Test of new sensors for the HL-LHC CMS upgrade

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Goals of the internship

- Test new sensors for the HL-LHC CMS upgrade

- Improve a LabView controlled probe station for testing sensors before and after irradiation

- Develop ROOT (CERN) software in order to analyze the data obtained from the sensor tests.

HL-LHC CMS Upgrade

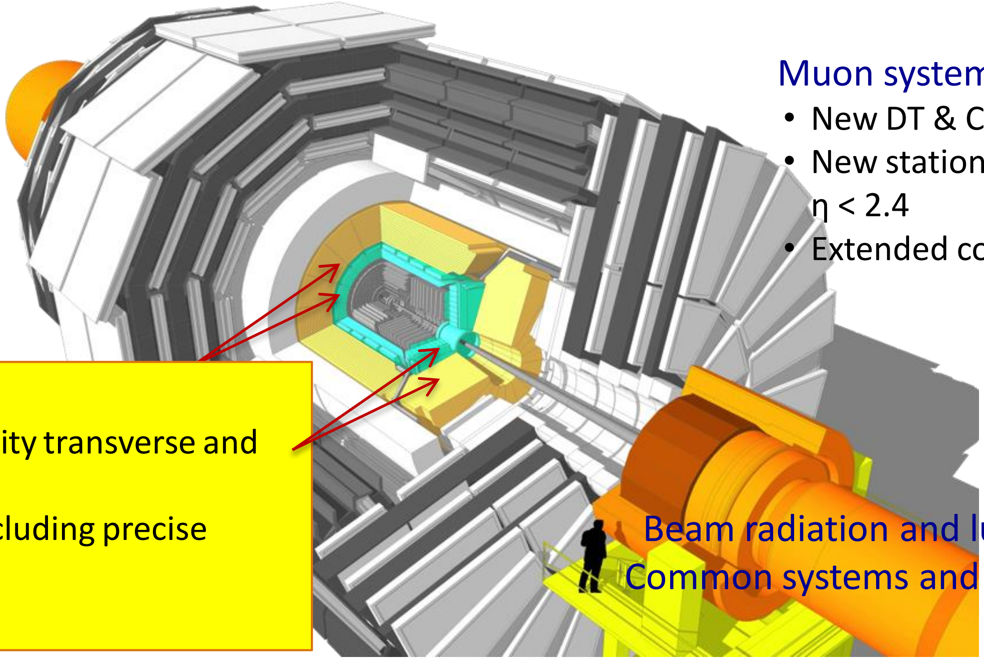
- LHC Luminosity increasing to $5 \times 10^{34} cm^{-2} s^{-1}$

Trigger/HLT/DAQ

- Track information in trigger at 40 MHz
- 12.5 μs latency
- HLT input/output 750/7.5 kHz

Barrel Calorimeter

- New FE/BE electronics for full granularity readout at 40 MHz - with improved time resolution
- Lower ECAL operating temperature (8°C)



Muon systems

- New DT & CSC FE/BE electronics
- New station to complete CSC at 1.6 < η < 2.4
- Extended coverage to η ≃ 3

New Endcap Calorimeters

- Rad. tolerant - High granularity transverse and longitudinal
- 4D shower measurement including precise timing capability

Beam radiation and luminosity

Common systems and infrastructure

New Tracker

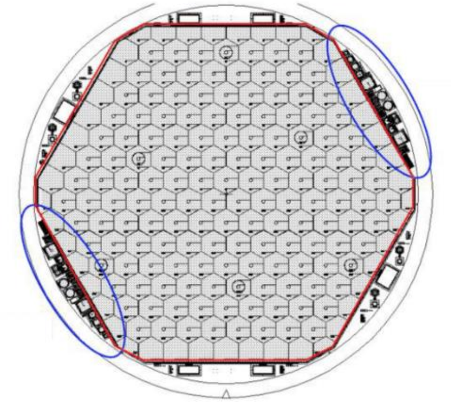
- Rad. tolerant - increased granularity - lighter
- 40 MHz selective readout (strips) for Trigger
- Extended coverage to η ≃ 3.8

MIP precision Timing Detector

- Barrel layer: Crystal + SiPM
- Endcap layer: Low Gain Avalanche Diodes

New detectors

CMS HGCal sensor



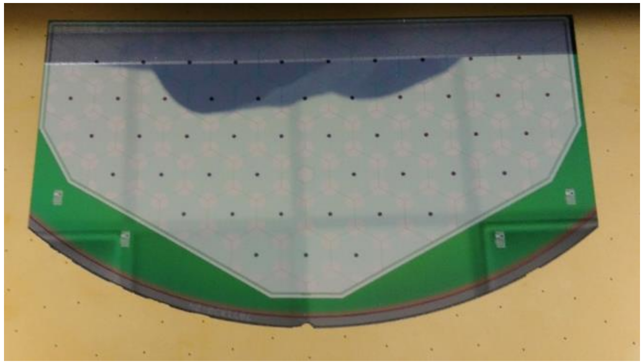
-Improved radiation hardness

-They have to provide improved trigger capabilites

-Higher detector granularity to reduce occupancy

I tested the new sensors made by
Nhanced Semiconductor:

Wafers 1,2,3,4 (half sensor)



- $200\ \mu m$ thick silicon sensors
- Exagonal structure

Tests

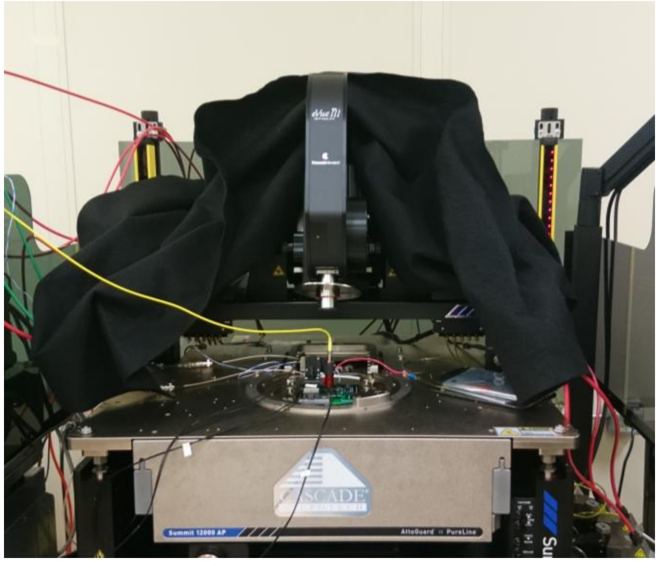
- **Laser Test**: we measure the signal height that comes from the detector when the light of a laser is focused on it. This Measurement allows to study the charge collection efficiency of the detector as a function of the bias potential

- **VI Test**: we measure the leakage current as a function of the bias potential

- **V Test:** we measure the potential of a single channel as a function of the bias potential

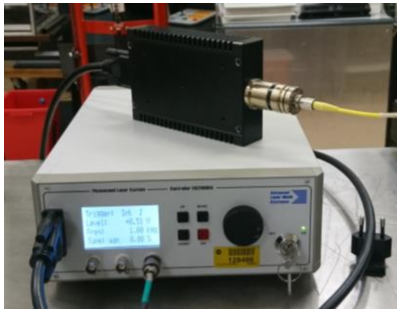
The automatic probe station allows to perform systematic measurements for different channels of a silicon sensor.

The probe station provides a cold chuck that allows operation of the sensors at -30 degrees after irradiation when they need to be kept cold

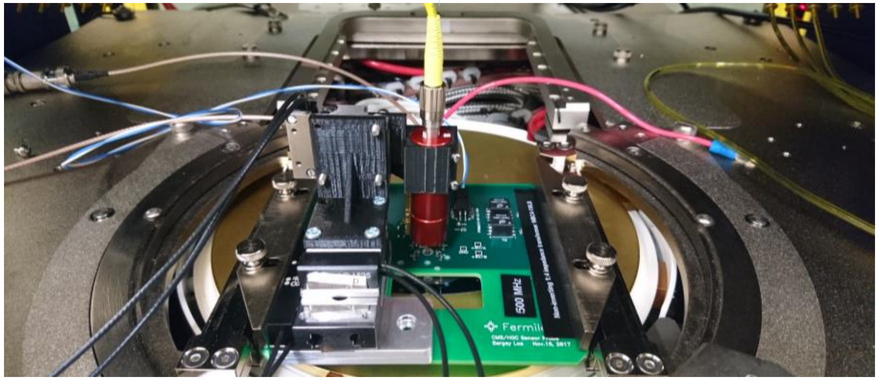


Laser Test: Setup

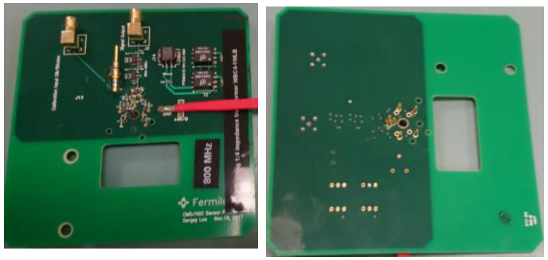
Laser 1080 nm



Automatic probe station

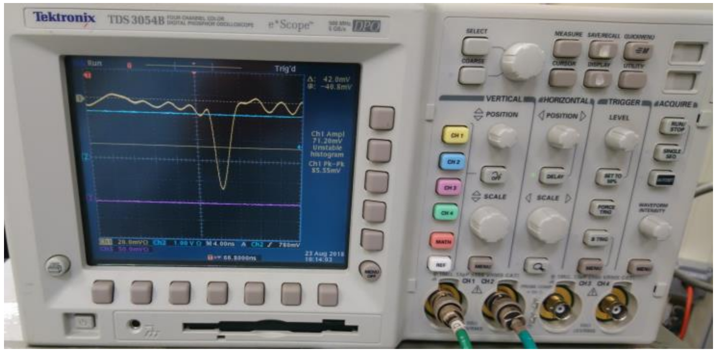


Probe card



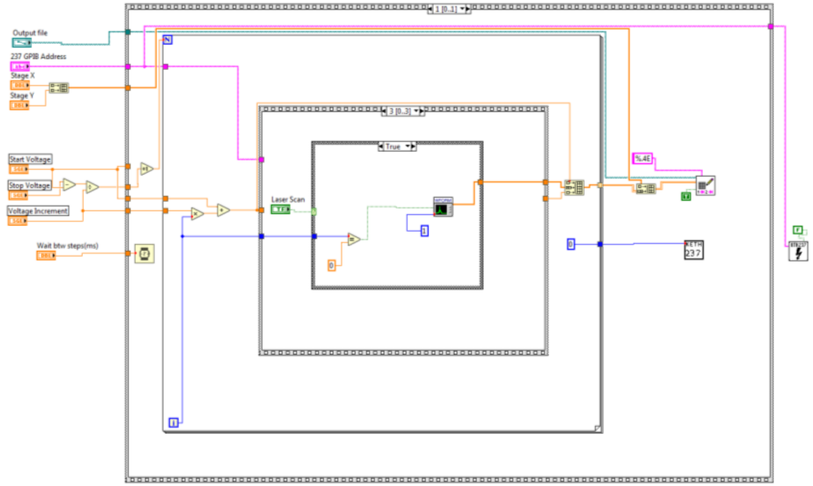
Power supply and measure unit

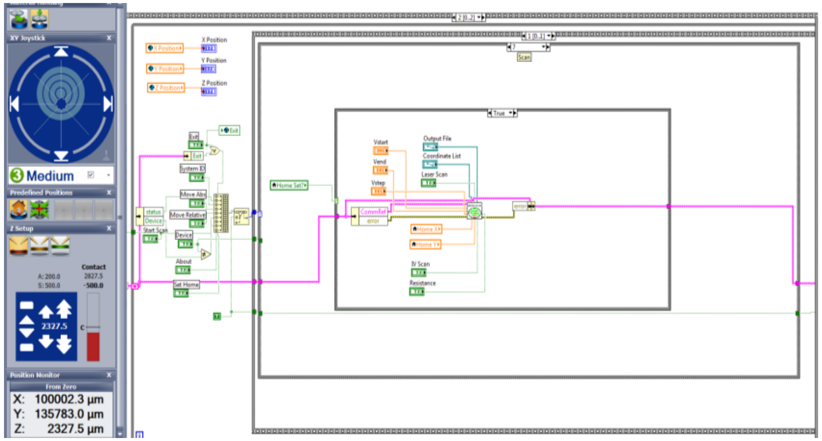
Oscilloscope



Laser Test: LabView VI

- Controls the power supply
- Moves the sample to make systematic measurement for different channels of the detector
- Background subtraction of the acquired data

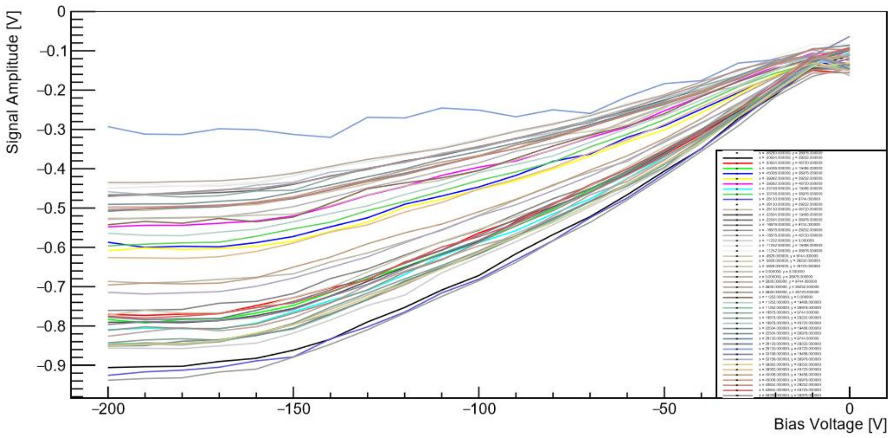


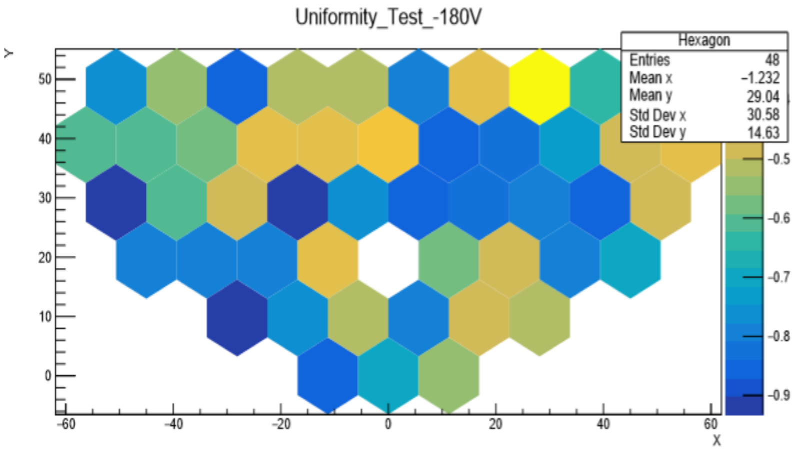


Laser Test: First results

- NHanced silicon sensor for the HGcal (Wafer 4)

Laser test for multiple channels





Signals are too spread out between channels

No correlation across the sensor

Solution: We changed the laser with a faster one

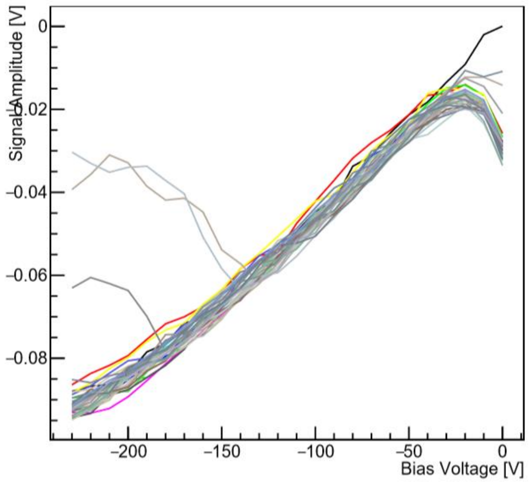
Laser Test: First Results

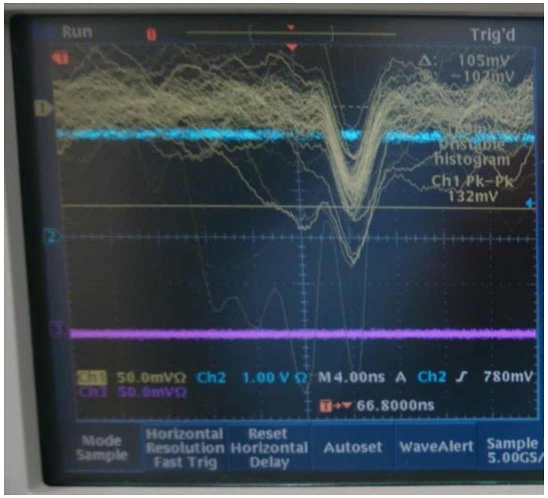
Channel pulse heights become more homogeneous

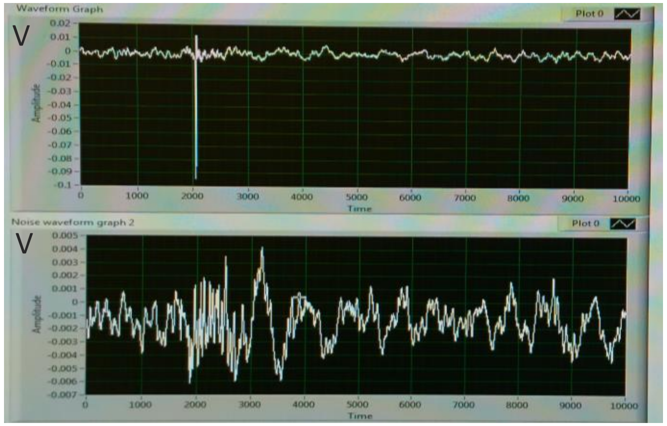
But this new laser is less powerfull than the previous one

There is too much noise and the plateau region isn’t as evident as before

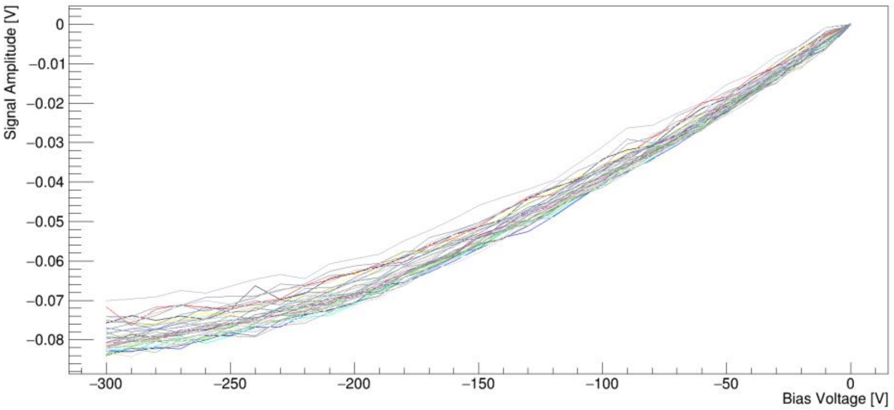
We tried increasing the number of averages and subtracting the noise before measuring the peak value

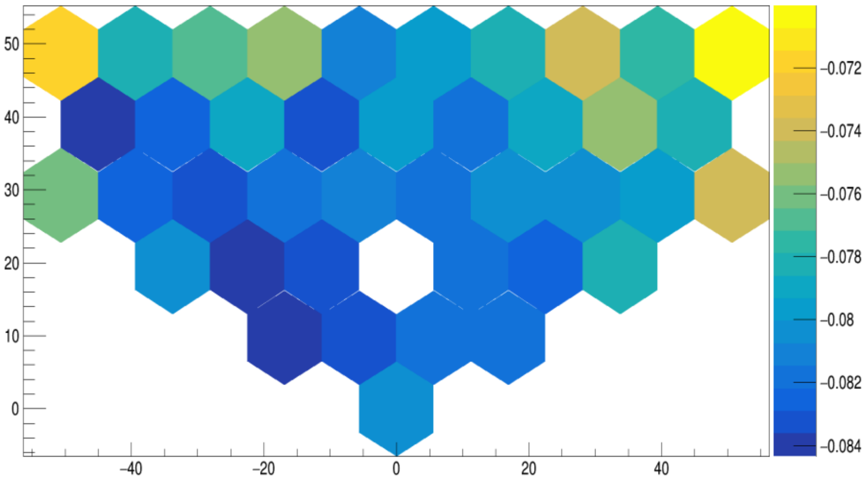


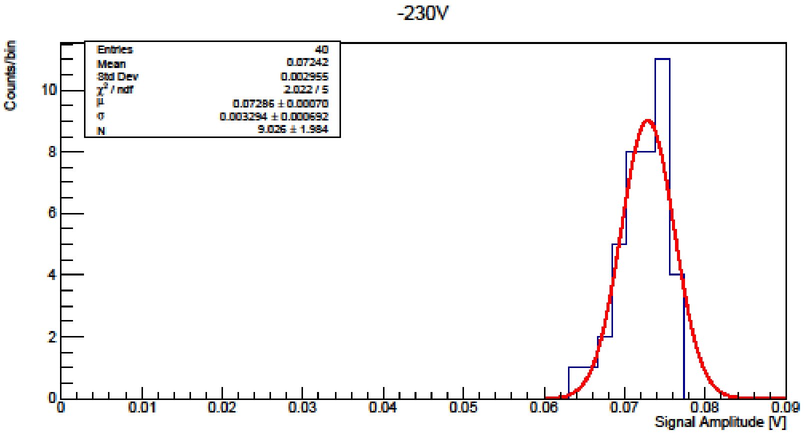




Laser Test: First Results





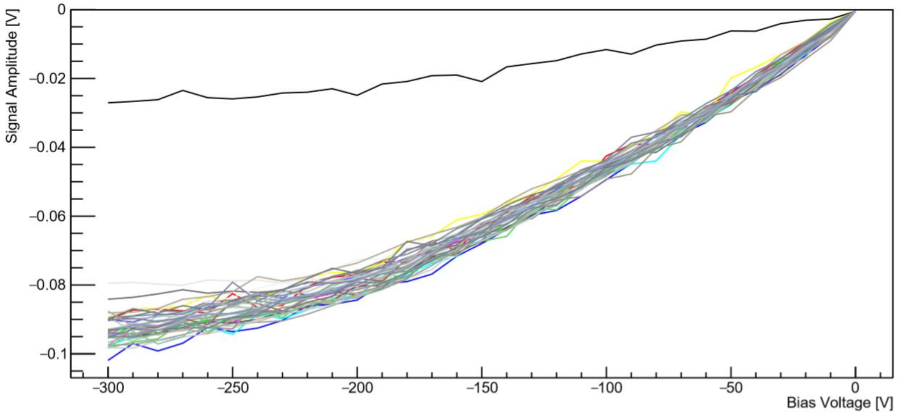


Good uniformity $\sigma \sim 3\ mV$. The setup seems to work.

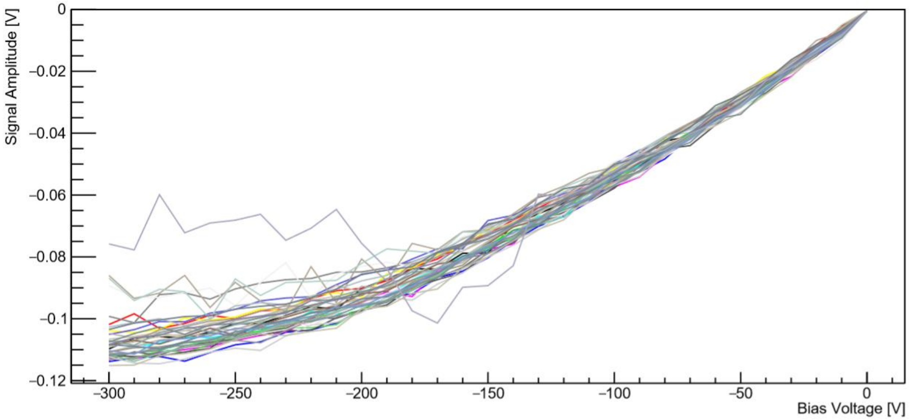
- I Tested all the other Wafers

Laser Test: Results

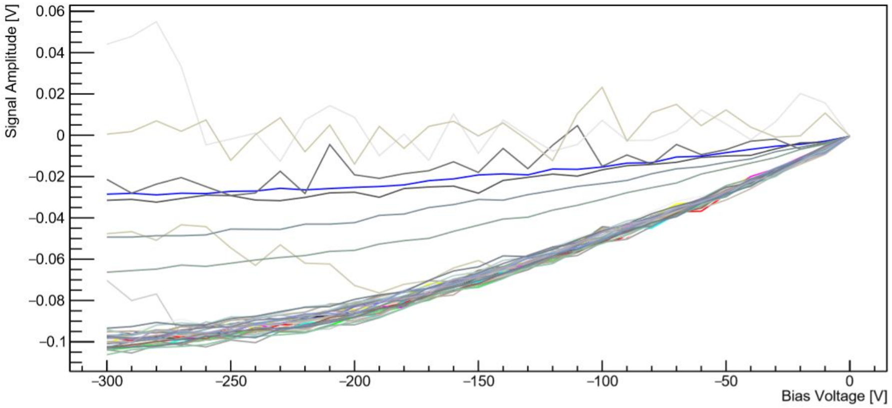
WAFER 1



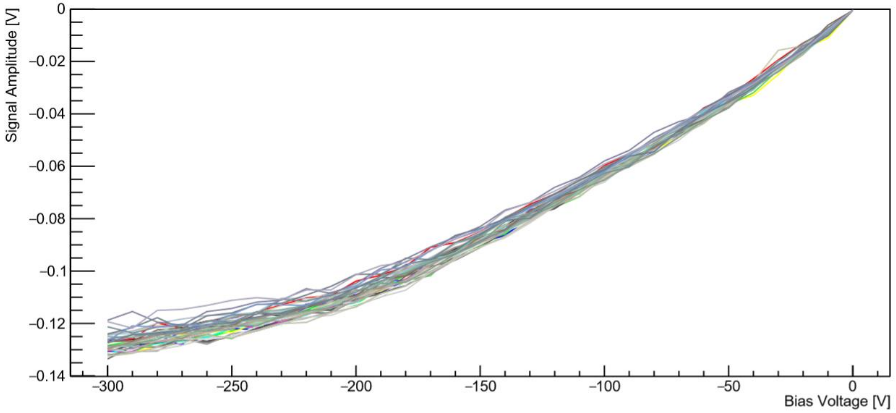
WAFER 2



WAFER 3

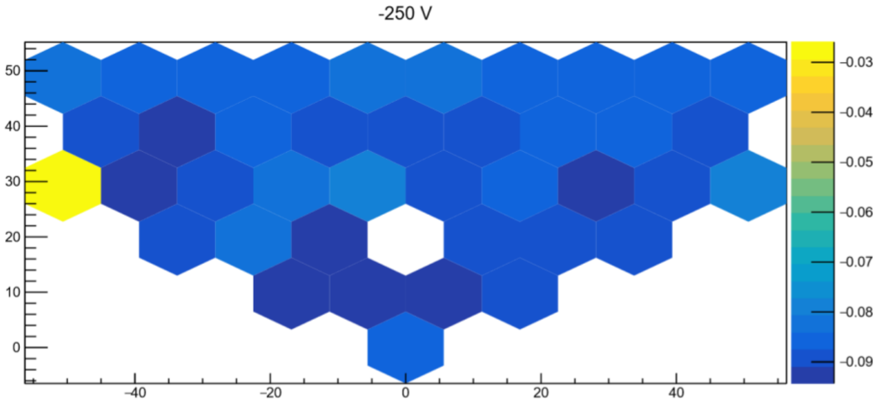


WAFER 4

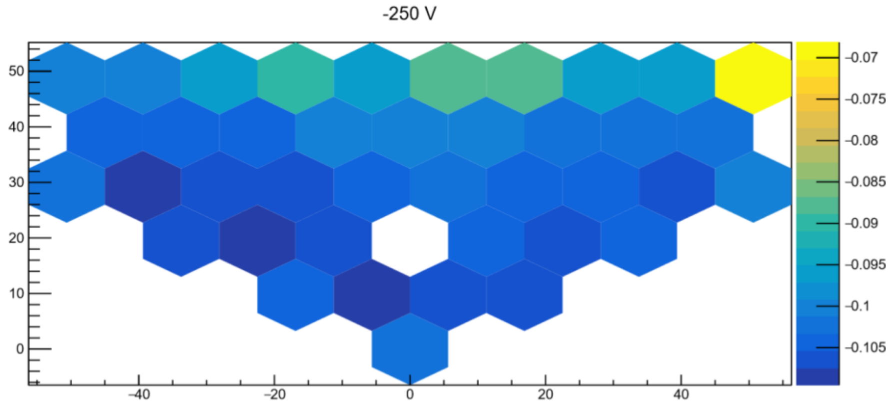


Laser Test: Results

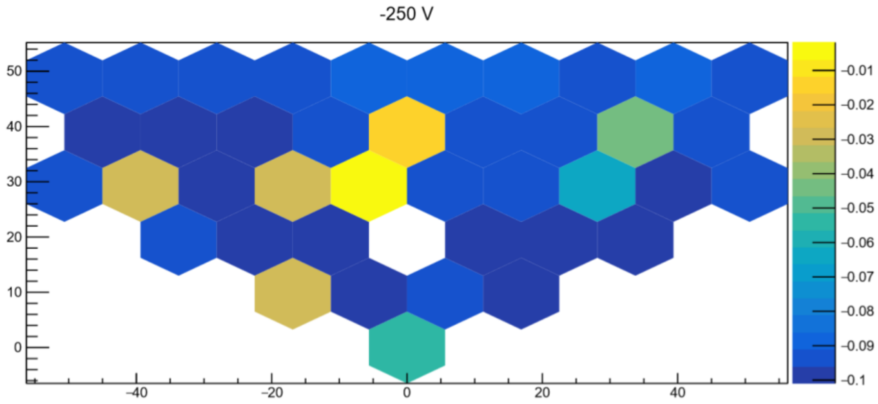
WAFER 1



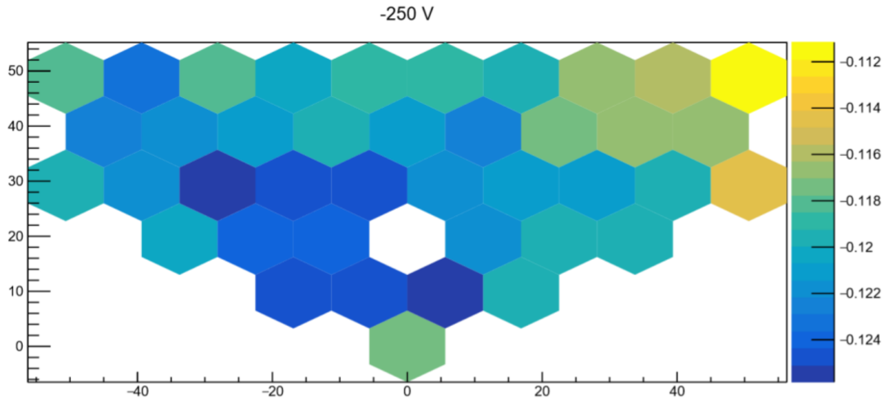
WAFER 2



WAFER 3

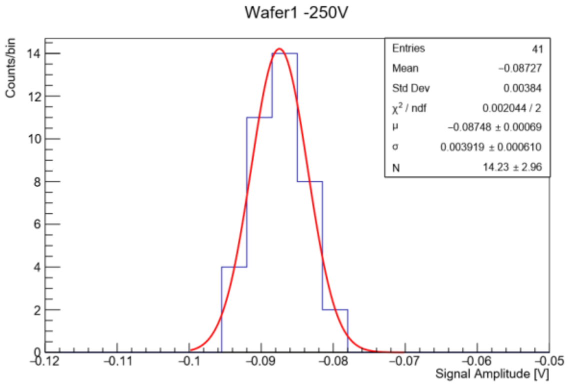


WAFER 4

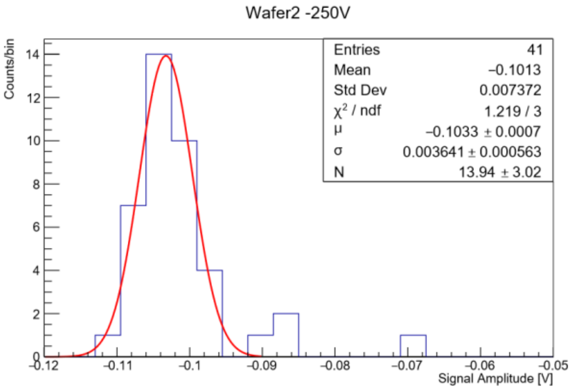


Laser test: Results

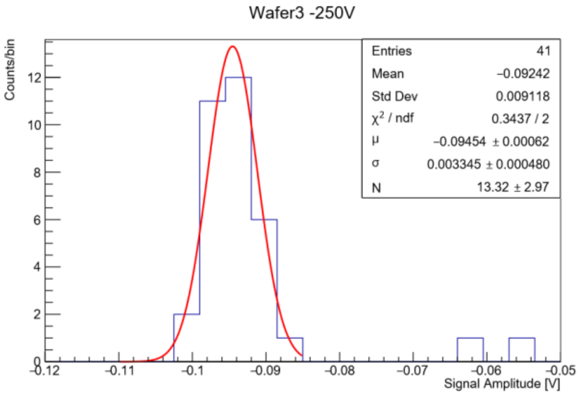
- Spread between channels for all the wafers $\sim 4\,mV$ @ 250 V



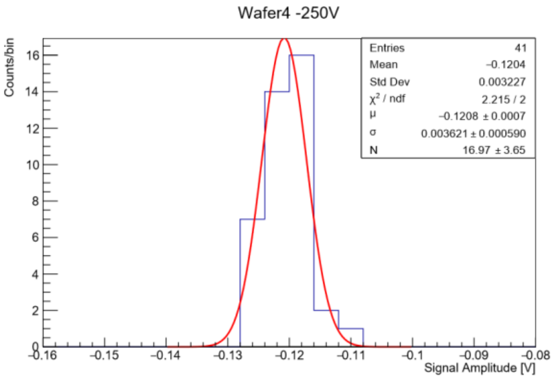
Entries	41
Mean	−0.08727
Std Dev	0.00384
χ^2 / ndf	0.002044 / 2
μ	−0.08748 ± 0.00069
σ	0.003919 ± 0.000610
N	14.23 ± 2.96



Entries	41
Mean	−0.1013
Std Dev	0.007372
χ^2 / ndf	1.219 / 3
μ	−0.1033 ± 0.0007
σ	0.003641 ± 0.000563
N	13.94 ± 3.02



Entries	41
Mean	−0.09242
Std Dev	0.009118
χ^2 / ndf	0.3437 / 2
μ	−0.09454 ± 0.00062
σ	0.003345 ± 0.000480
N	13.32 ± 2.97



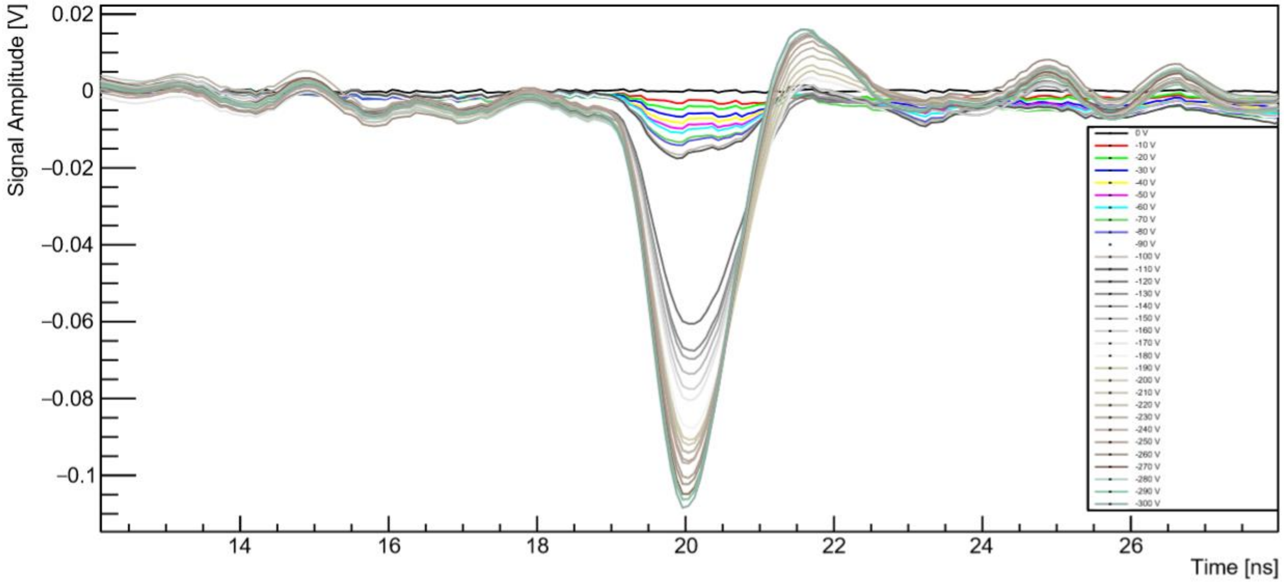
Entries	41
Mean	−0.1204
Std Dev	0.003227
χ^2 / ndf	2.215 / 2
μ	−0.1208 ± 0.0007
σ	0.003621 ± 0.000590
N	16.97 ± 3.65

Laser test: Results

- Same behavior for all the wafers, lack of the plateau until 250 V

Possible explanation

- Change of the pulse shape as the bias voltage increases past the depletion voltage because of the increased drift speed.
- Increase of the maximum, more narrow pulses, but same charge collected

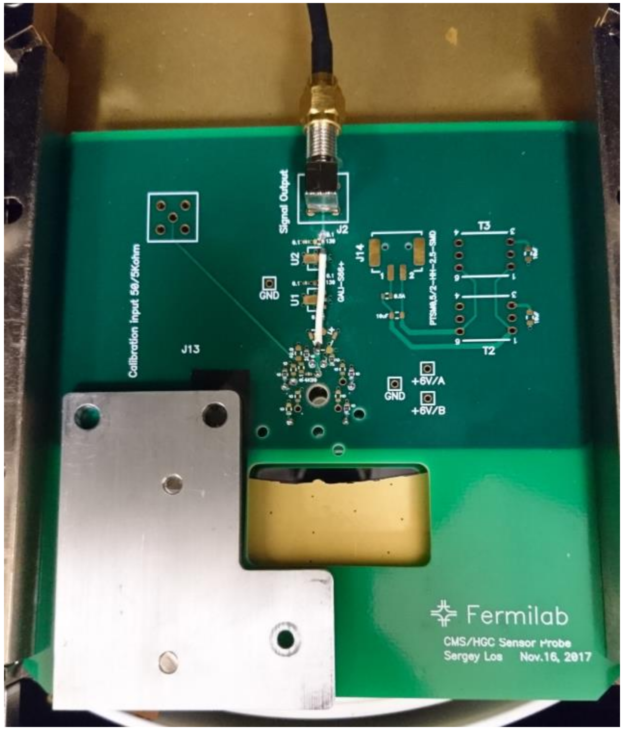


VI test: Setup

Keithley 486 Picoammeter measures the Leakage current.

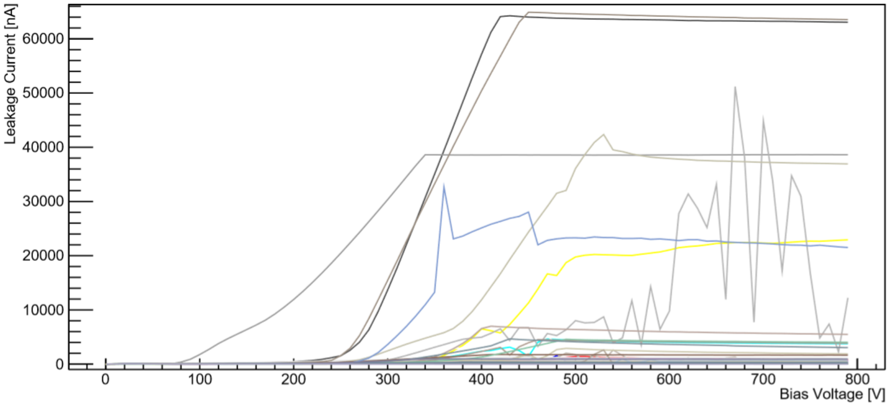
Power supply

New Probe card: allows current of a single channel to flow to the Picoammeter and it grounds the six surroundings pads

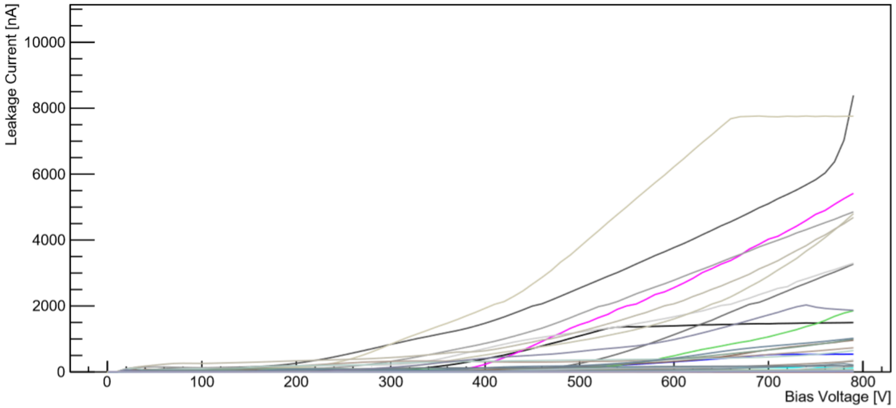


VI test: Results

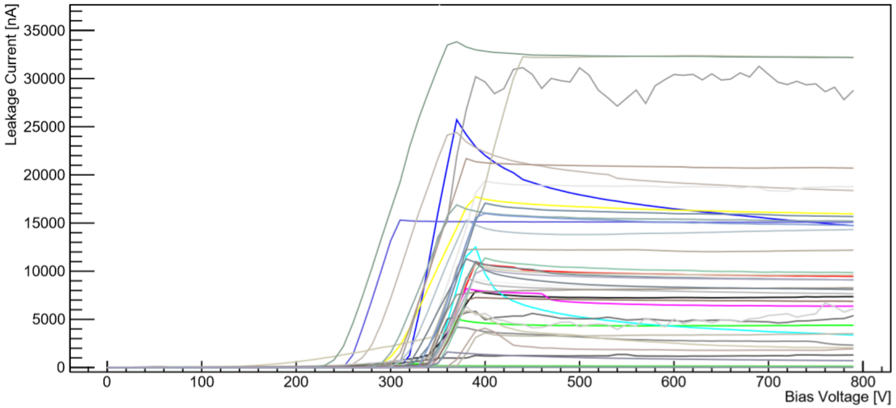
WAFER 1



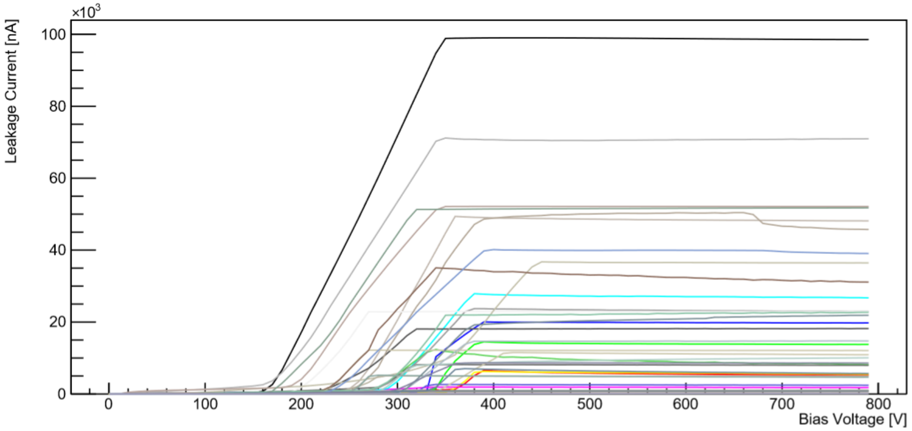
WAFER 2



WAFER 3

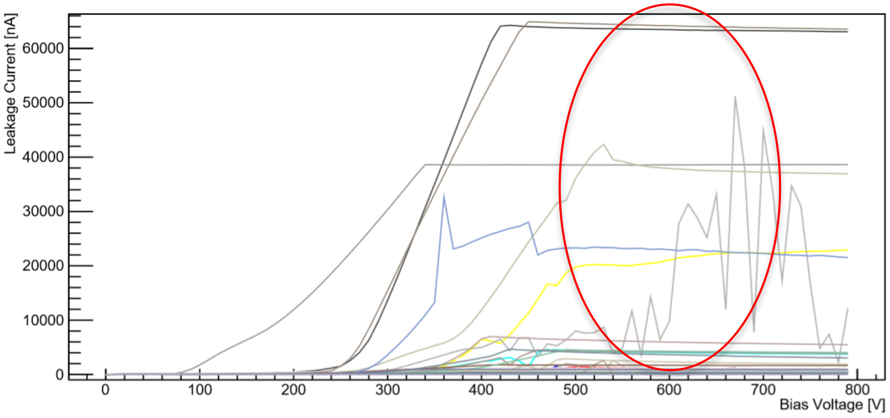


WAFER 4

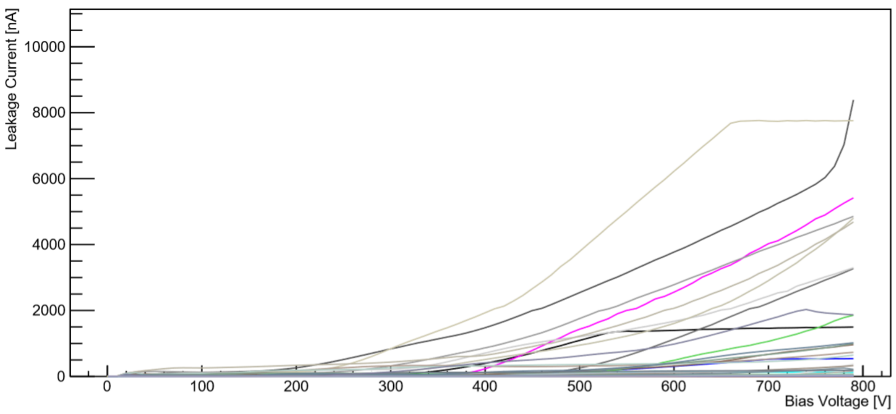


VI test: Results

WAFER 1



WAFER 2



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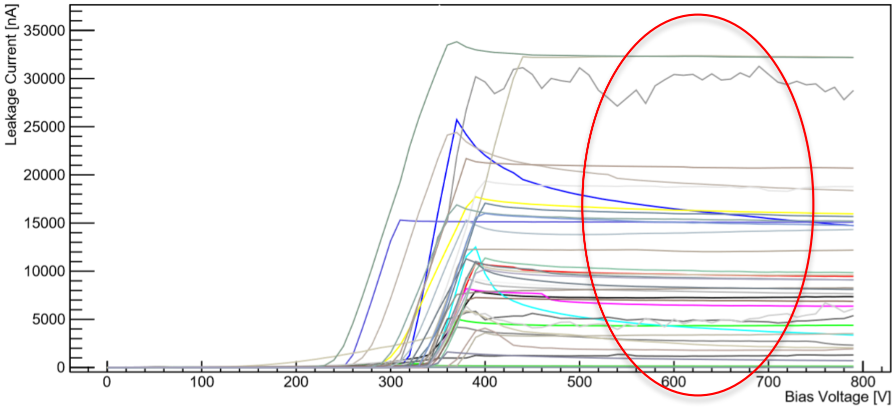
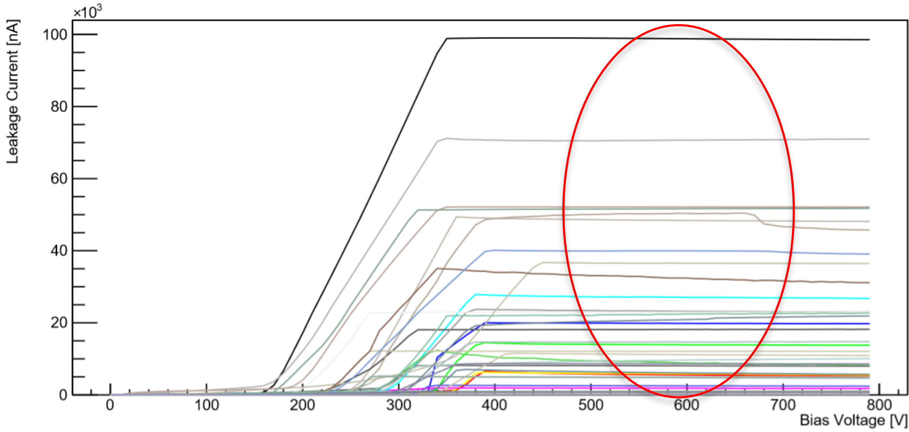


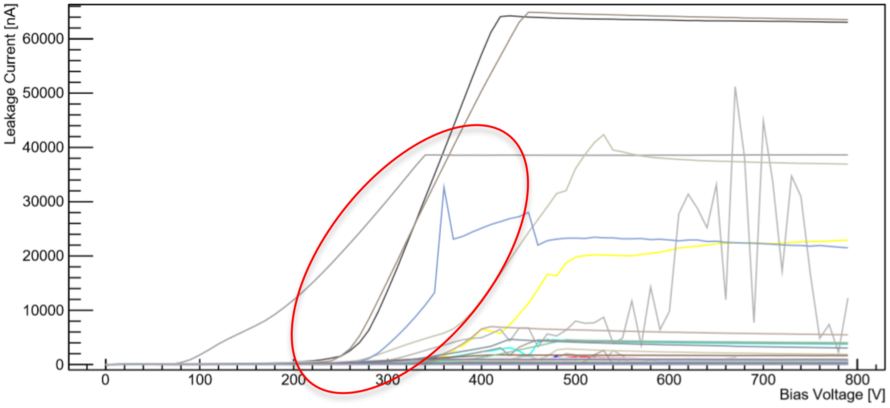
WAFER 4



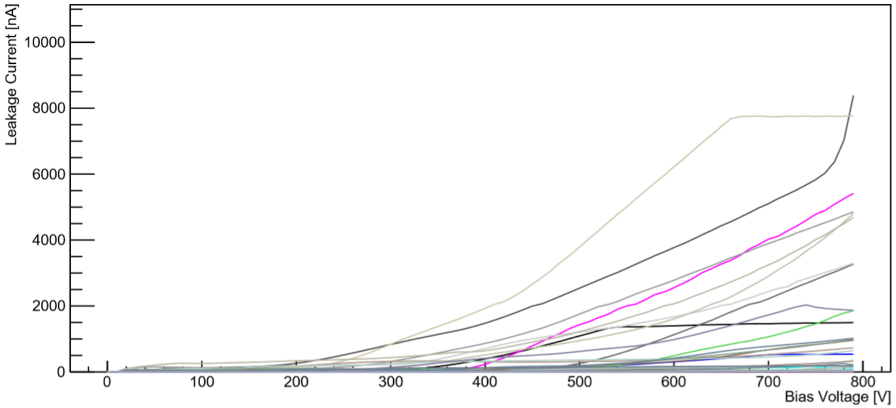
Fermilab

VI test: Results

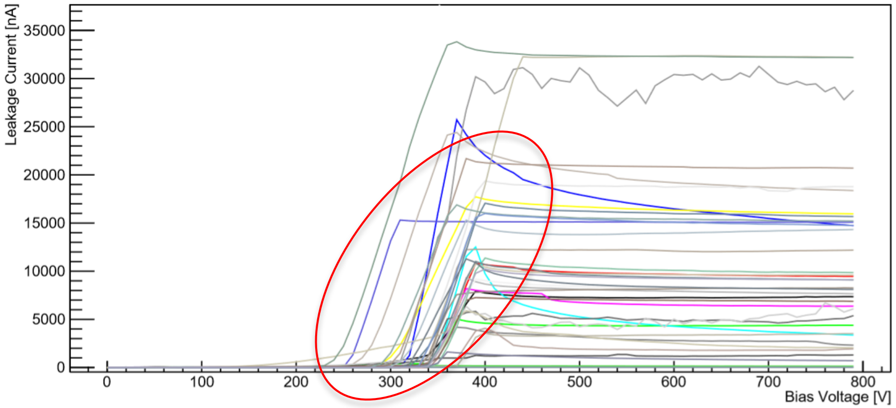
WAFER 1



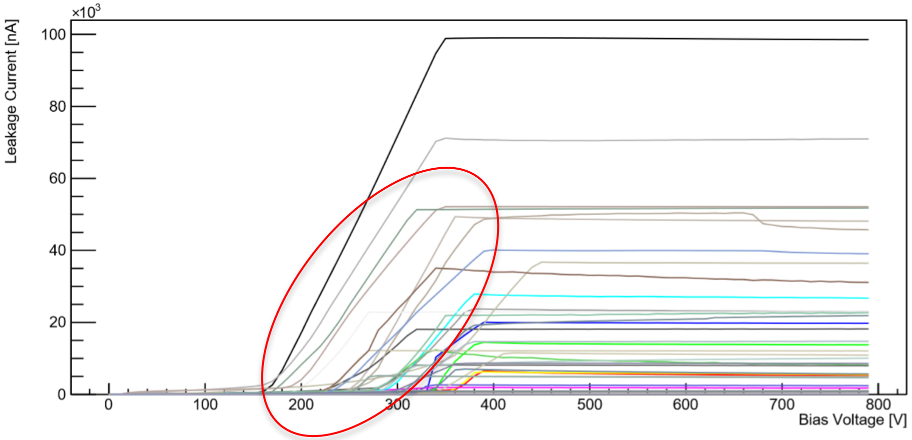
WAFER 2



WAFER 3



WAFER 4



VI test: Results

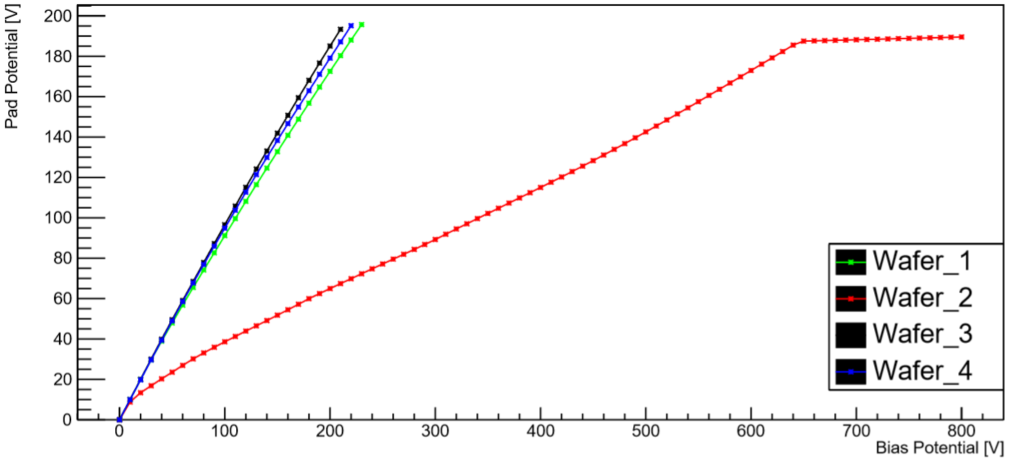
- Differences between Wafer 2 and the other Wafers

- Flat regions corresponds to the current limit of the PS

- It seems that the other channels are contributing to the current collected to the 7- pin setup, increasing the total current of the power supply

- This effect depends on the resistance between the six surrounding pads and the other pads on the detector
- We tried to make a measurement where the central pad is floating and the other pads are tied to ground

VV test: Results

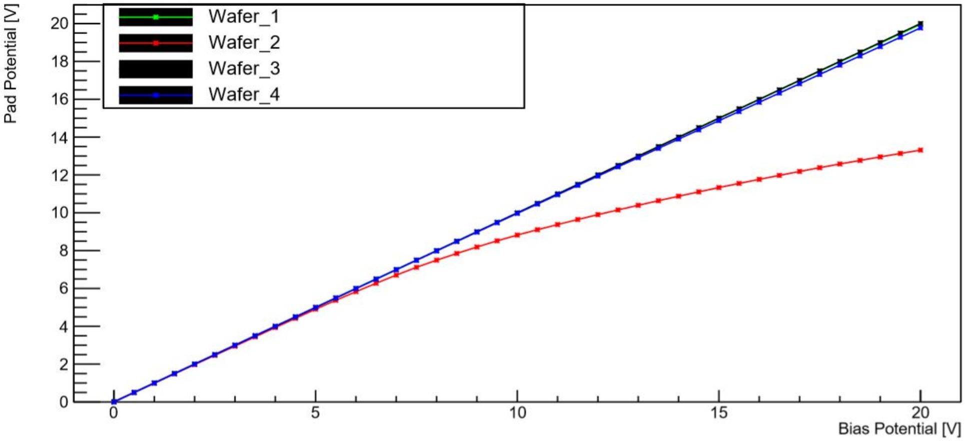


Different response of the Wafer 2

Also for low Bias voltages Wafer 2 looks different

- It may be due to different p-stop dose in the wafers

- Studies of other wafers are needed to confirm that



Conclusions

- Similar response for all the Wafers to the pulse of the laser all the Wafers have a $\sigma \sim 4\,mV$ @ 250 V

- Problems in the IV curves, too low breakdown voltages and too spreadout between channels.

- IV curves and V curves show that Wafer 2 and the other Wafers tested have different behaviors, probably due to the isolation of the channels

Future studies

- More quantitatively studies of the charge collection are needed to understand the lack of the plateau

- Studies of other wafers will allow us to confirm if the differences between the Wafers is due to the different p-stop dose

- Also simulations are needed to better explain if there are problems in the isolation of the channels

- After the irradiation of the sensors all the studies have to be repeated

Thank you for the attention!