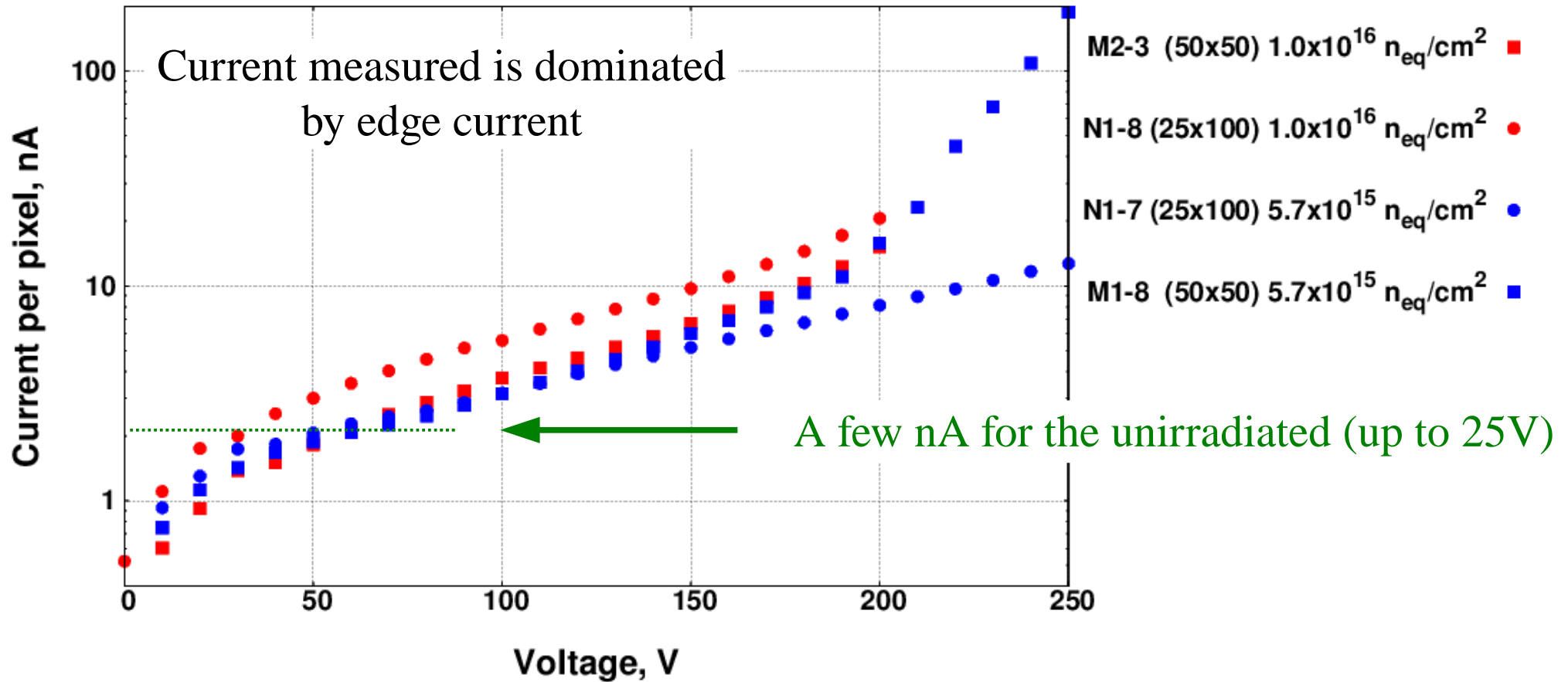
Strips power consumption after irradiation
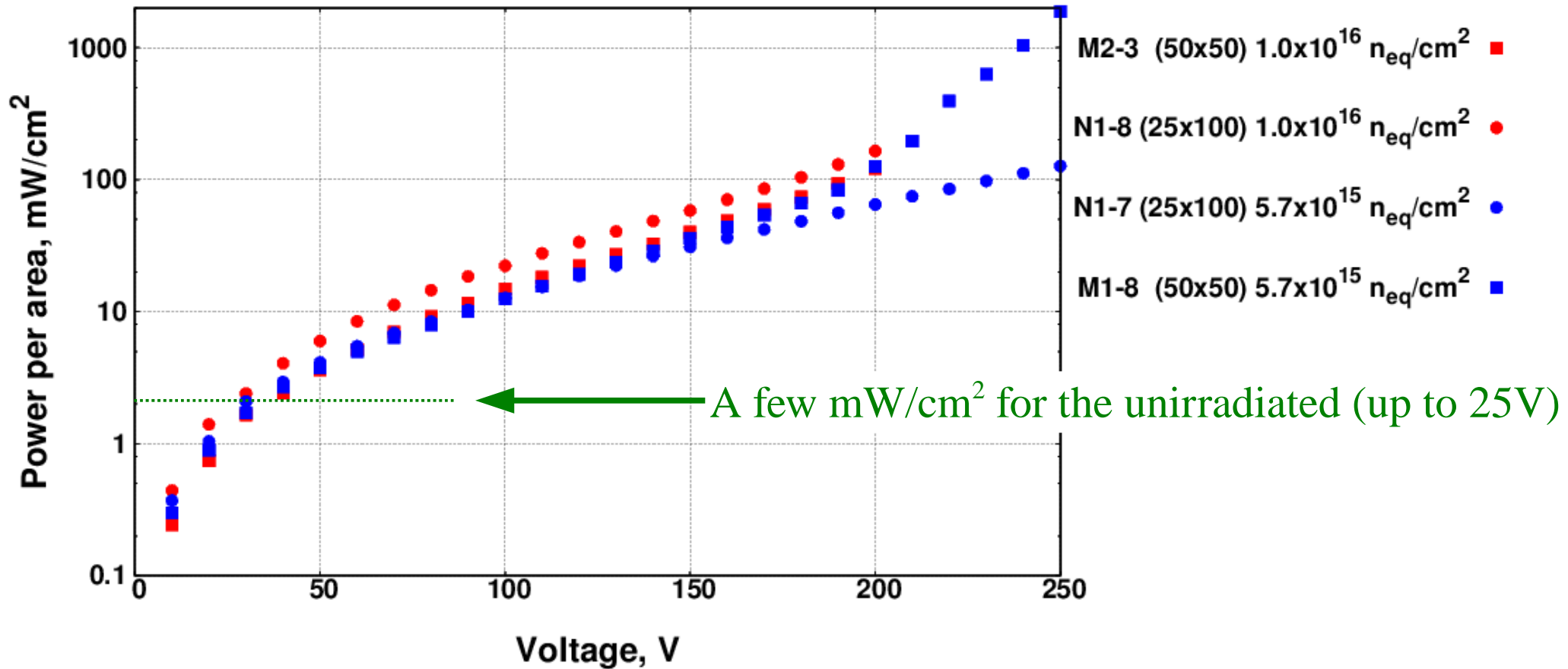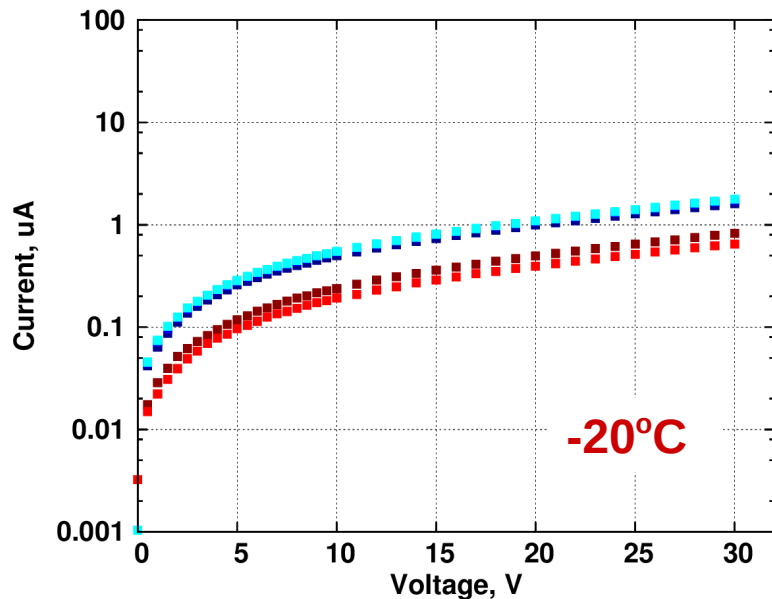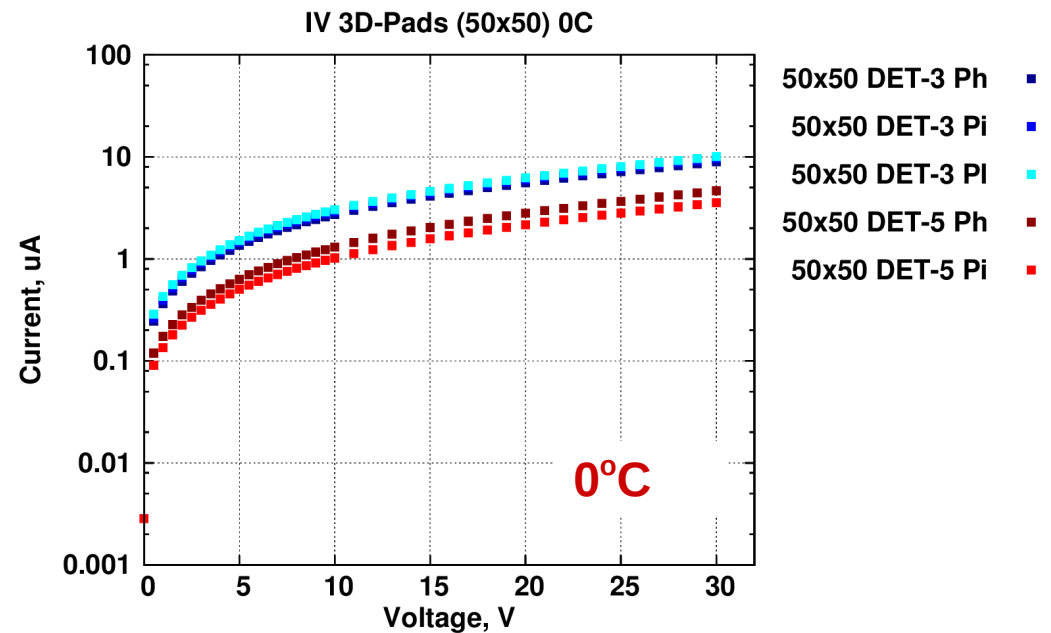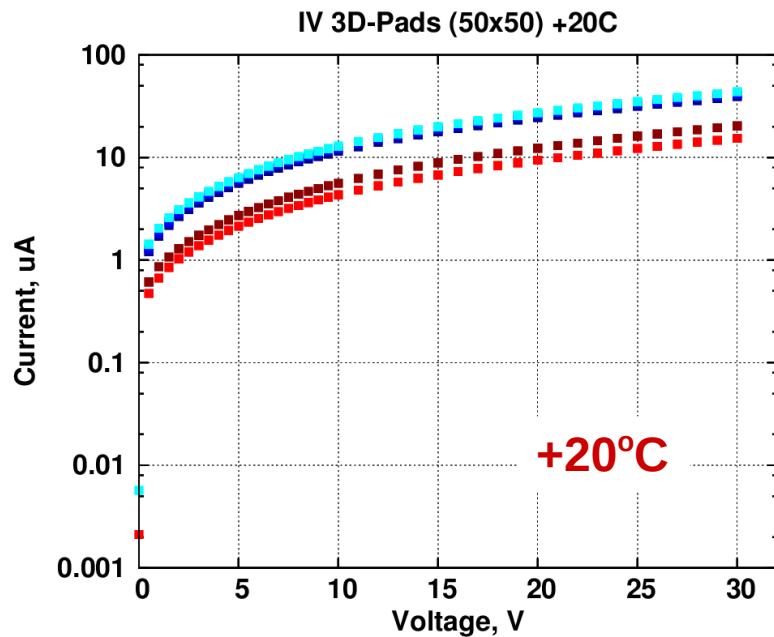
IV measurement at -25°C

M2-3 (50x50) 1.0×10^{16} n_{eq}/cm^2 ■ (red)

N1-8 (25x100) 1.0×10^{16} n_{eq}/cm^2 ● (red)

N1-7 (25x100) 5.7×10^{15} n_{eq}/cm^2 ● (blue)

M1-8 (50x50) 5.7×10^{15} n_{eq}/cm^2 ■ (blue)

A few mW/cm^2 for the unirradiated (up to 25V)

IV and CV characterization of 3D pads sensors

IV 3D-Pads (50x50) +20C

IV 3D-Pads (50x50) 0C

Legend:
- 50x50 DET-3 Ph
- 50x50 DET-3 Pi
- 50x50 DET-3 Pl
- 50x50 DET-5 Ph
- 50x50 DET-5 Pi

-20°C

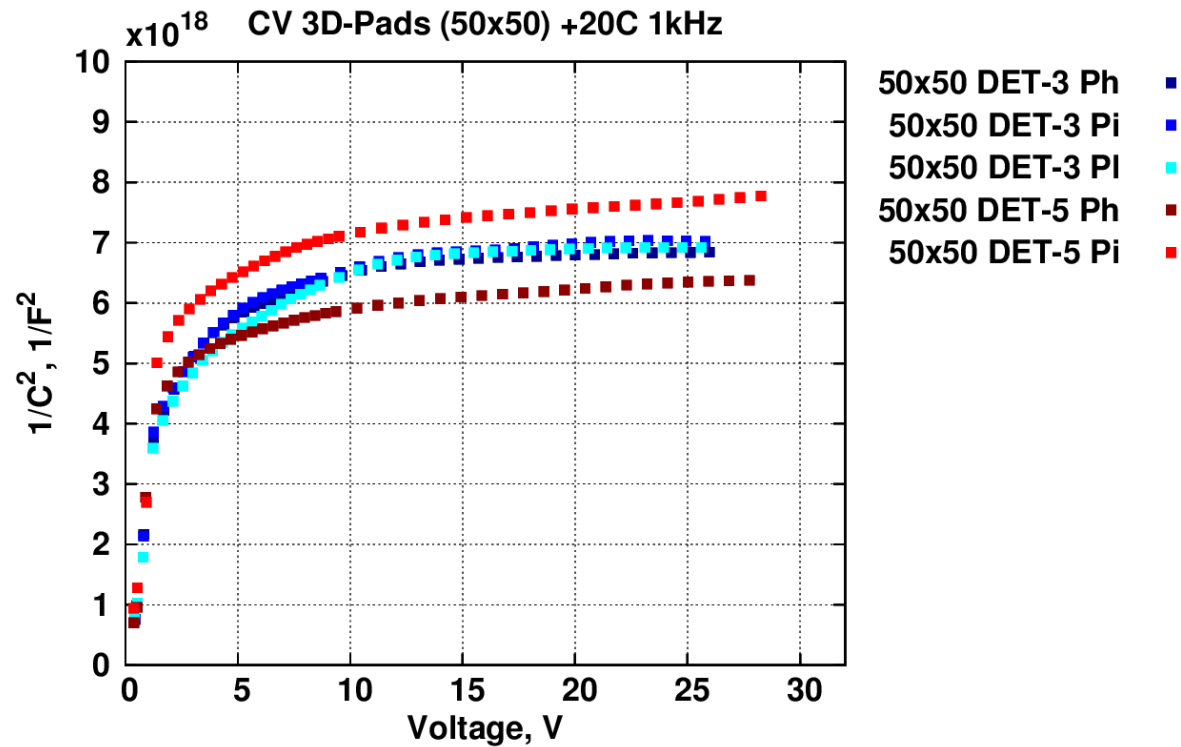## 50x50 μm^2

Total current → per pixel is 10^4 times lower (10^4 pixels per pad)

Current measured dominated by edge current

IV and CV characterization of 3D pads sensors

CV 3D-Pads (50x50) +20C 1kHz

CV 3D-Pads (50x50) +20C 1kHz

Legend:
50x50 DET-3 Ph
50x50 DET-3 Pi
50x50 DET-3 PI
50x50 DET-5 Ph
50x50 DET-5 Pi

50x50 μm^2

Capacitance of one single pixel → ≈ 40 fF

IV and CV characterization of 3D pads sensors

IV 3D-Pads (25x50) +20C

+20°C

IV 3D-Pads (25x50) 0C

0°C

-20°C
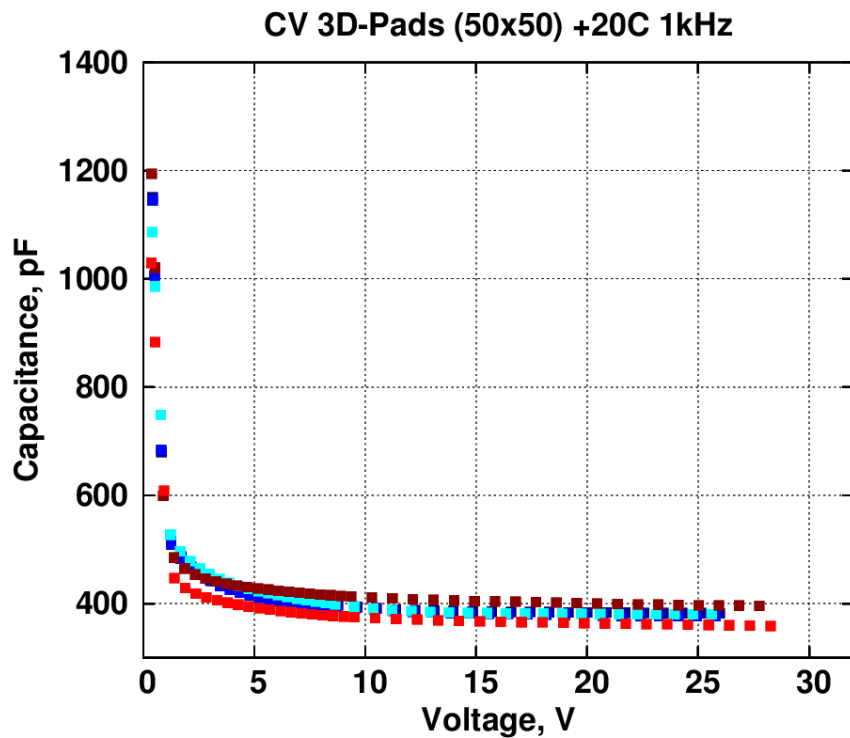
25x50 DET-3 Pu
25x50 DET-3 Pv
25x50 DET-4 Pv
25x50 DET-5 Pu
25x50 DET-5 Pv

25x50 μm^2

Total current → per pixel is 10^4 times lower (10^4 pixels per pad)

Current measured dominated by edge current

Esteban Curras

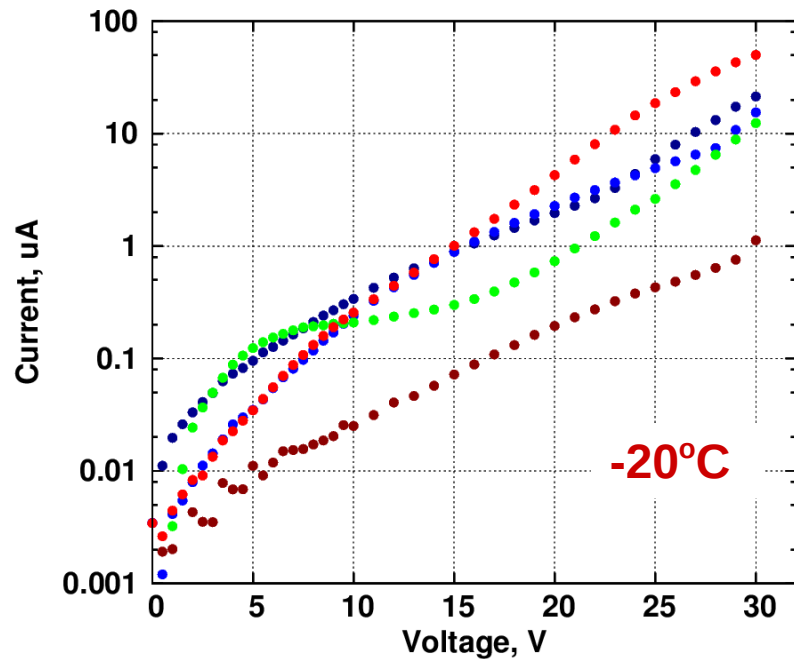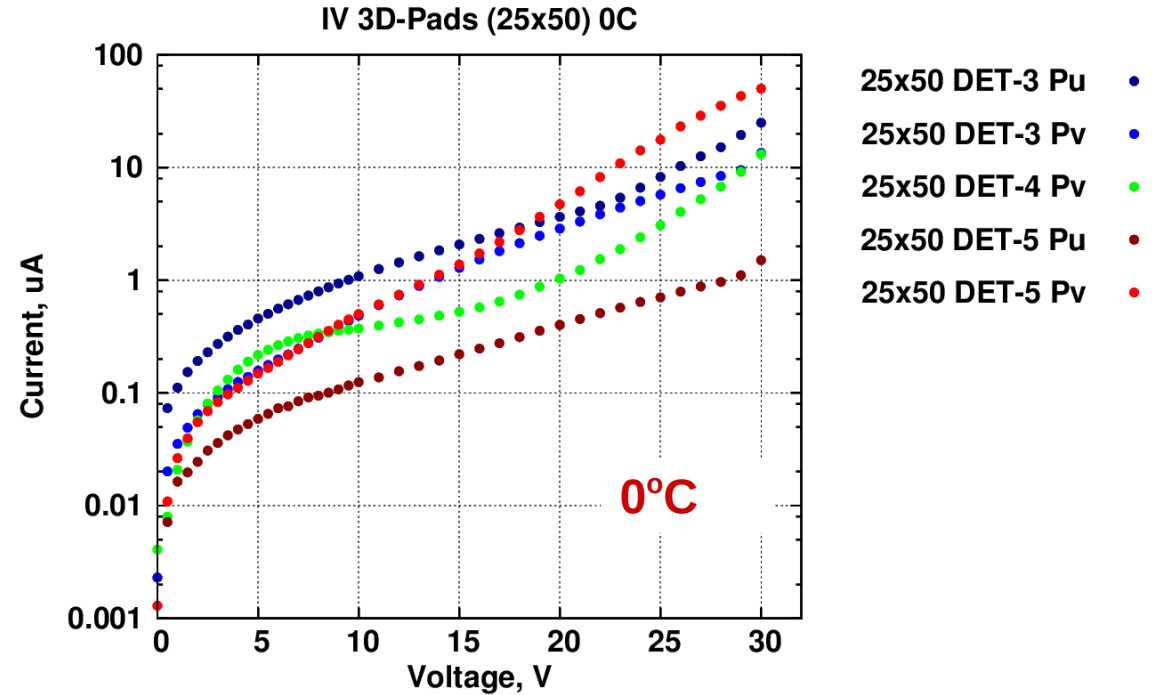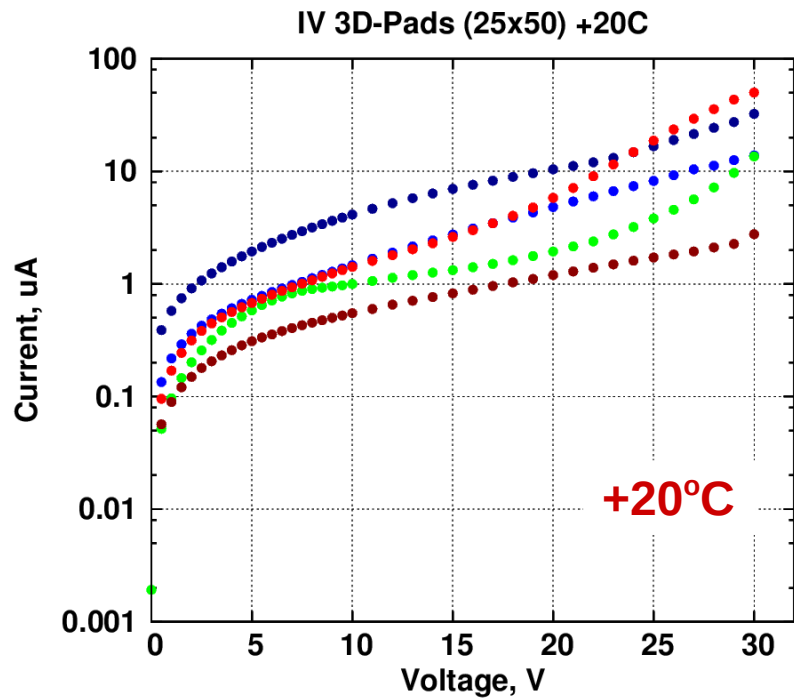# IV and CV characterization of 3D pads sensors

CV 3D-Pads (25x50) +20C 1kHz

CV 3D-Pads (25x50) +20C 1kHz

Legend:
- 25x50 DET-3 Pu
- 25x50 DET-3 Pv
- 25x50 DET-4 Pv
- 25x50 DET-5 Pu
- 25x50 DET-5 Pv

25x50 μm^2

Capacitance of one single pixel → ≈ 60 fF

Summary

- Strip sensors

  Proton irradiated at fluence up to 1.0×10^{16} n_{eq}/cm^2 done

  $\rightarrow$ Good charge collection at not very high Vbias

  $\rightarrow$ Better behavior of 50x50 μm after irradiation

  IV/power consumption measurements done

  $\rightarrow$ Current measured dominated by edge current.

  ^{90}Sr characterization done

  Tested in a test beam $\rightarrow$ analysis ongoing

  Compare results with ^{90}Sr characterization $\rightarrow$ to be done

  Measurements of efficiency $\rightarrow$ to be done

- Pad sensors

  IV/CV measurements done

  TCT characterization with IR laser $\rightarrow$ to be done

  Proton irradiation (up to 2.0×10^{16} n_{eq}/cm^2)

  IV/CV measurements

  TCT characterization

Backup slides

Strips noise measurements after irradiation

Noise measured at -25°C

M2-3 (50x50) 1.0×10^{16} n_{eq}/cm^2 ■

N1-8 (25x100) 1.0×10^{16} n_{eq}/cm^2 ●

N1-7 (25x100) 5.7×10^{15} n_{eq}/cm^2 ●