INFN

Istituto Nazionale di Fisica Nucleare

HASPIDE COLLABORATION MEETING 02/02/2023

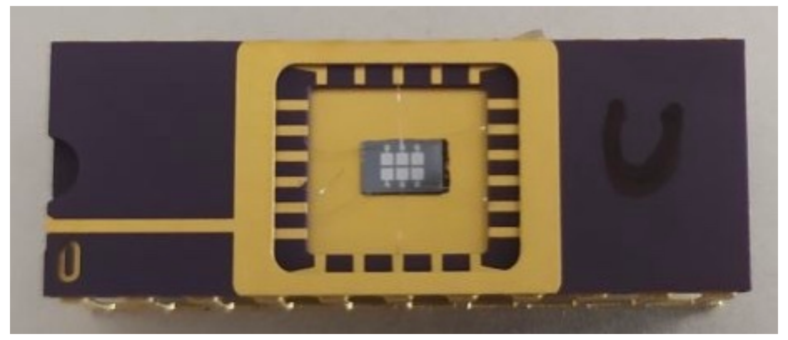
SUMMARY OF CHARACTERIZATION TESTS IN PERUGIA

SENSORS UNDER TEST

Basic detector configurations will be test to assess the performances of the various prototypes (basic physical, electrical and charge collection performances).

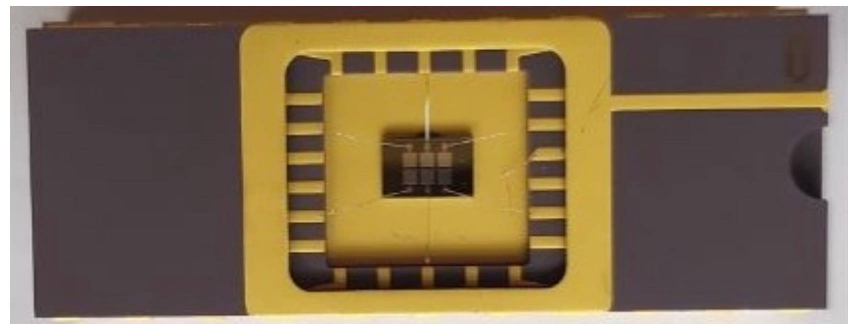
- Small arrays of **diodes** with different areas and diode spacings deposited on **c-Si**;

d=10 μm; V=0.0025mm^3



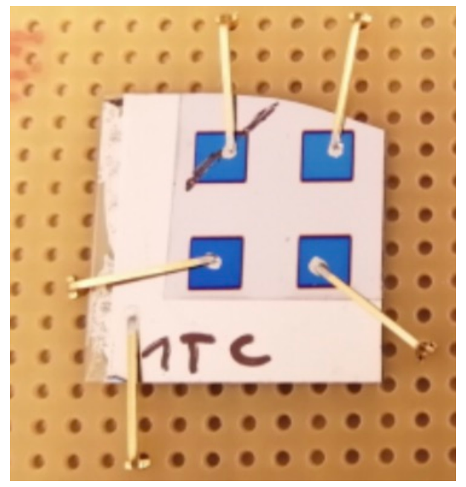
a-Si:H p-i-n Pad

d=10 μm; V=0.01mm^3



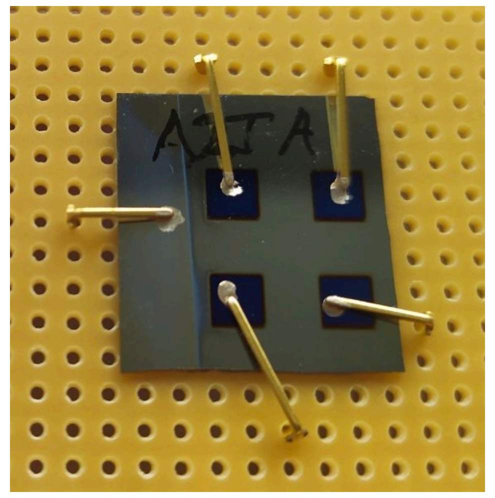
a-Si:H p-i-n Pad

- **CSC** with various thickness;



a-Si:H CSC Pad

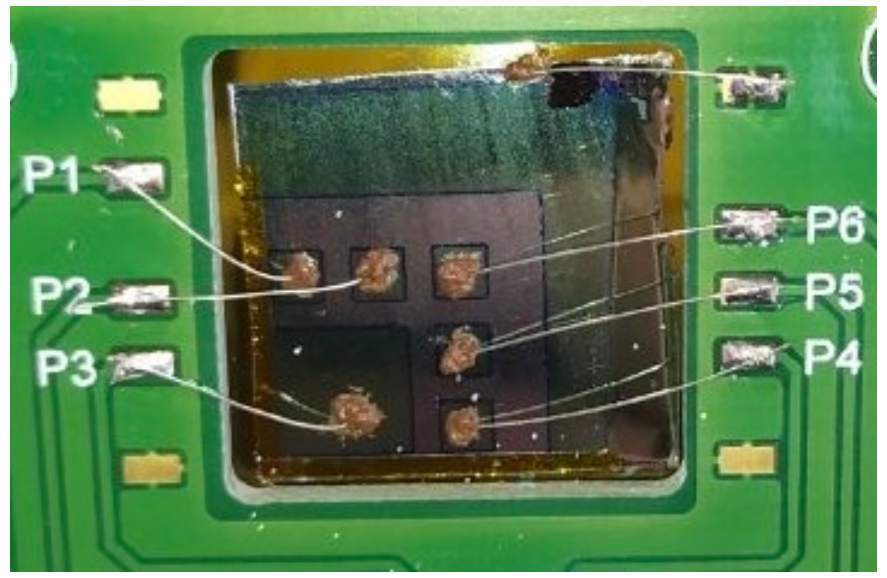
d=8.2 μm; V=0.13 mm^3



a-Si:H CSC Pad

d=6.2 μm; V=0.10 mm^3

- **Diodes** with different areas deposited on **Kapton**;



a-Si:H p-i-n Pad

d=2.5 μm; V=0.06 mm^3

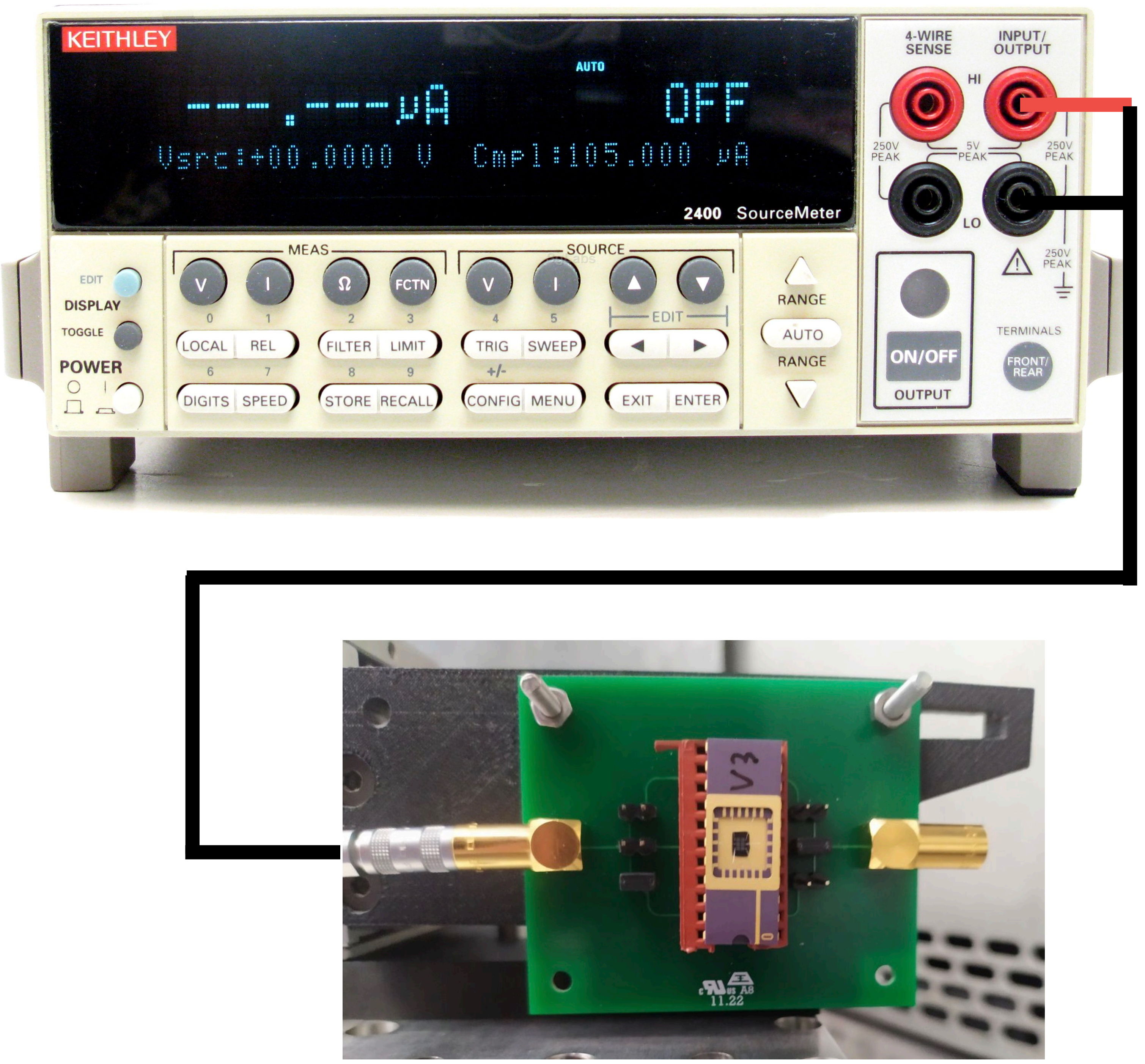
a-Si:H p-i-n Pad

d=2.5 μm; V=0.04 mm^3

All the measures presented were acquired over the curse of one and a half years, a **retrospective study** was carried out.

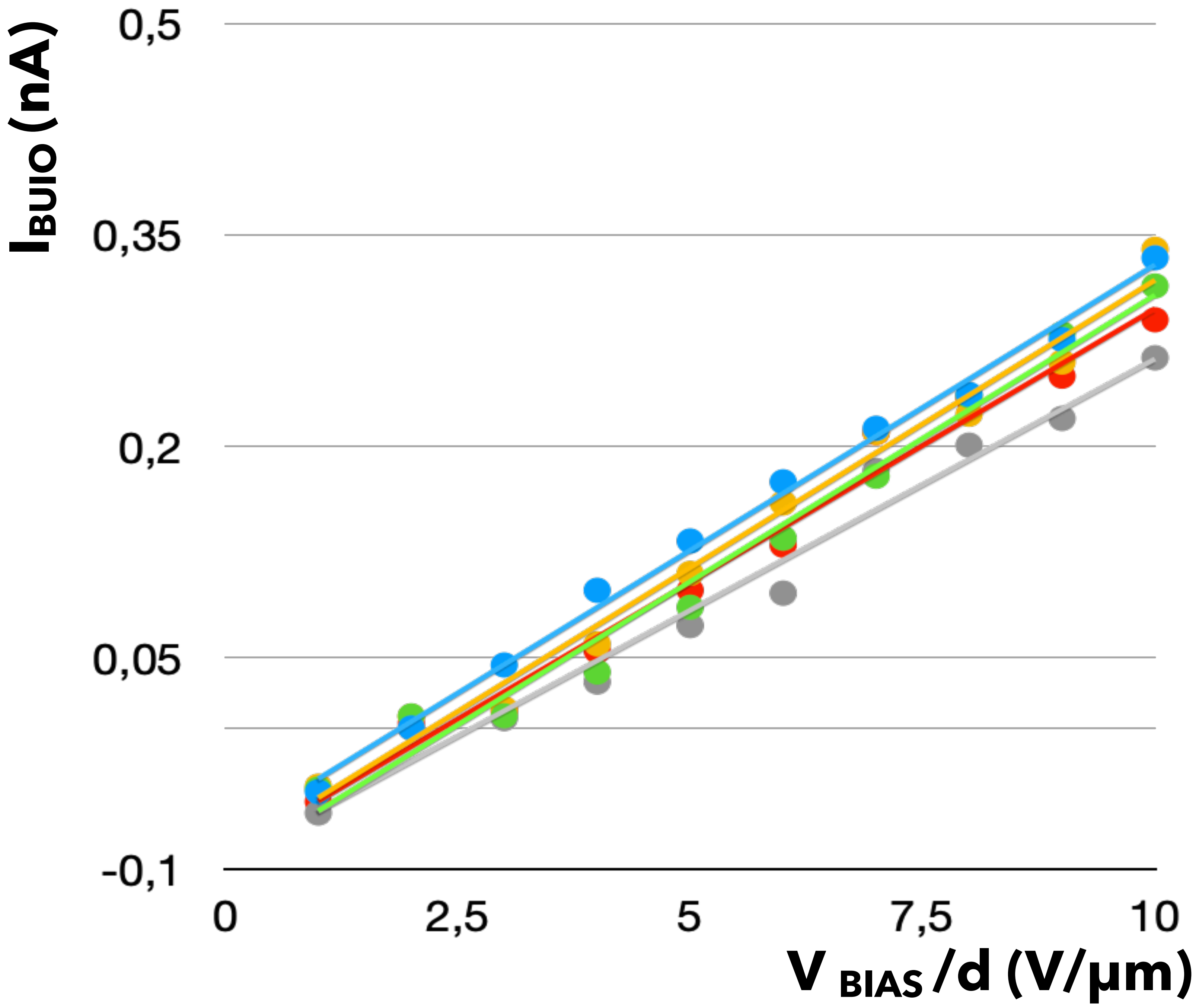
EXPERIMENTAL SET UP

We initially studied the detector response in the absence of a signal source for different bias voltage values, to evaluate the noise. The goal of this first phase of characterization is to establish the ideal working point.



Max Voltage: **200V**

Resolution: **1pA**



We use a digital multimeter that supplies the bias to the detector and reads the current output from the sensor.

The experimental set up allows us to read only one pad at time.

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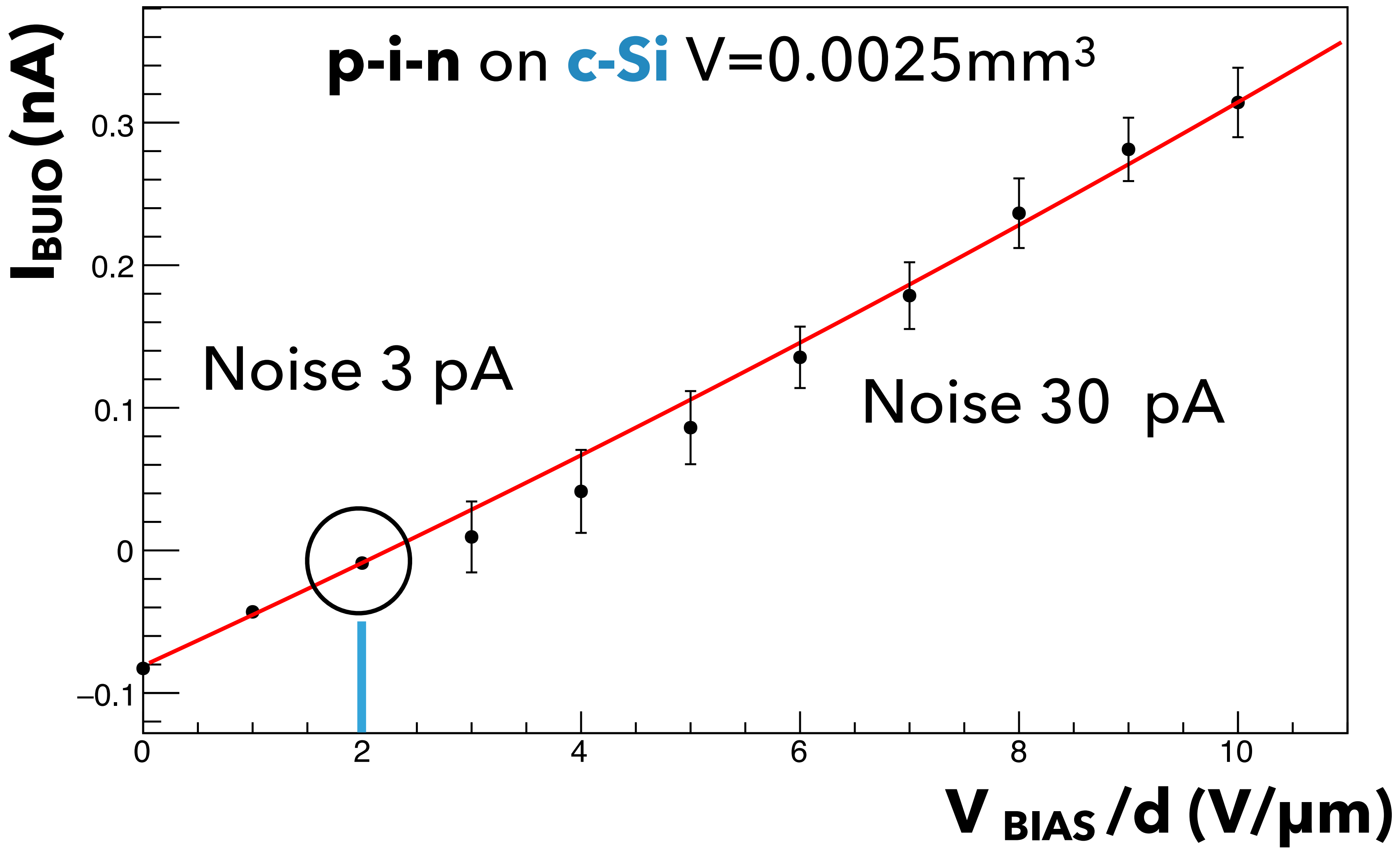
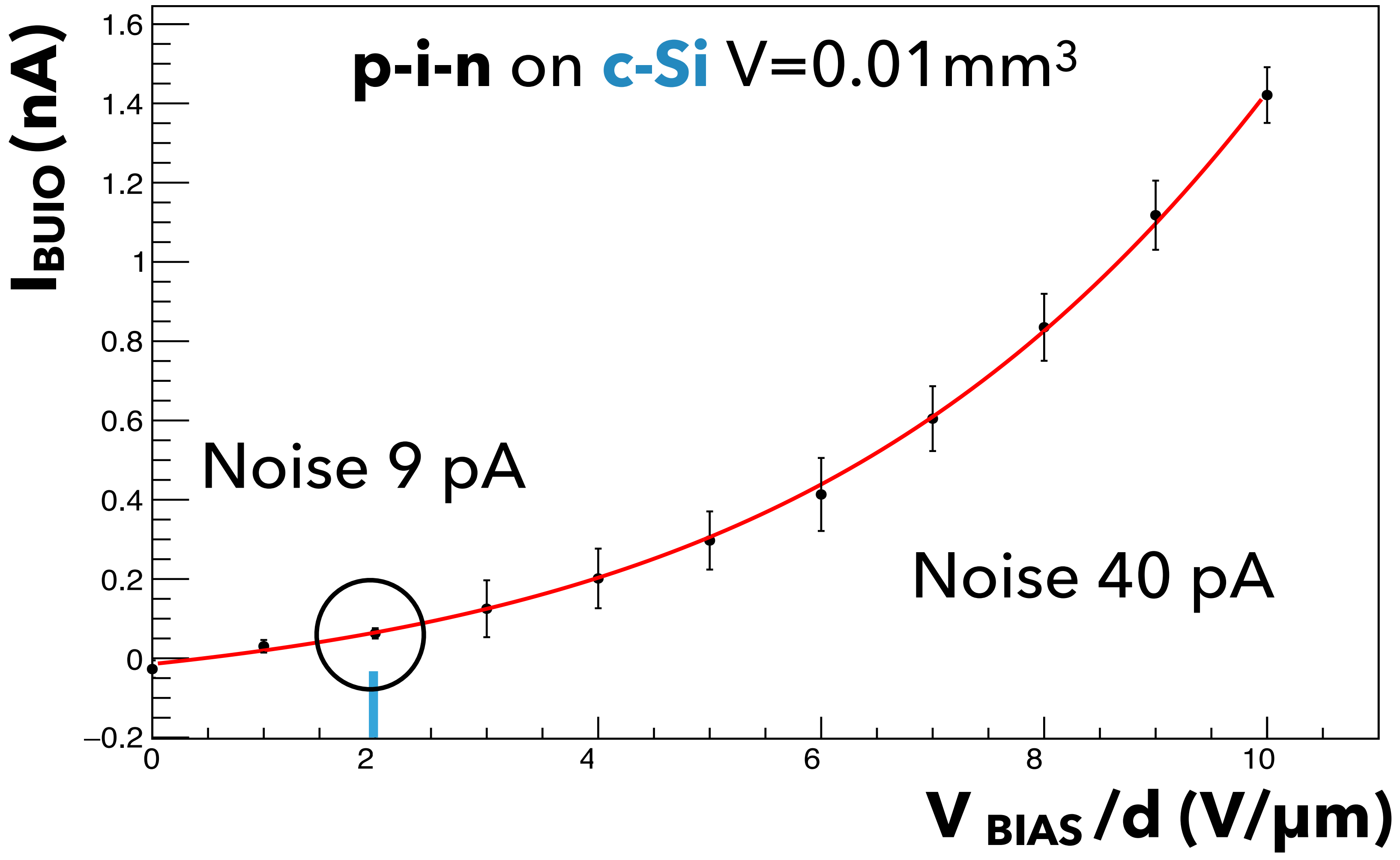
The analysis presented was then repeated for each pad contained in the detector, from the results of the analysis we can say that all six devices provide comparable results.

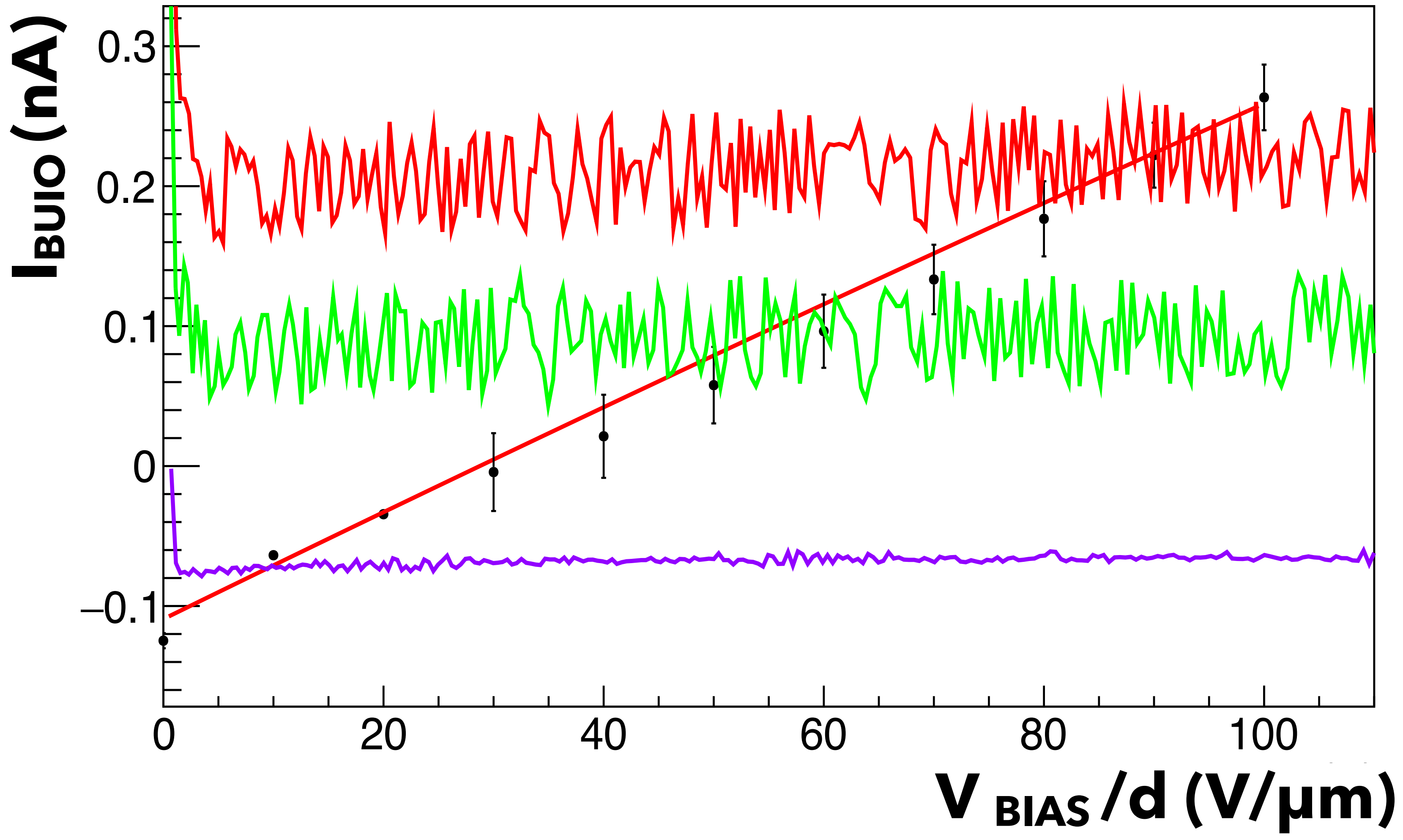
DARK CURRENT CHARACTERIZATION





After estimating the maximum voltage applicable to the sensor the following characterization was made with each of the devices:

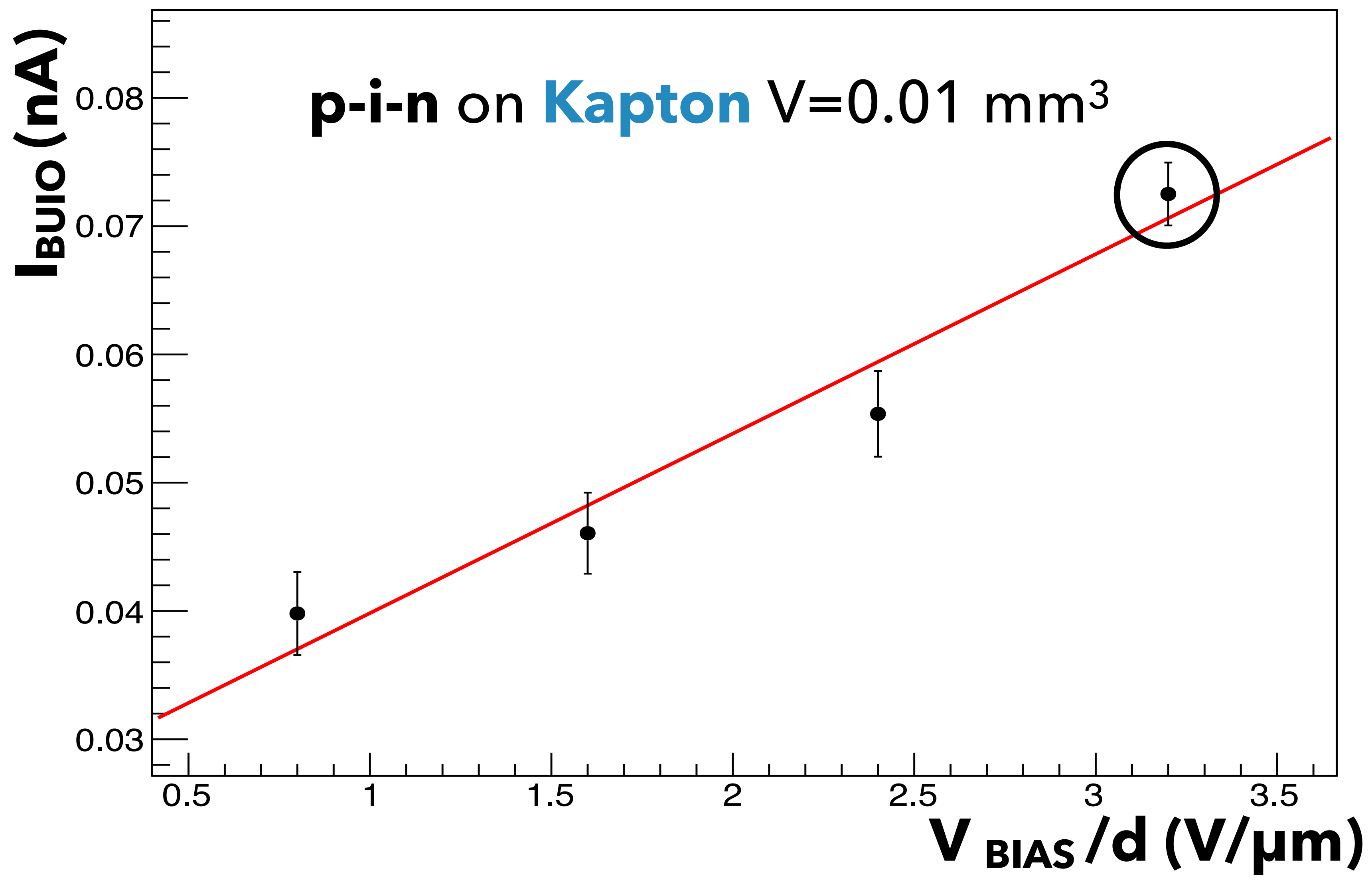
- ~30 minutes of stabilization at maximum voltage;
- voltage scan;
- identification of the working point;

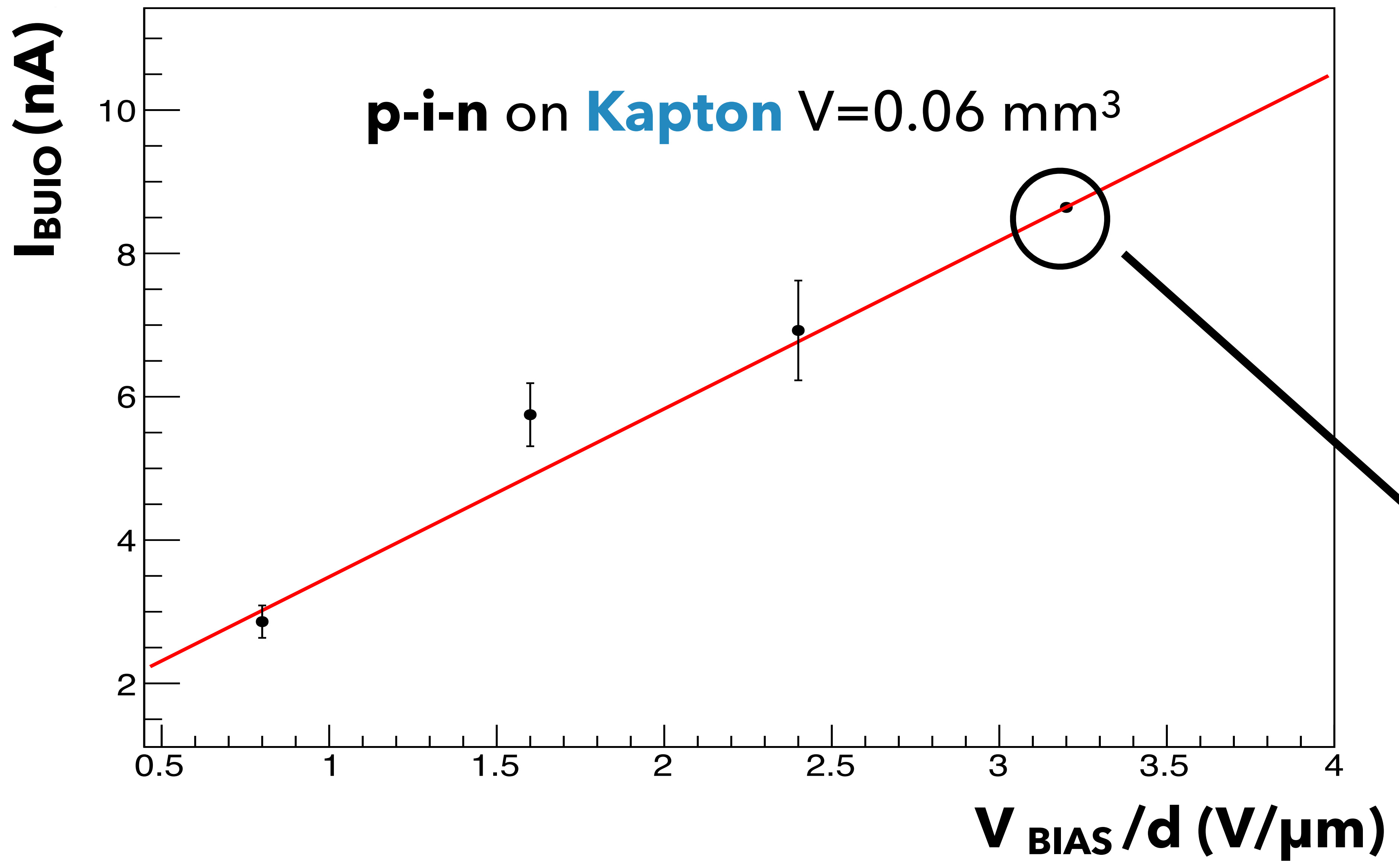


The noise value increases by about an order of magnitude when exceeding **20V** of bias.

However, this phenomenon is not due to the sensor, the dominant noise contribution is in fact that due to the acquisition system.

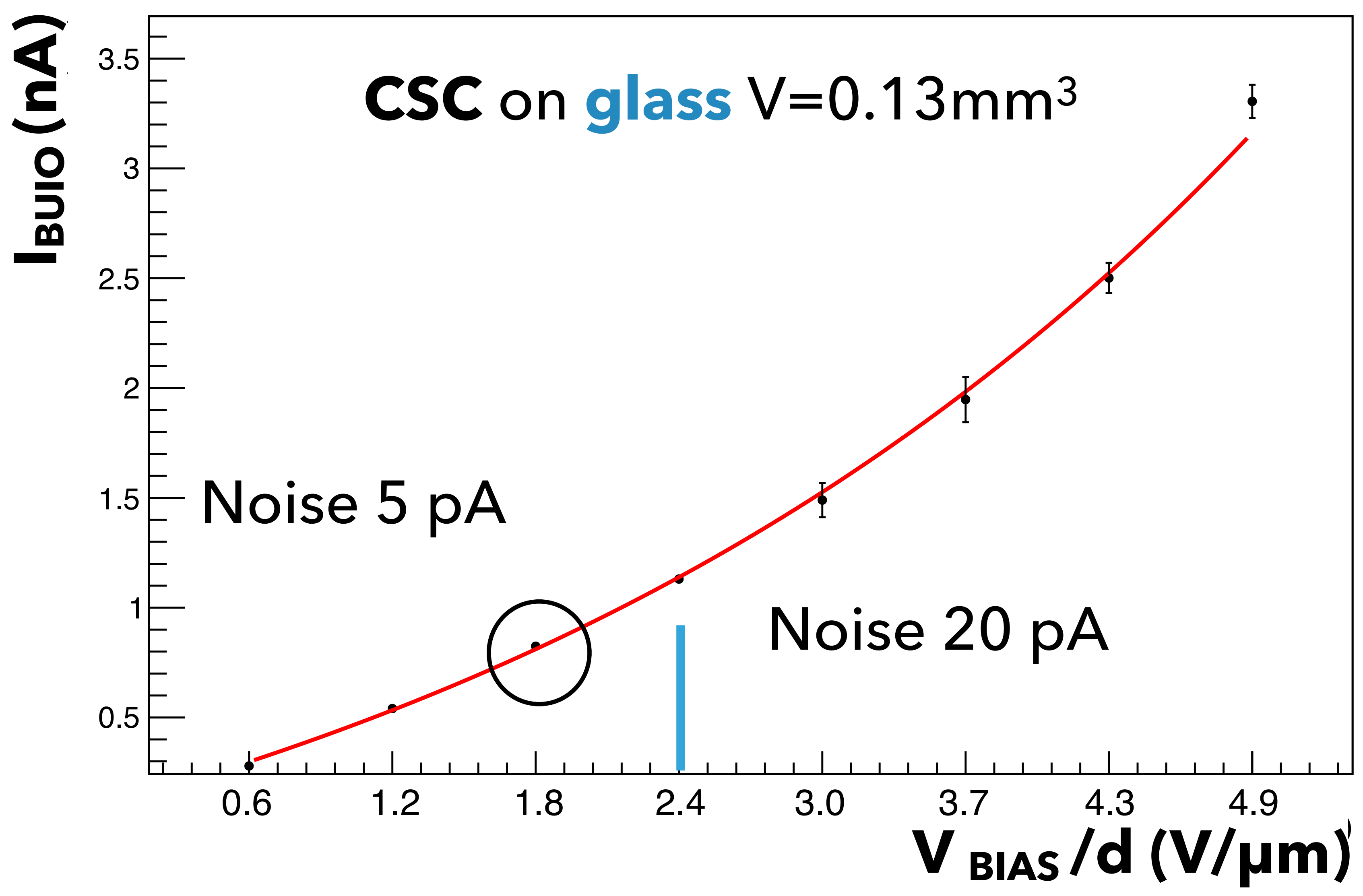
DARK CURRENT CHARACTERIZATION

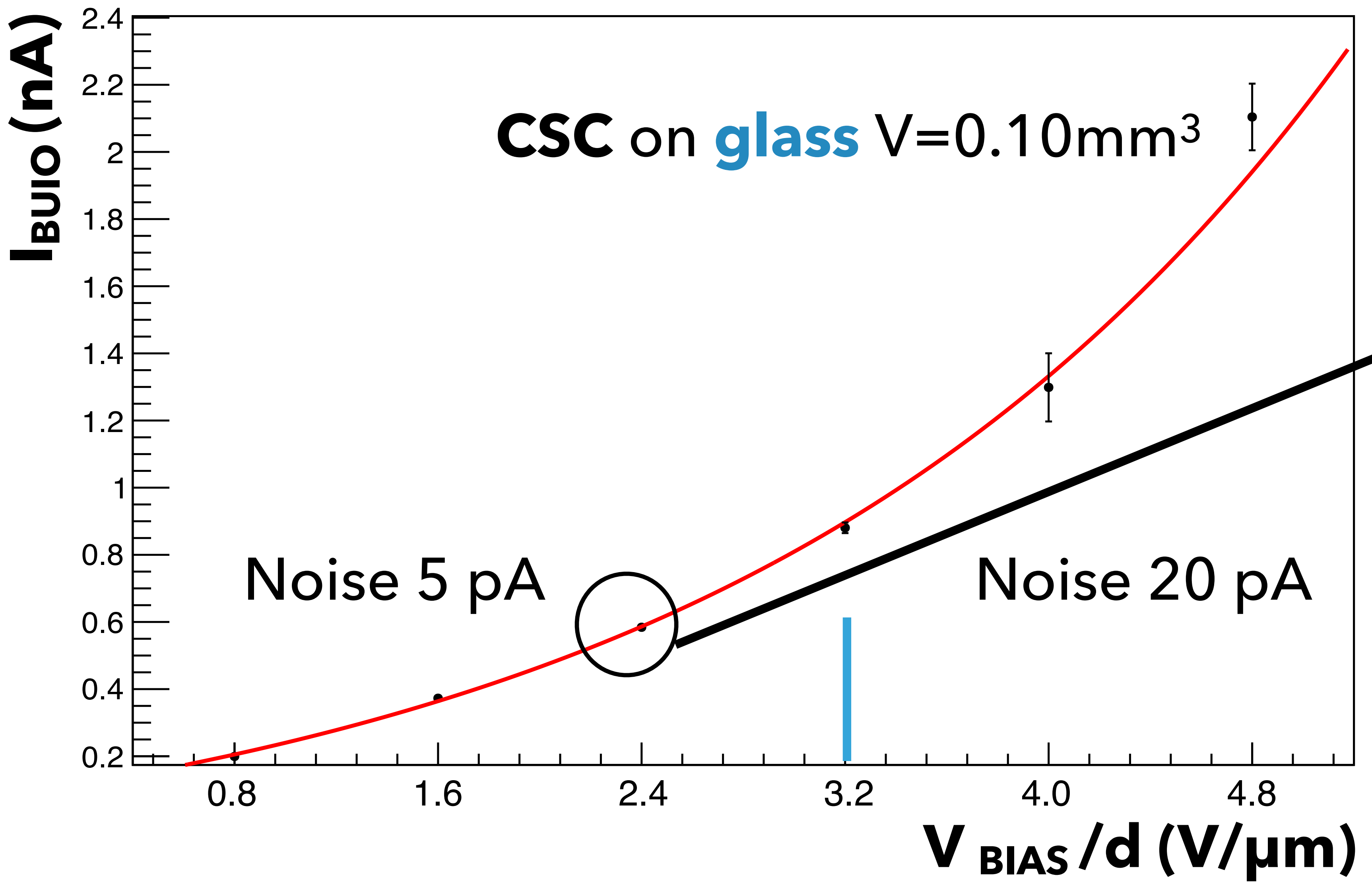




The working points for each detector have been chosen.

The goal is to find the right compromise between **noise level** and **signal level**.





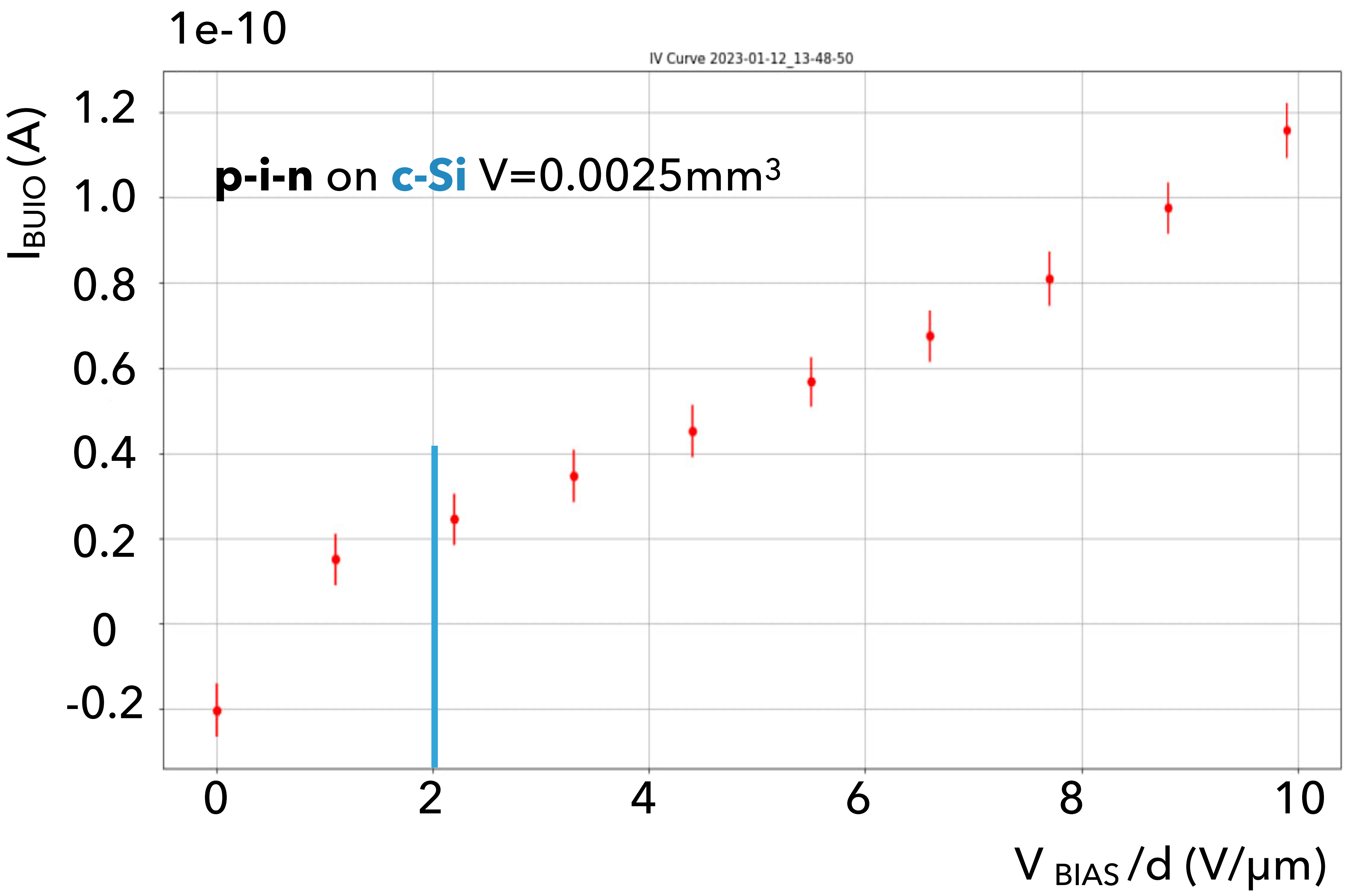
$$Noise = \sigma_L = \sqrt{\frac{1}{N}\sum_i (x_L - \mu_L)^2}$$

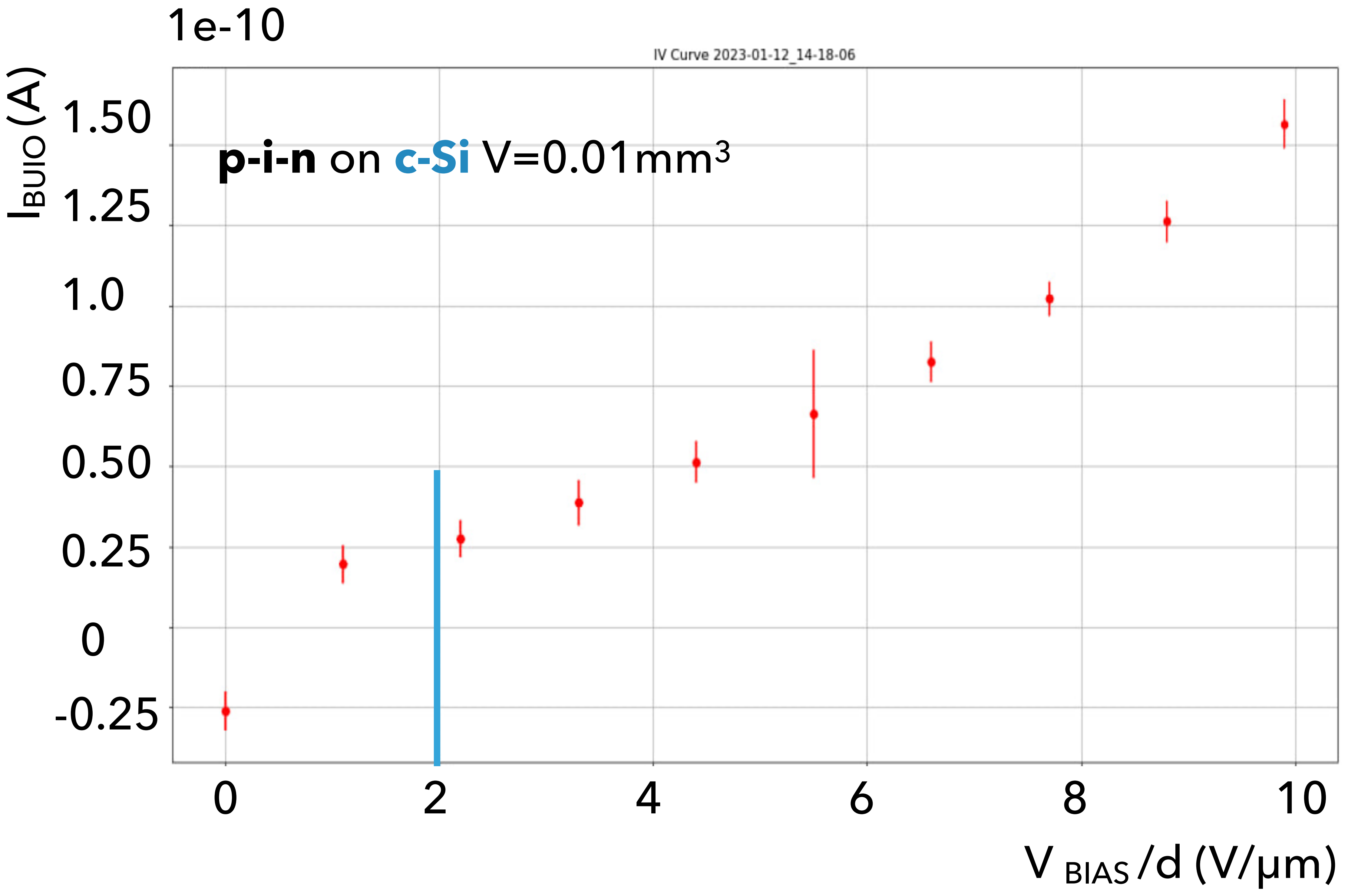
Leakage current

DARK CURRENT CHARACTERIZATION

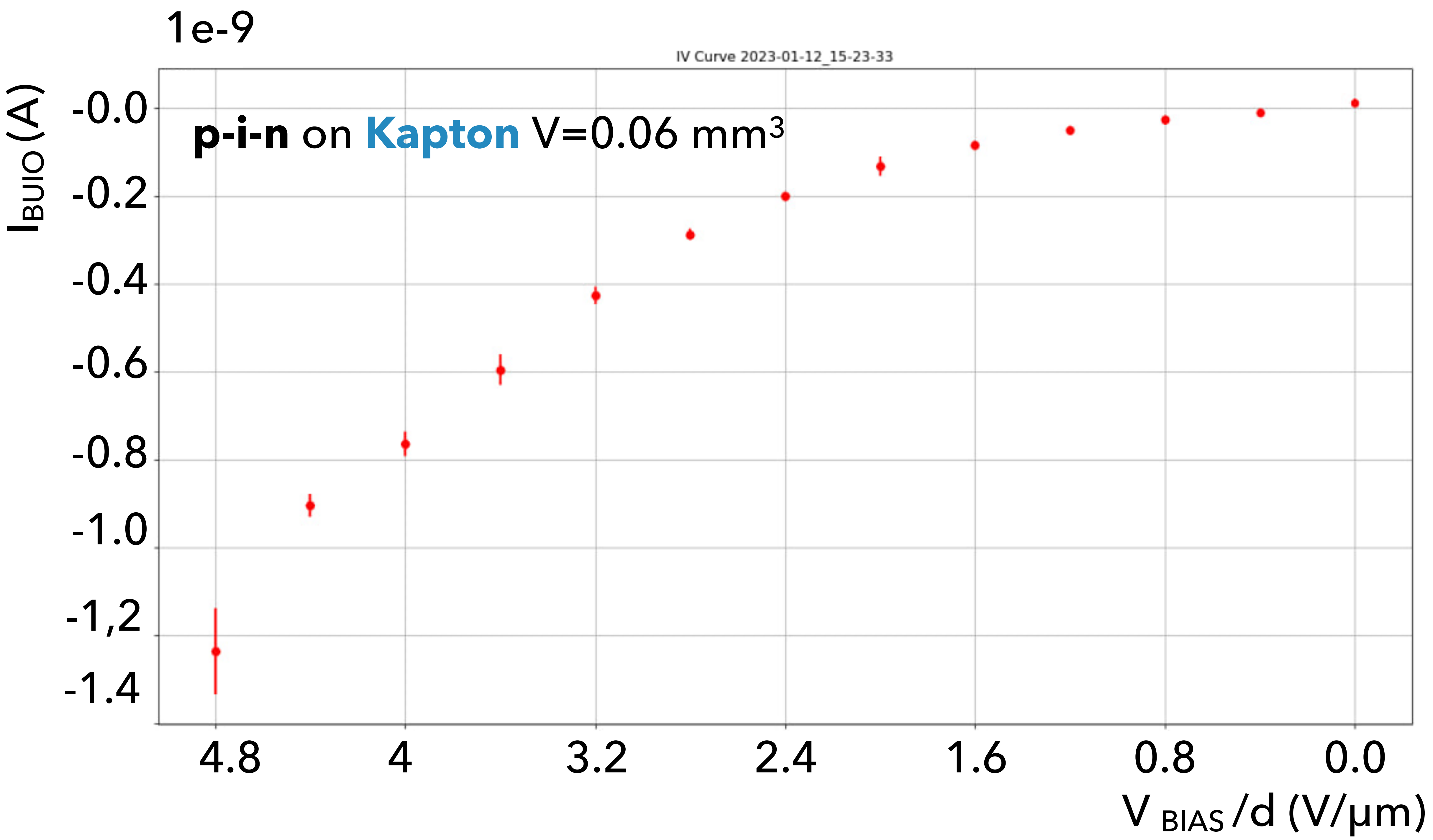
We used a second acquisition system to get around the problem of noise increase above 20 V bias.

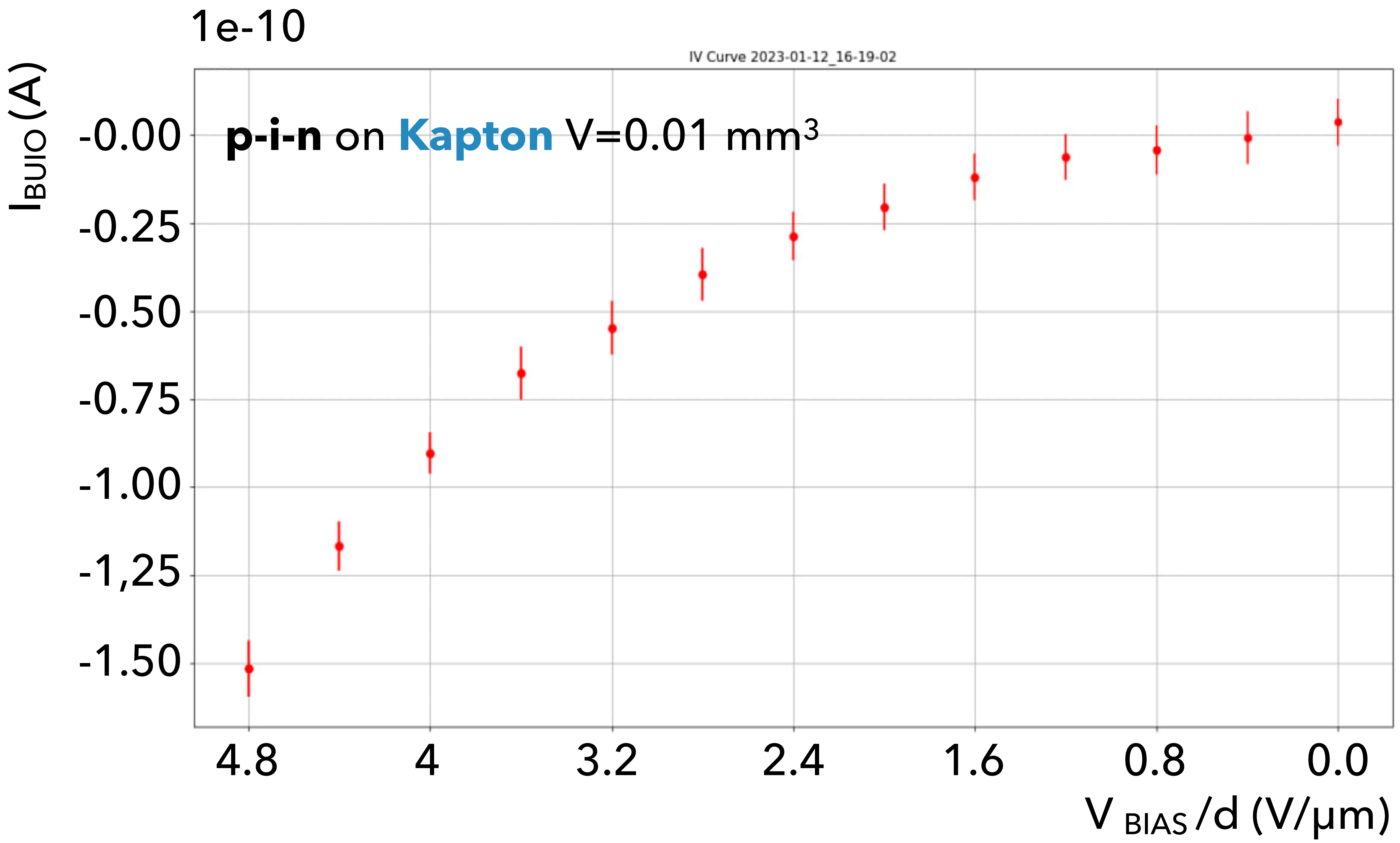
With the second acquisition system we obtain a **uniform noise level** (**<10 pA instead of tens of pA**) with respect to the applied bias, even when the voltage exceeds 20V.





DARK CURRENT CHARACTERIZATION



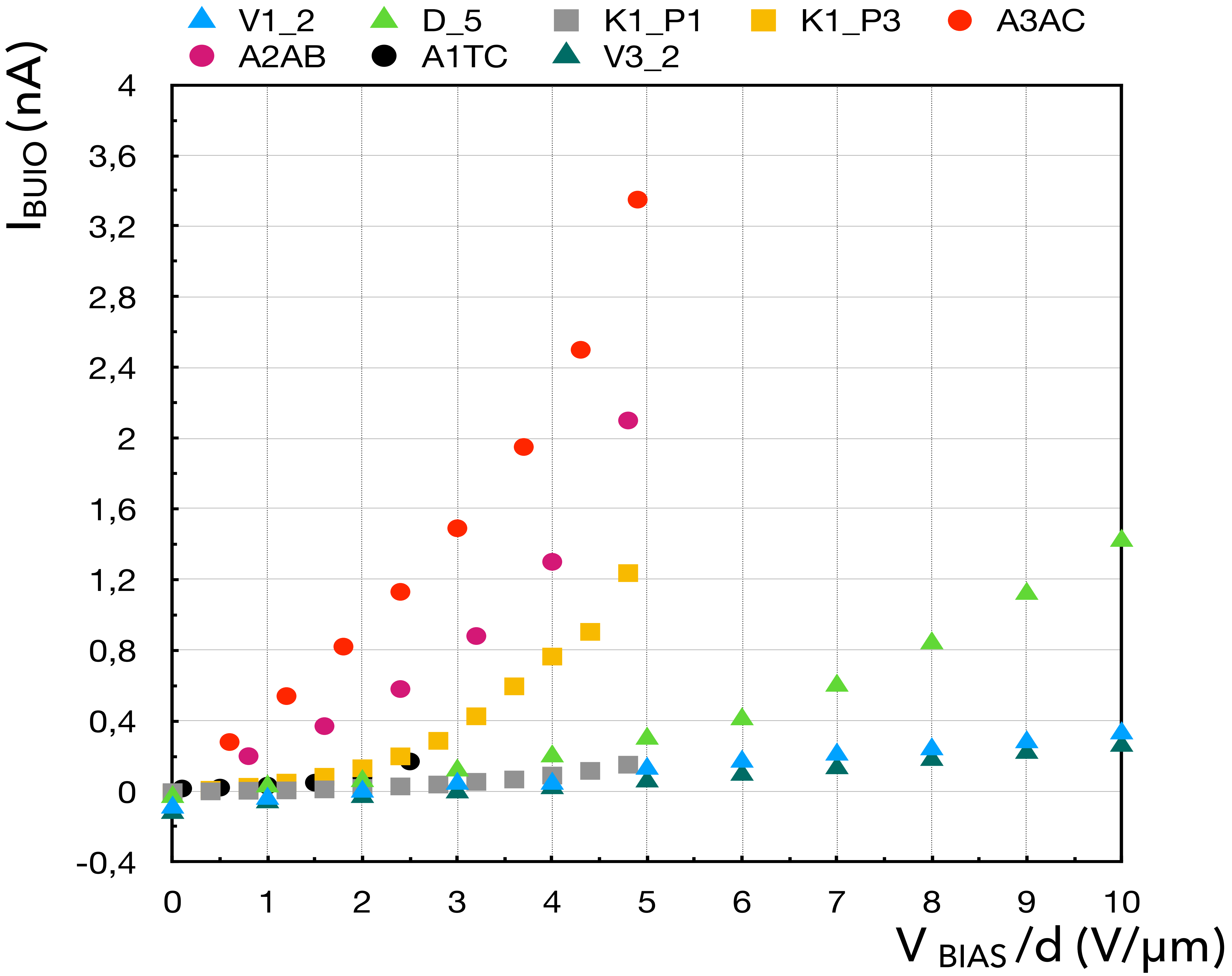


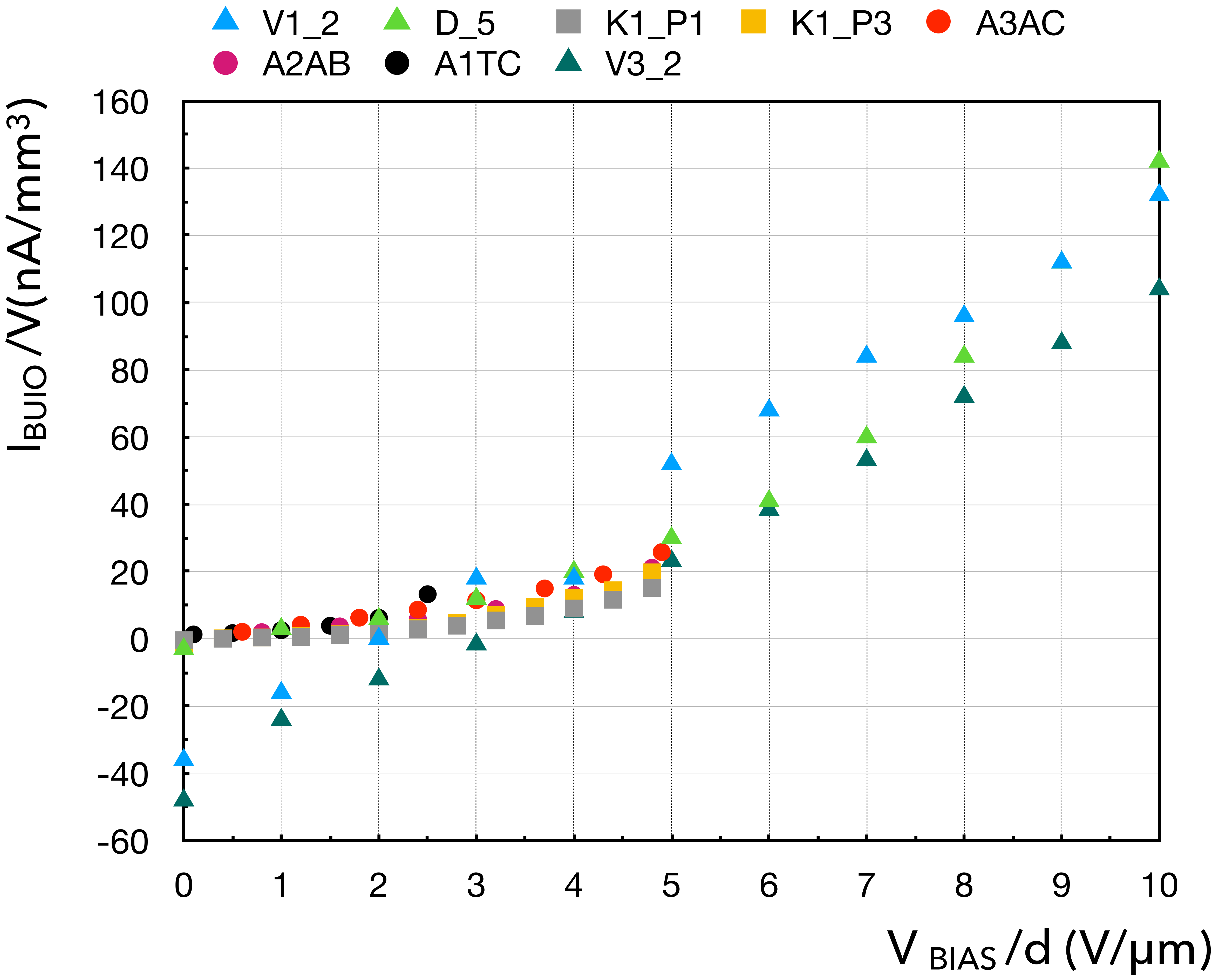
Once the noise has been evaluated with another acquisition system, we could subtract the contribution due to our acquisition system during the analysis.

DARK CURRENT CHARACTERIZATION

The second phase of device characterization focuses on the comparison between the different sensors, the aim is to understand if some types are more advantageous than others.

Variables: **contact type**, **substrate** and **thickness**.

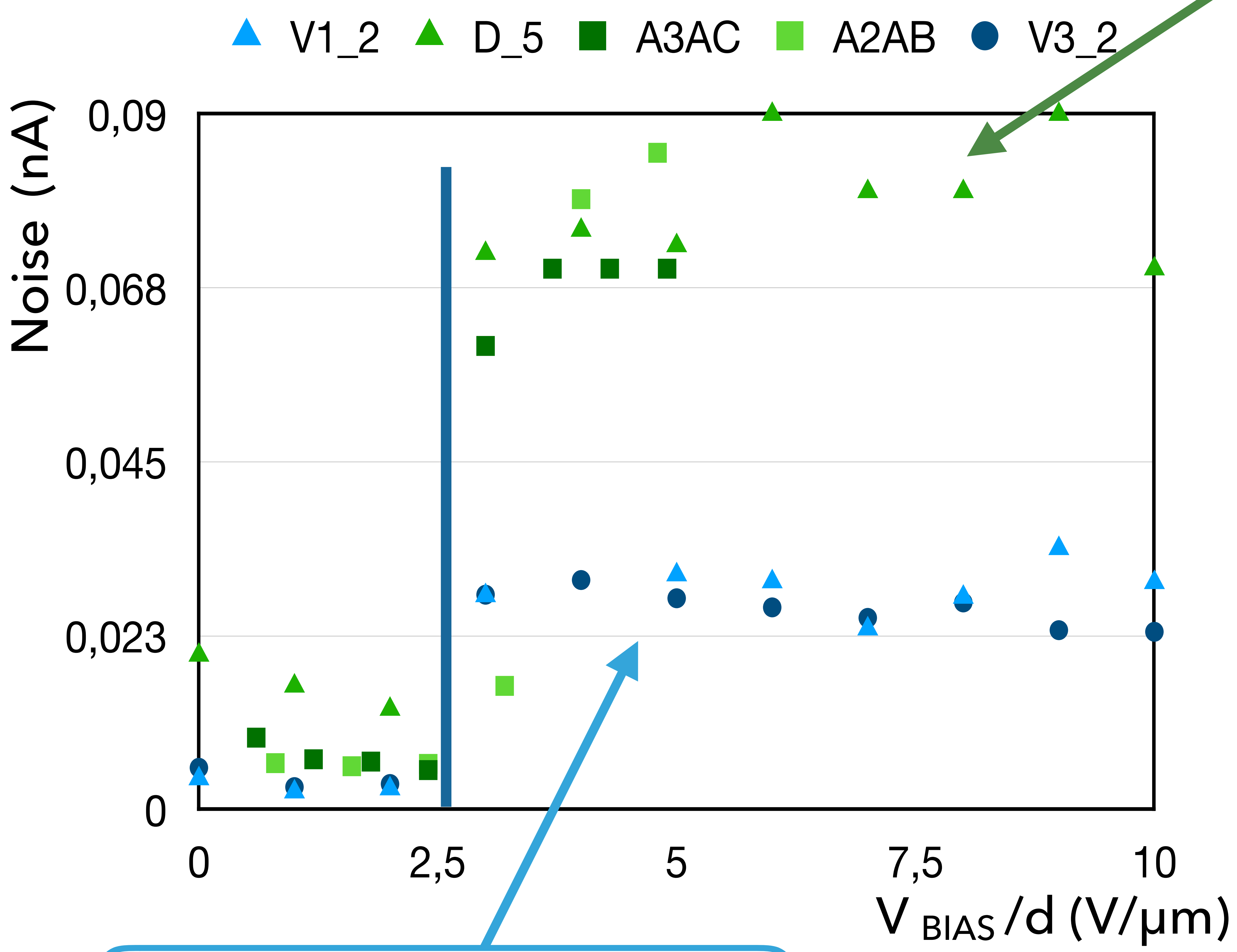




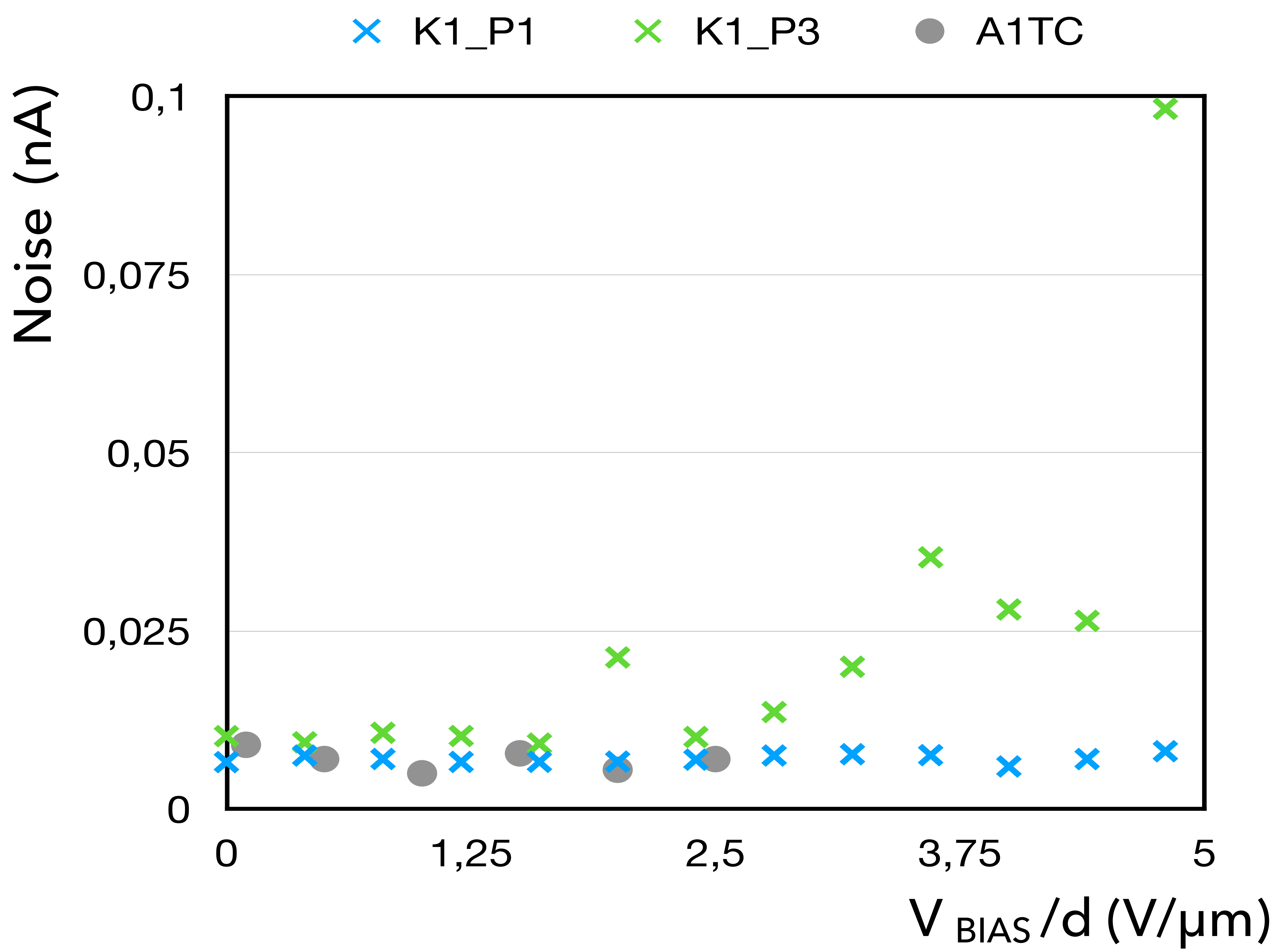
NOISE CHARACTERIZATION

p-i-n on **c-Si** V=0.01mm^3
CSC on **glass** V=0.13mm^3
CSC on **glass** V=0.10mm^3

Noise is almost always below 20 pA.



p-i-n on c-Si V=0.0025mm^3

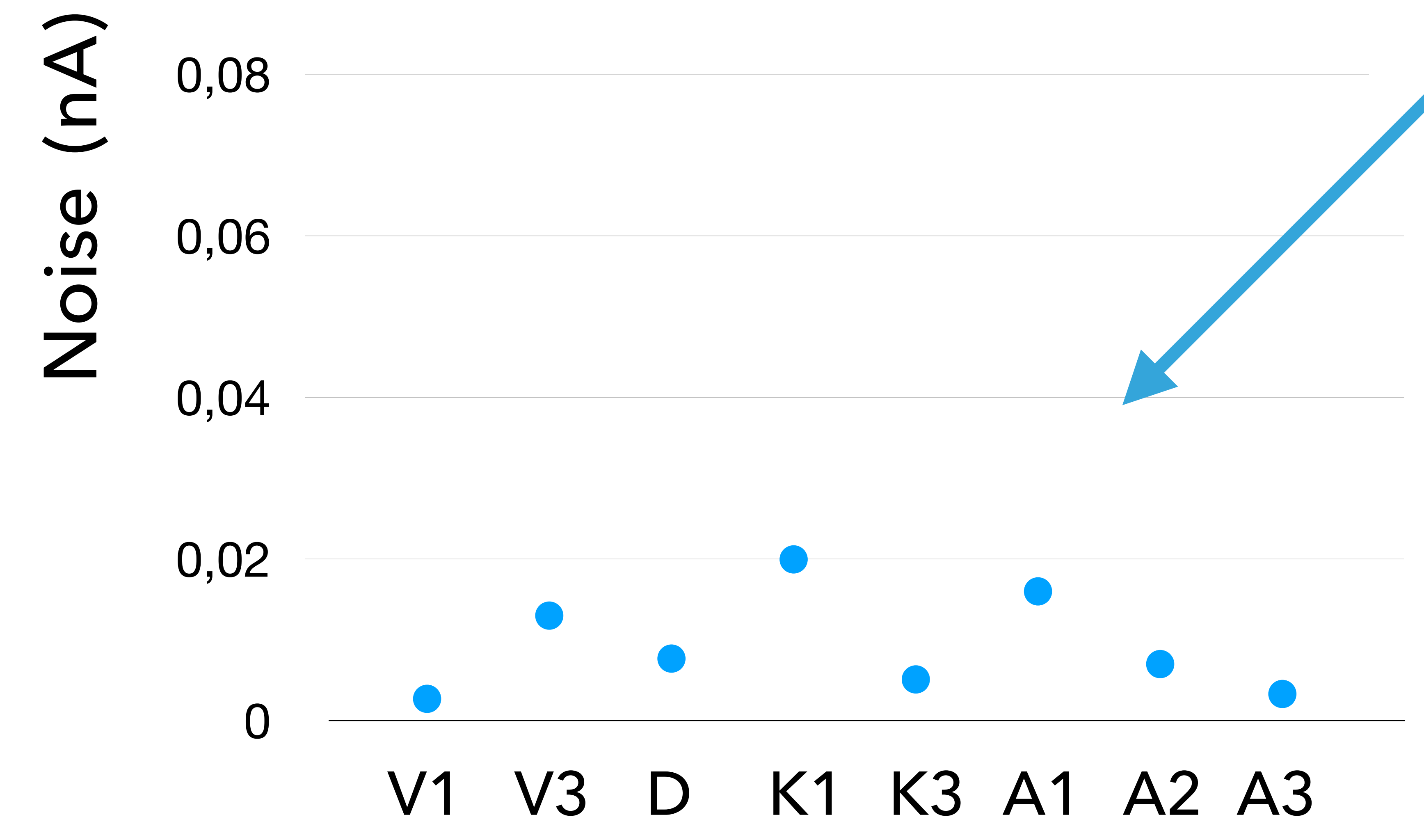


p-i-n on **Kapton** V=0.06 mm^3
p-i-n on **Kapton** V=0.01 mm^3
CSC on **glass** V=0.10mm^3

NOISE CHARACTERIZATION

At the operating voltage the noise is uniform for all the devices tested.

If we normalize to the volume of the device we find that diodes deposited on a crystalline silicon substrate have a slightly higher noise fluctuation.



	p-i-n on **c-Si** V = 0.01 mm^3	**p-i-n** on **c-Si** V = 0.0025 mm^3	**CSC** on **glass** V = 0.13 mm^3	**CSC** on **glass** V = 0.0992 mm^3	**p-i-n** on **Kapton** V = 0.06 mm^3	**p-i-n** on **Kapton** V = 0.01 mm^3
Leakage Current (Bias Voltage)	<1.4 nA	<0.3 nA	<3.0 nA	<2.0 nA	<1.2 nA	<0.2 nA
Noise (Bias Voltage)	<15 pA	<3 pA	<5 pA	<20 pA	<20 pA	<8 pA

We have obtained typical **noise values** of the order of few **pA**.

CONCLUSION AND FUTURE WORK

- Within the same device the different detectors show a **uniform** electronic behavior;
- The **noise** level is uniform for all type of prototypes and is around a few tens of pA (**~ 20 pA**), this implies detection capability down to tens of pA with a reasonable S/N ratio, hence a good sensitivity;
- We can state that the **noise** level is not related to the volume, thickness or type of device contacts, may be we are still dominated by DAQ noise;

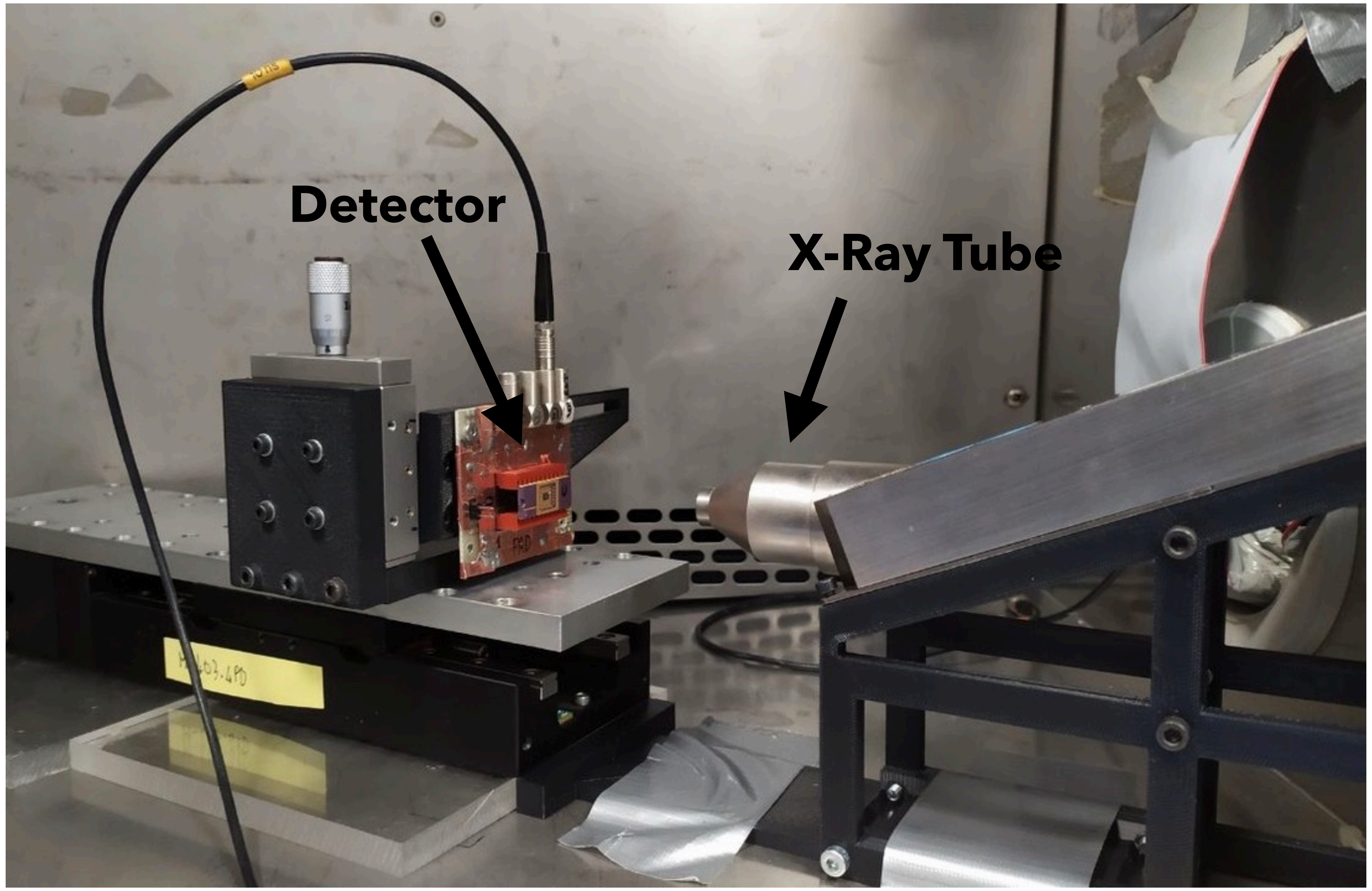
FUTURE WORK

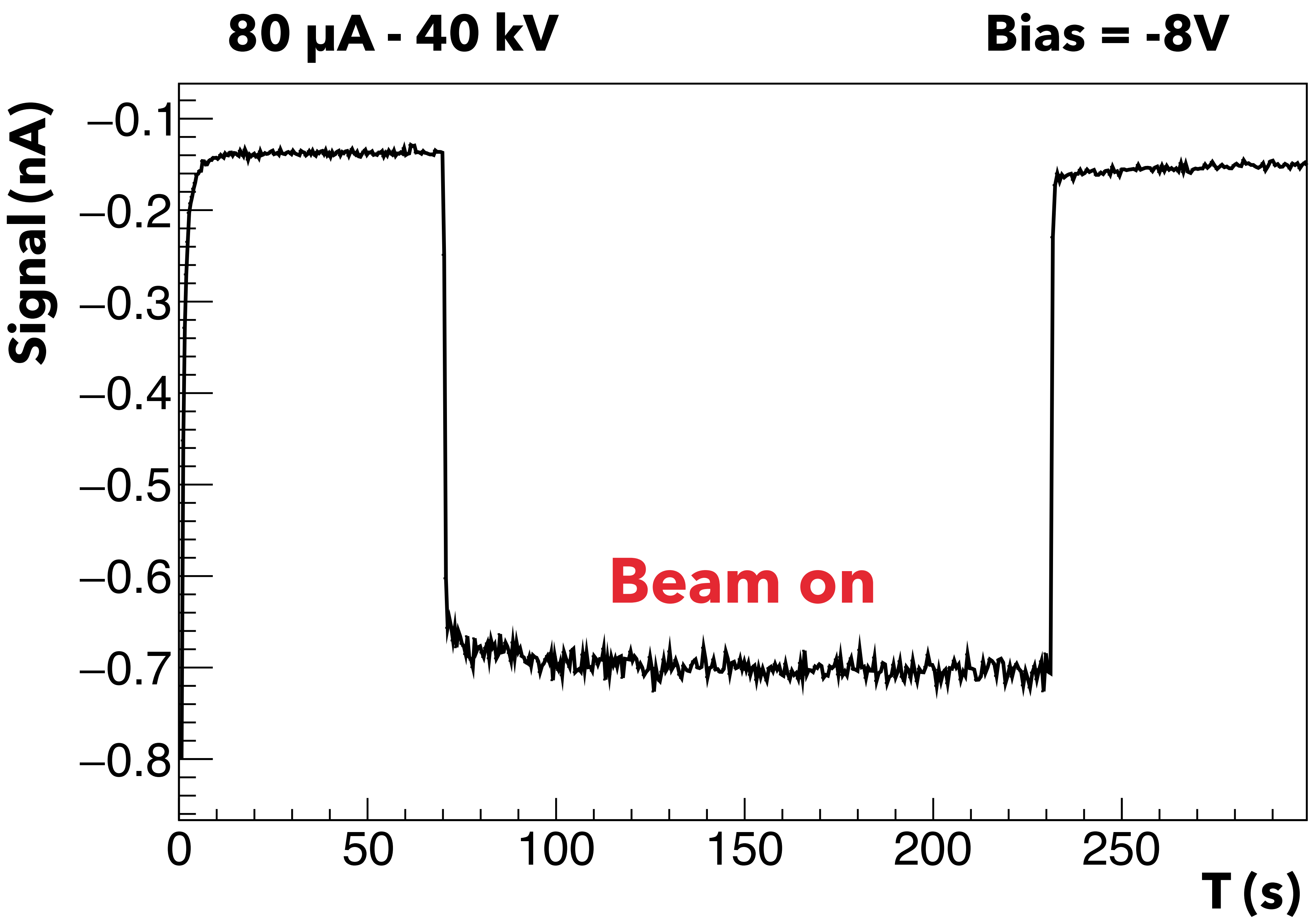
- We have to test sensors with different **thicknesses** and volumes to understand if there is any dependence of the noise, and also use better front-end systems for DAQ;

SIGNAL CHARACTERIZATION

The devices were initially characterized in Perugia, to do it they were exposed to an **X-ray** source.

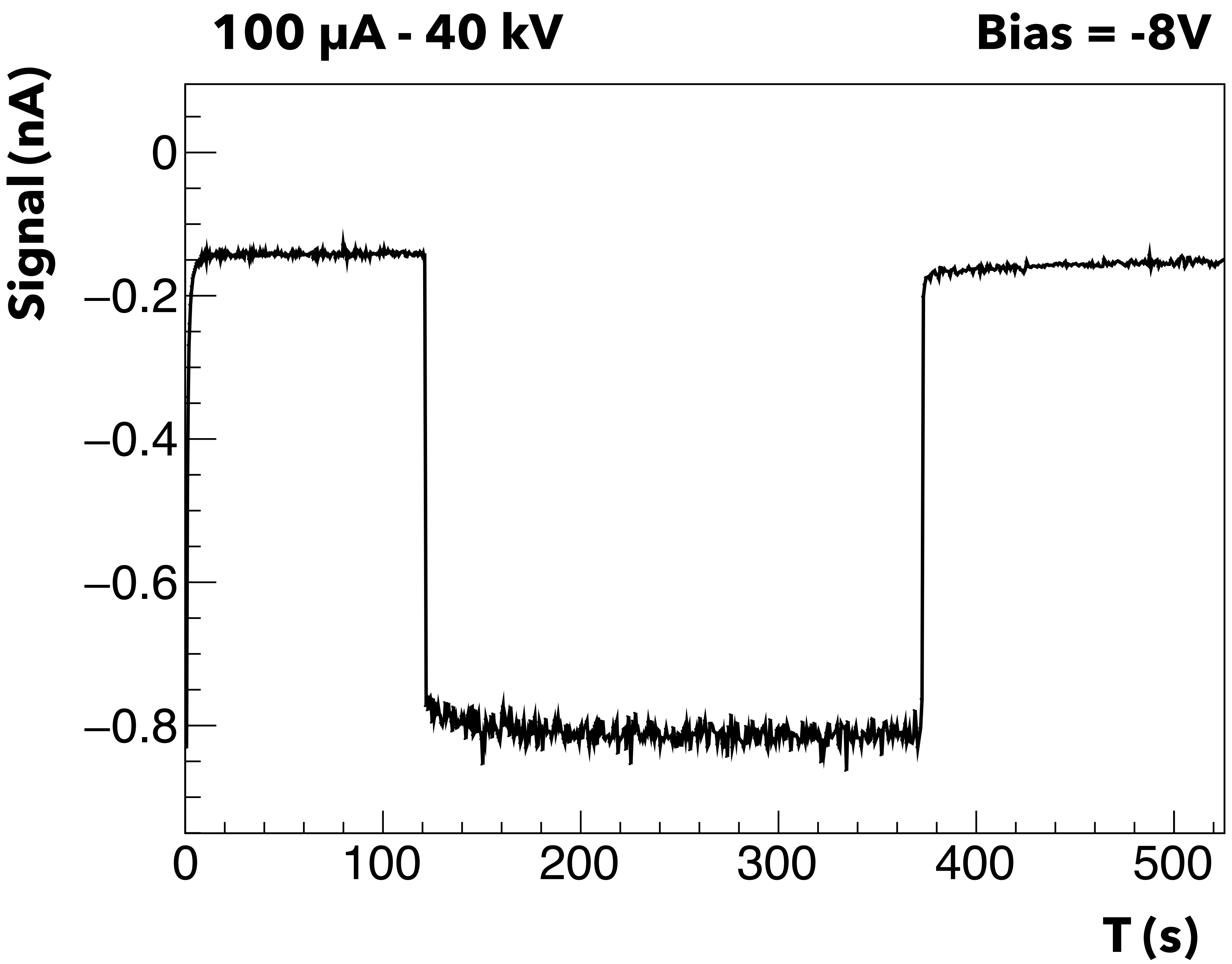
The experimental set up allows us to read only one pad at time, the analysis presented was then repeated for each pad contained in the detector, we can say that all six devices provide comparable results.

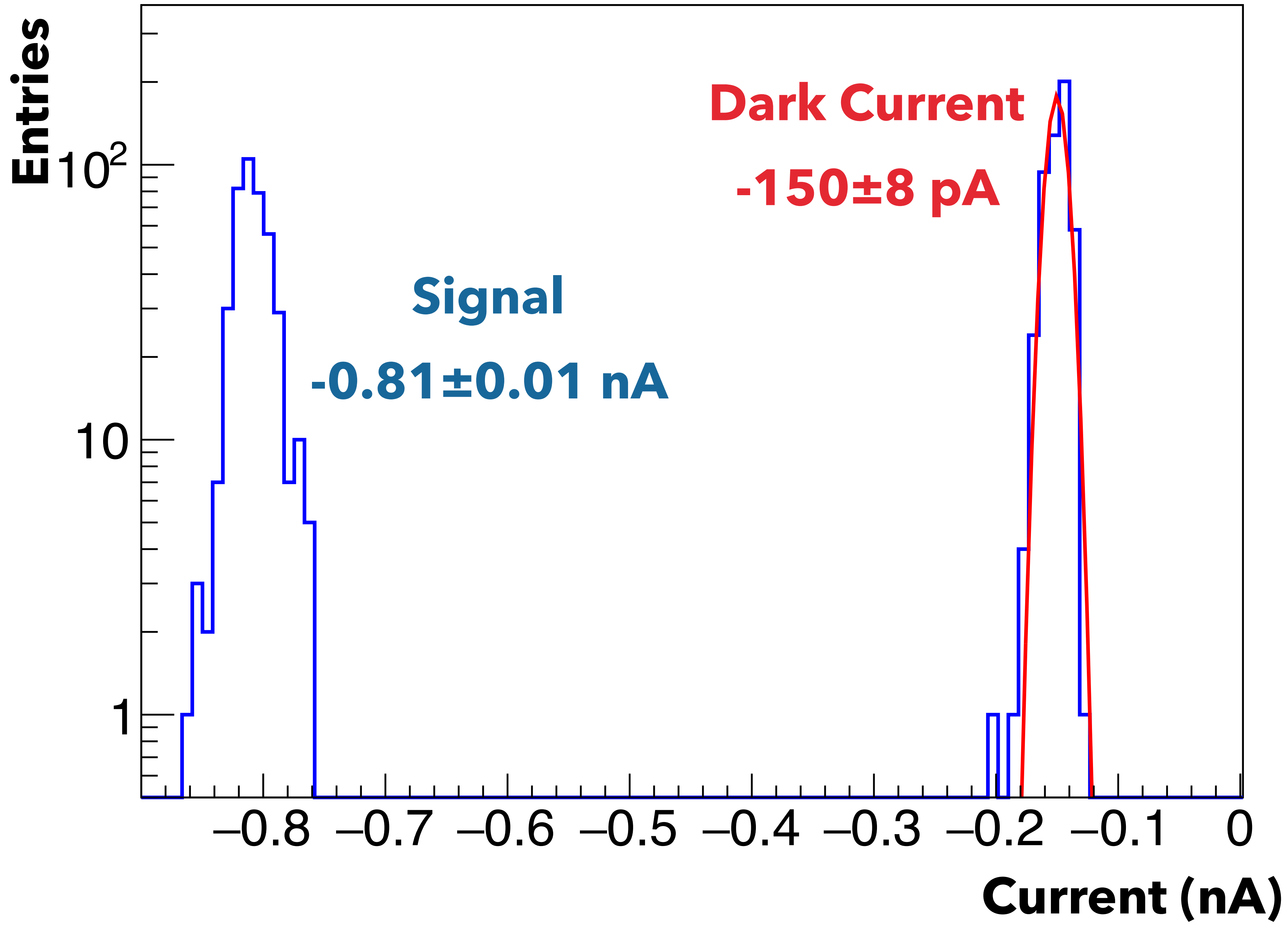




SIGNAL CHARACTERIZATION

To make a first characterization of the sensor we exposed the detector to an X-ray source. Here are some time profiles of the measurements made with 20 V bias:





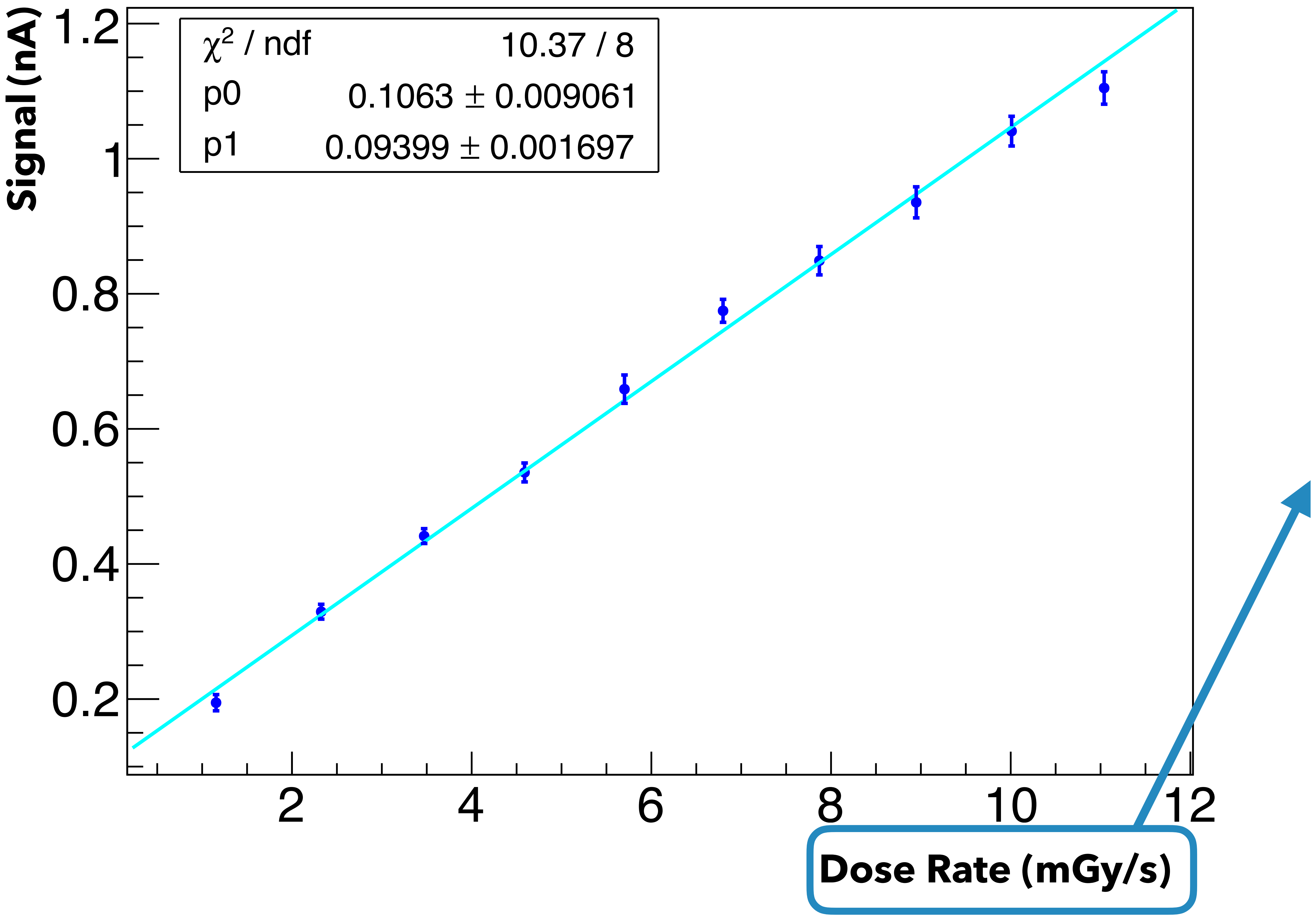
The values for the signal and noise are extrapolated from the Gaussian fits, the mean value represent the measured current and the sigma value identifies the oscillation.

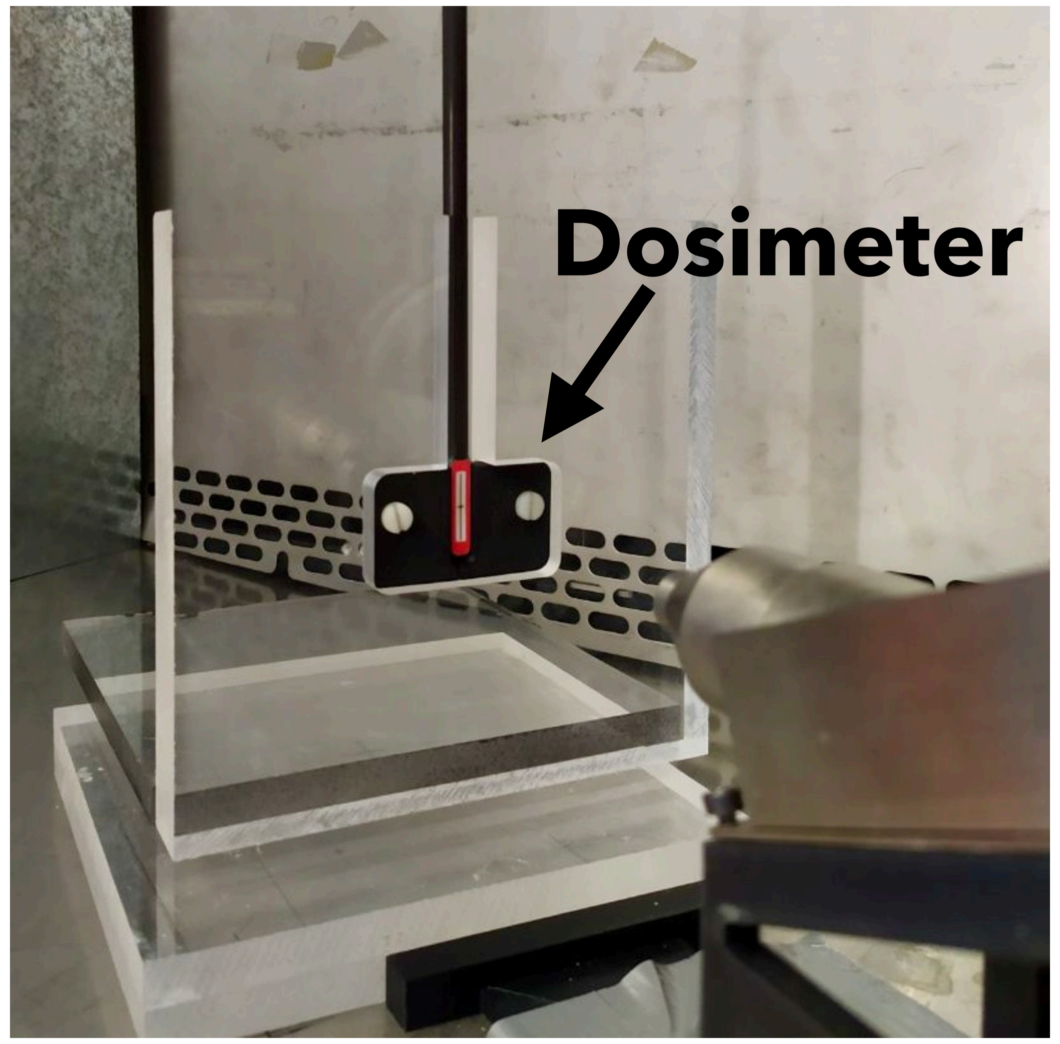
$$S = I_{Signal} - I_{Dark} \qquad \delta S = \delta I_{Signal} + \delta I_{Dark}$$

SIGNAL CHARACTERIZATION

To obtain the sensor response as a function of the X-ray tube current or dose rate, we subtracts from the current, measured during beam exposition, the value of the dark current that precedes it.

p-i-n on **Kapton** V = 0.01 mm^3

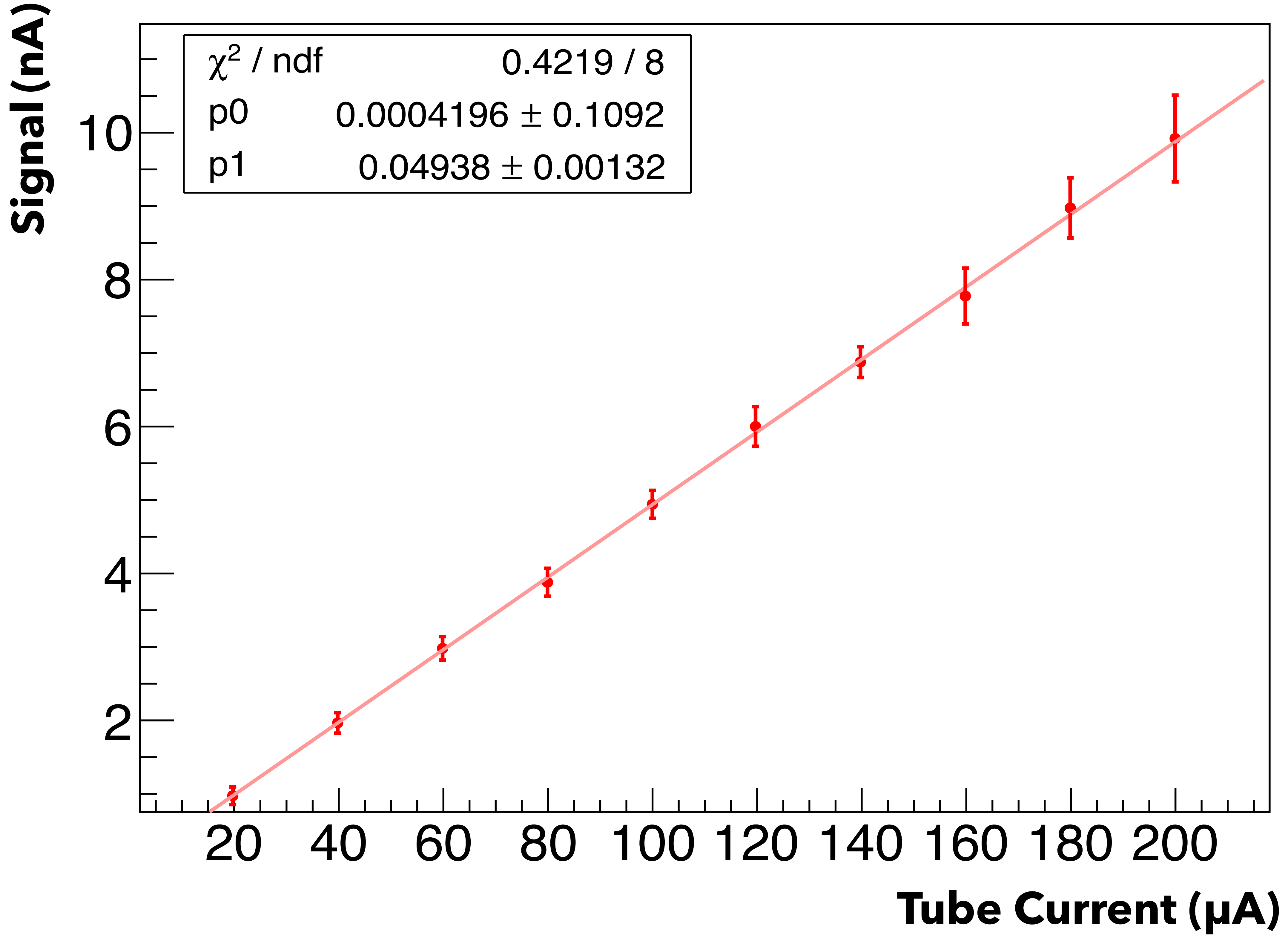




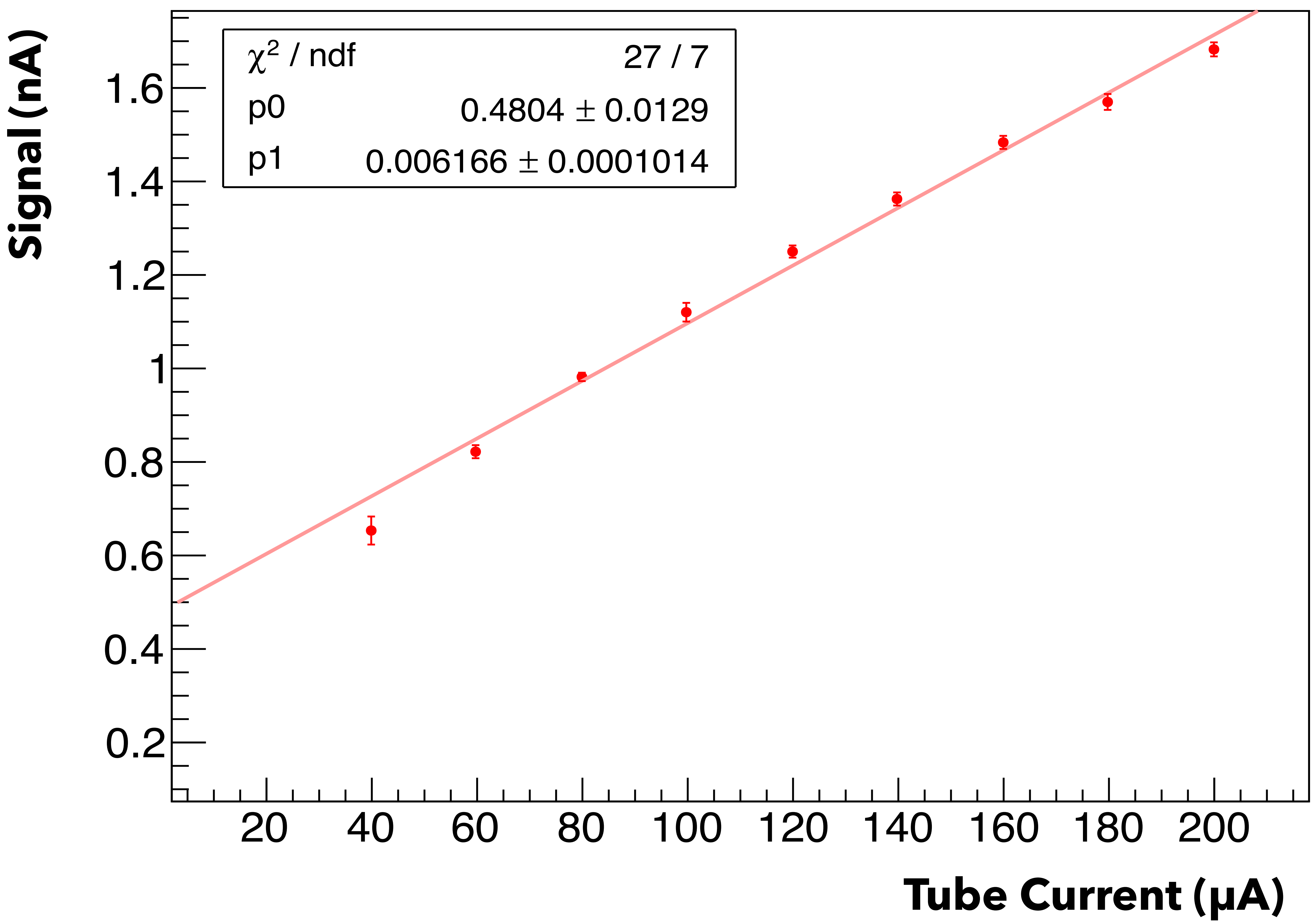
To evaluate the **dose rate** released by the **x-ray tube**, measurements were made with a **dosimeter.**

We mapped the response of the X-Ray tube as a function of the position of the detector and the settings of the tube.

SIGNAL CHARACTERIZATION



p-i-n on **c-Si** V = 0.01 mm³



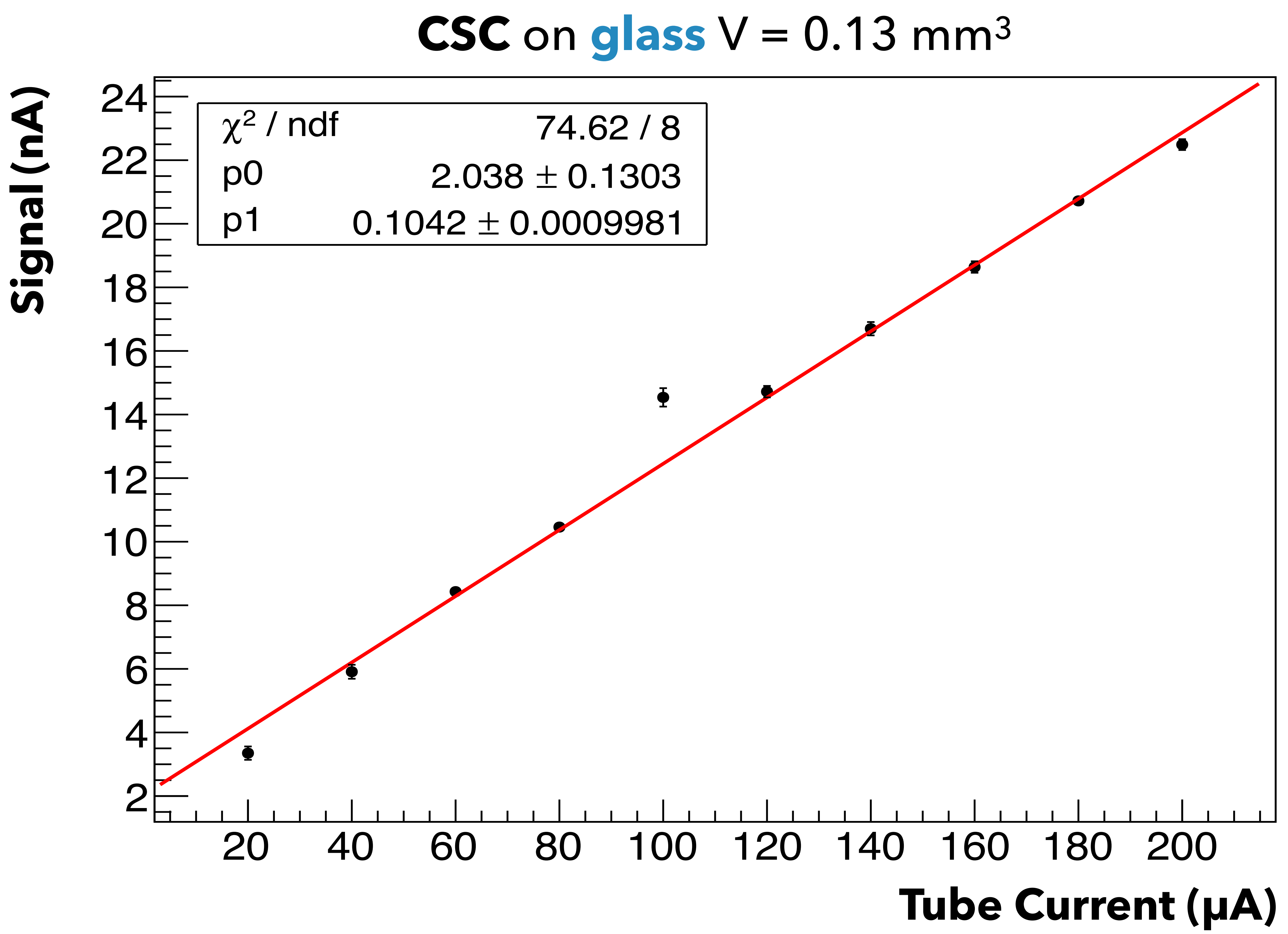
p-i-n on **c-Si** V = 0.0025 mm³

If the angular coefficient of the fit line is normalized to the volume of the two sensors, seems to indicate a higher sensitivity of the sensor with larger area with the same thickness.

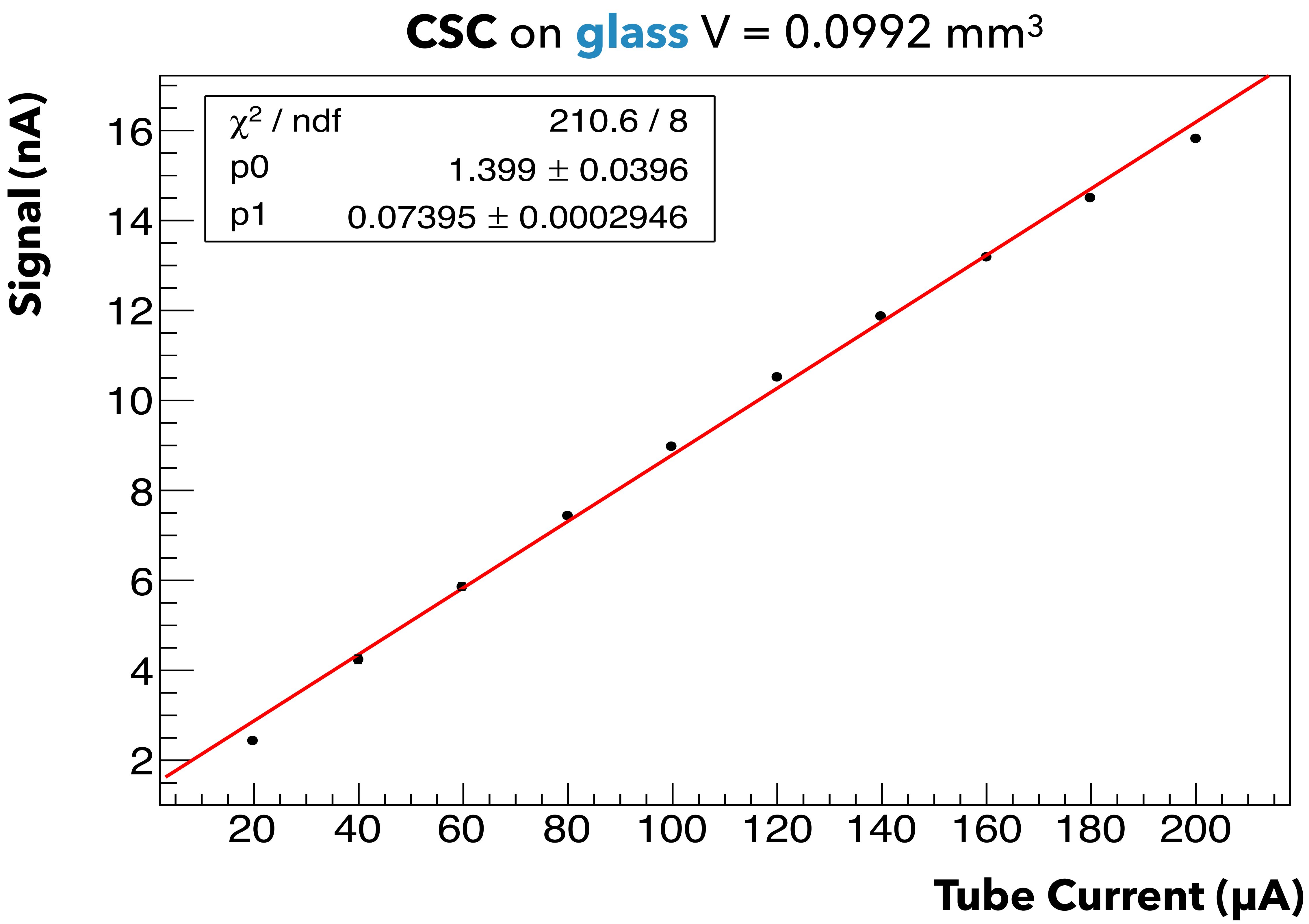
$$S_D = \frac{0.049 \pm 0.001}{0.01} = 4.9 \pm 0.01 \ \frac{\text{nA}}{\mu\text{A mm}^3} \qquad S_V = \frac{0.0062 \pm 0.0001}{0.0025} = 2.47 \pm 0.04 \ \frac{\text{nA}}{\mu\text{A mm}^3}$$

SIGNAL CHARACTERIZATION

CSC on **glass** V = 0.13 mm³



CSC on **glass** V = 0.0992 mm³

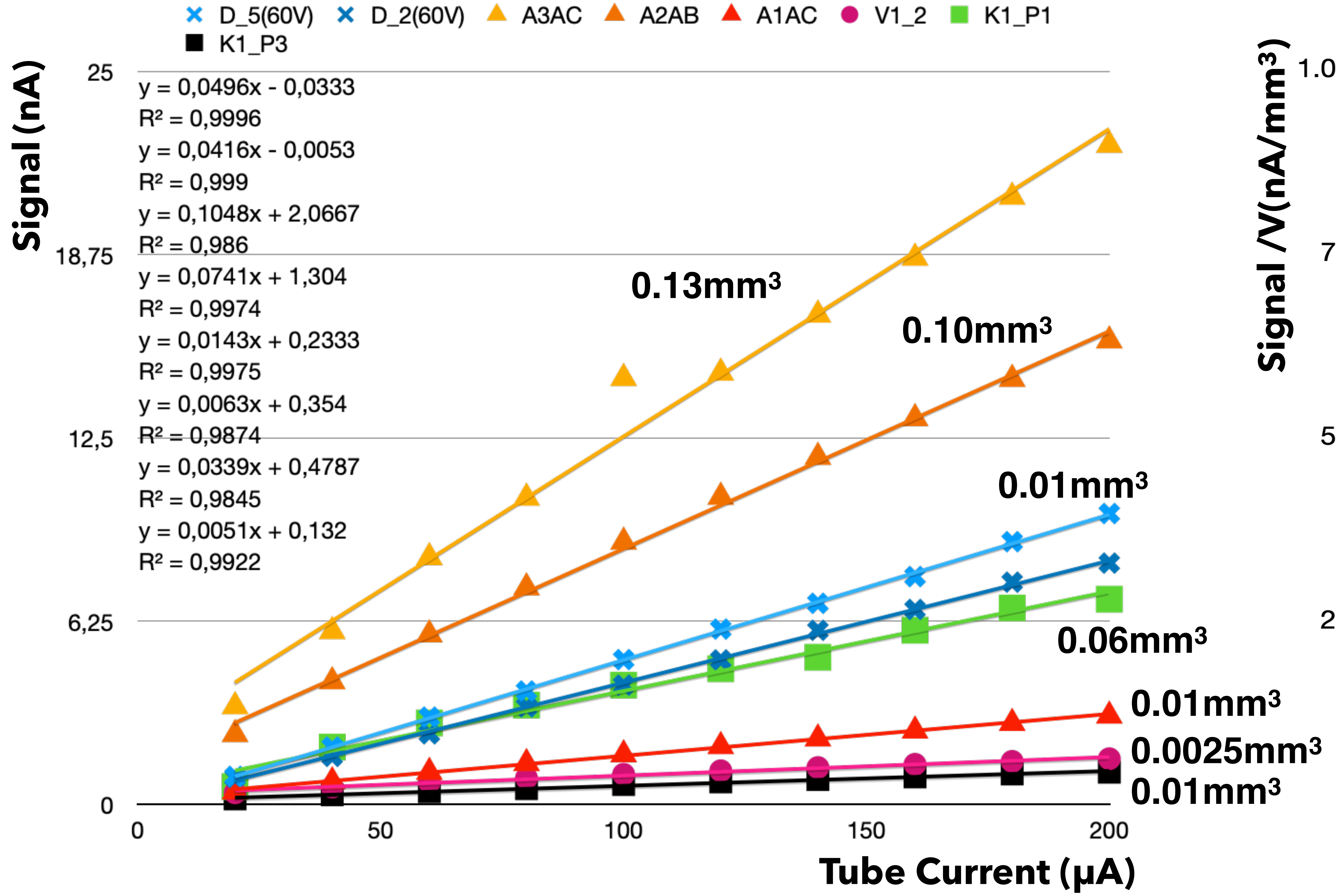


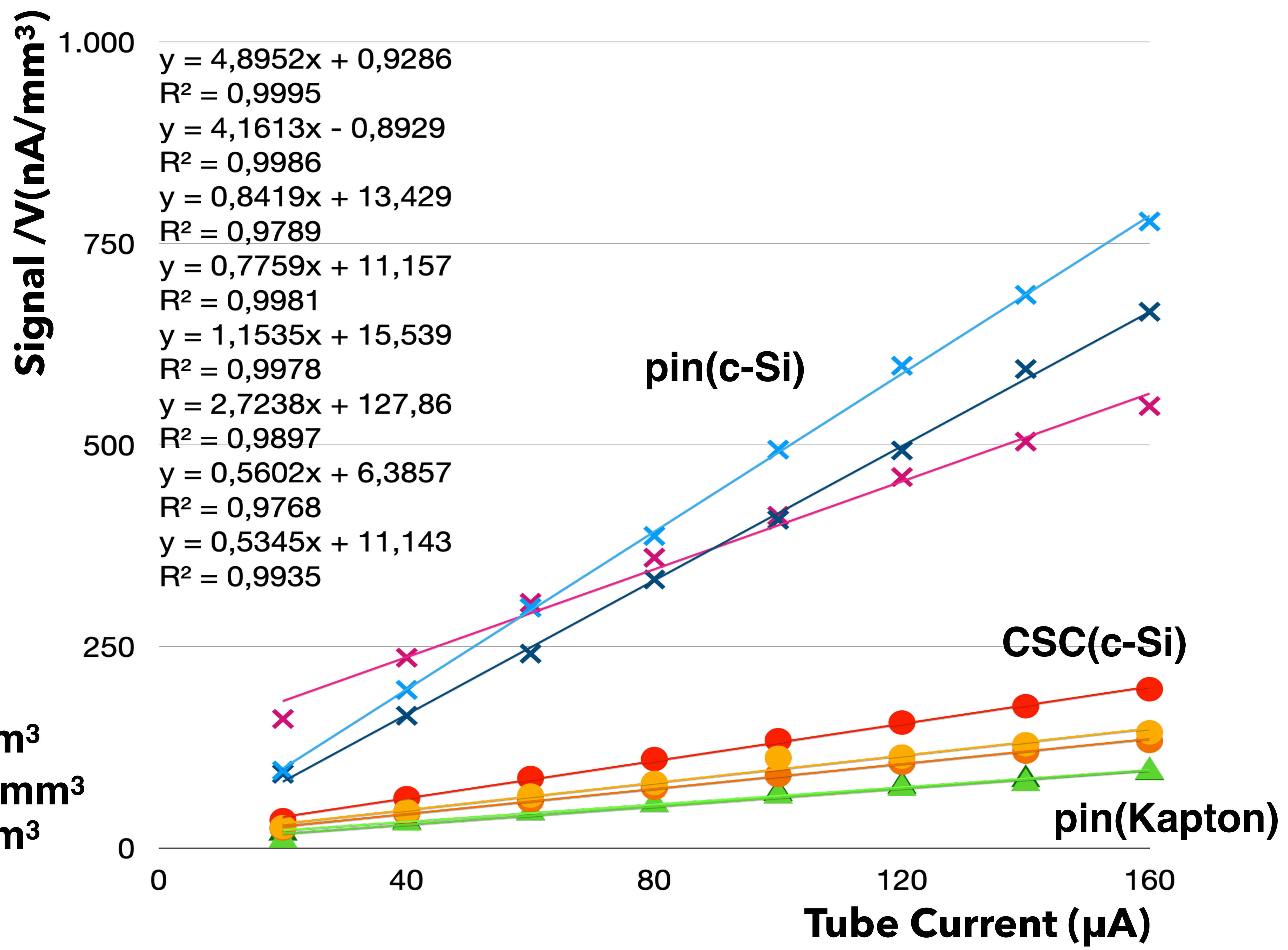
If the angular coefficient of the fit line is normalized to the volume of the two sensors, sensitivity scale to the sensor's thickness.

$$S_{A3AC} = \frac{0.1042 \pm 0.001}{0.13} = 0.80 \pm 0.01 \ \frac{\text{nA}}{\mu\text{A mm}^3}$$

$$S_{A2AC} = \frac{0.07395 \pm 0.0003}{0.0992} = 0.745 \pm 0.003 \ \frac{\text{nA}}{\mu\text{A mm}^3}$$

SIGNAL CHARACTERIZATION



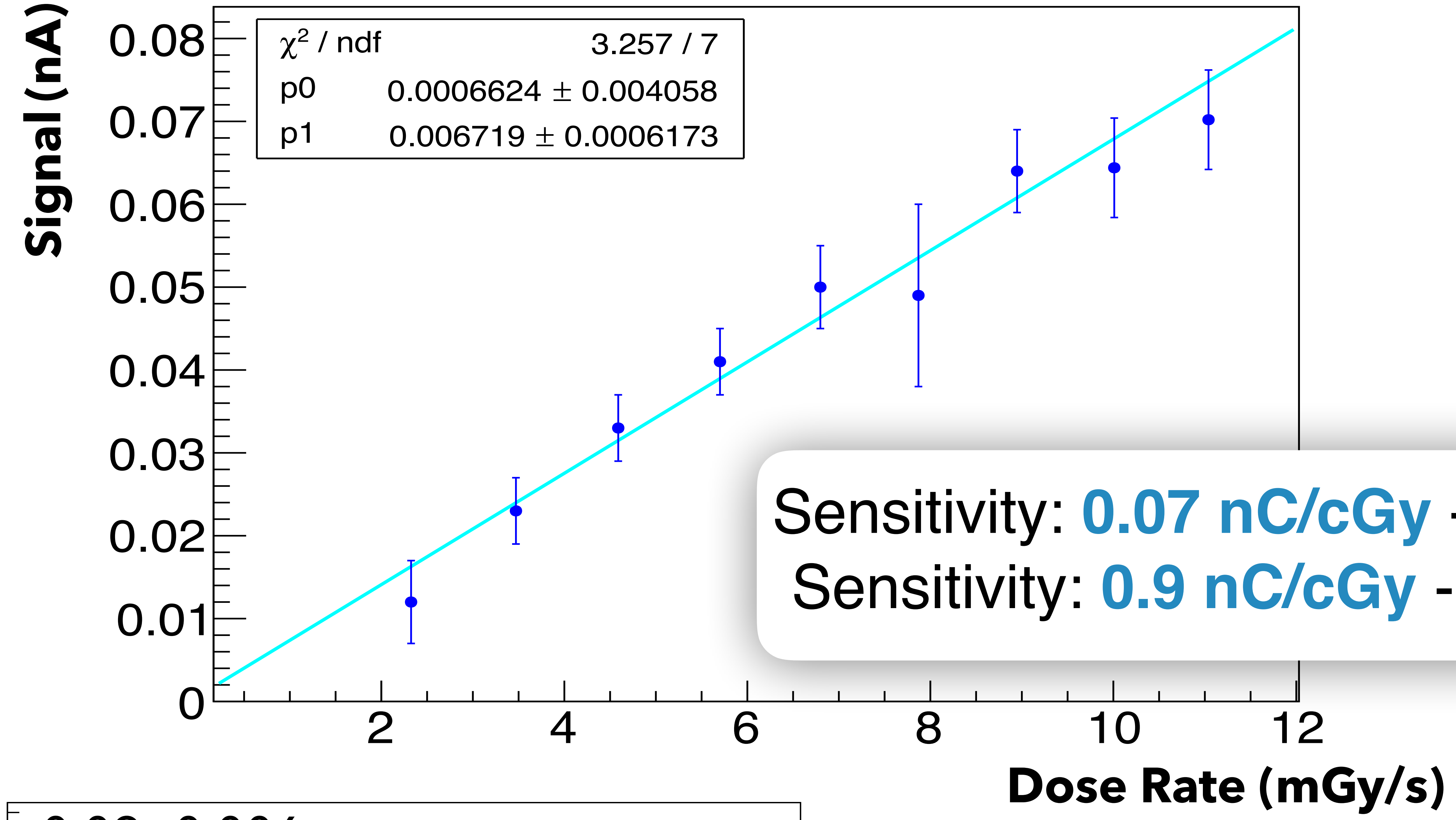


With the same volume the best sensitivity appears to be associated with pin-type devices deposited on crystalline silicon, while the lowest is recorded by devices deposited on kapton.

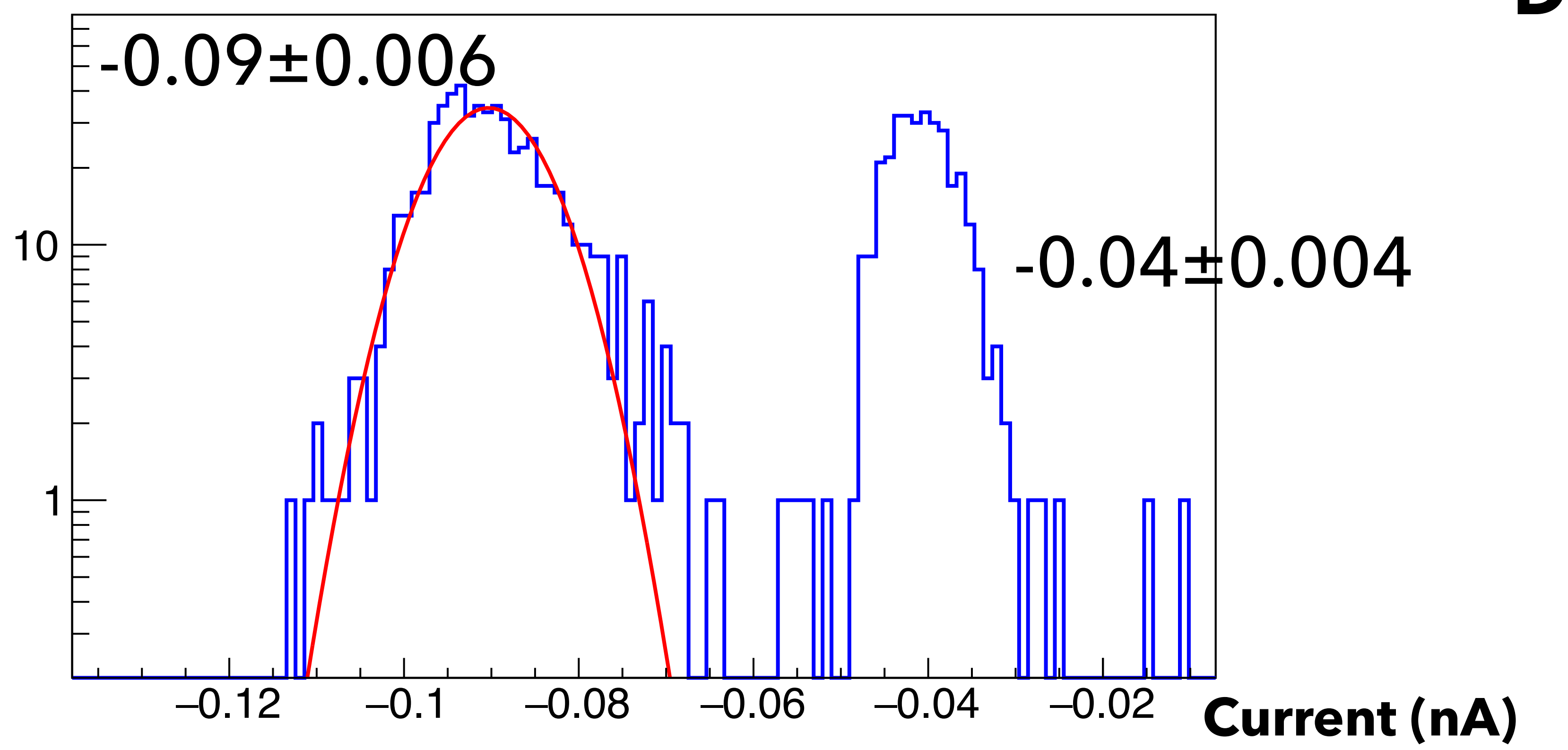
SIGNAL CHARACTERIZATION

For the sensors deposited on kapton an acquisition test with bias equal to 0 V was also carried out.

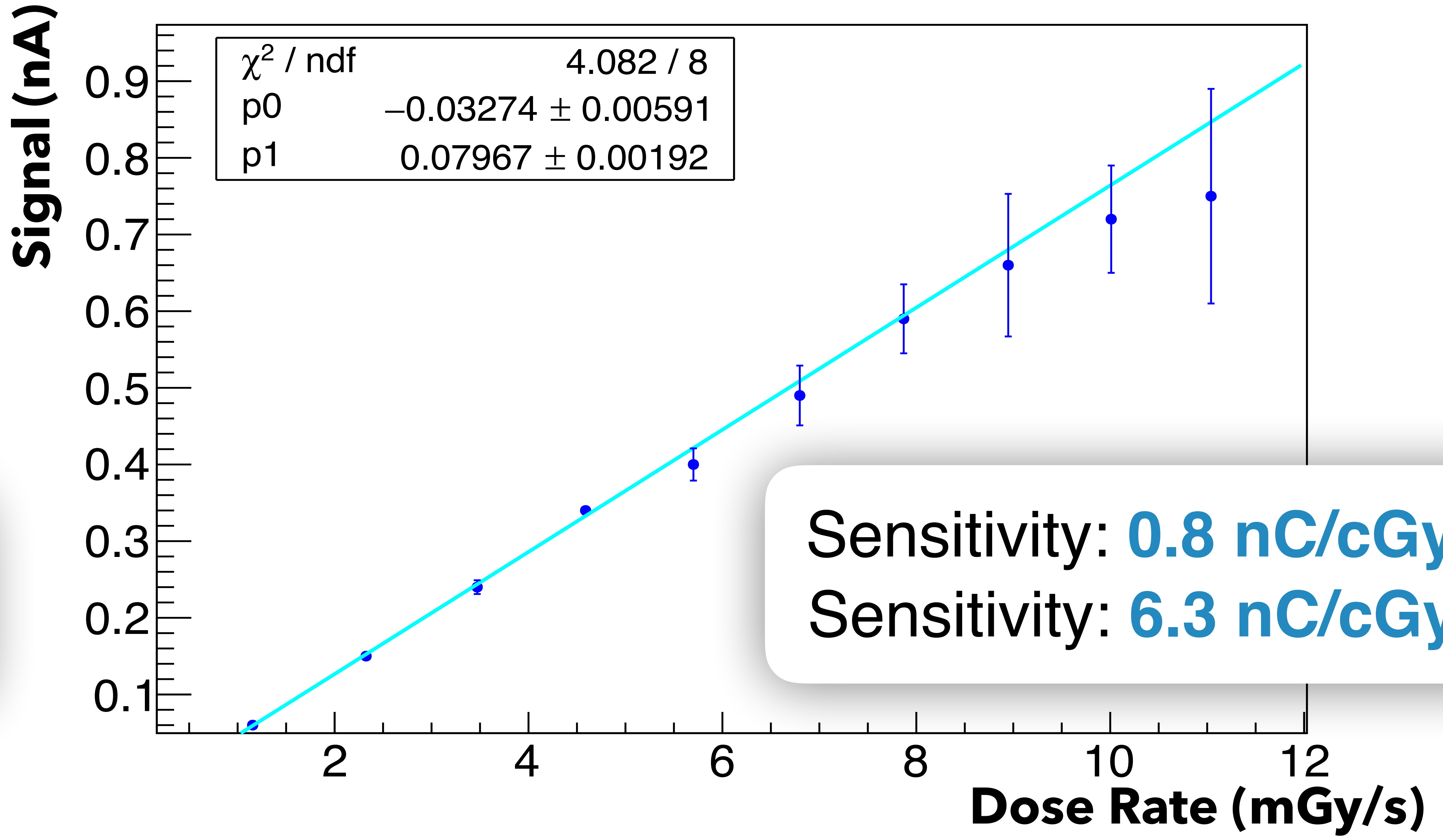
p-i-n su **Kapton** V = 0.01 mm^3



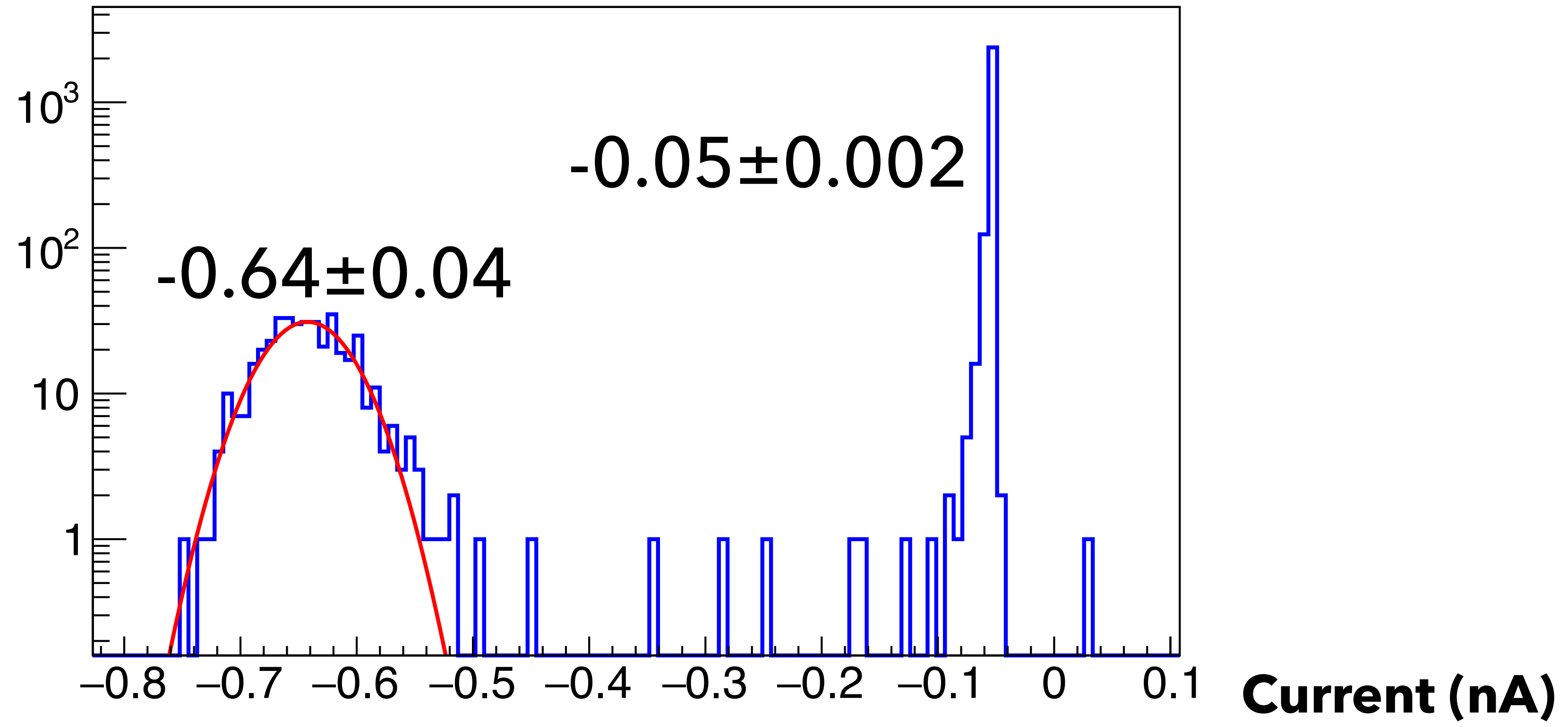
Sensitivity: **0.07 nC/cGy** - 0V
Sensitivity: **0.9 nC/cGy** - 8V



p-i-n su **Kapton** V = 0.06 mm^3



Sensitivity: **0.8 nC/cGy** - 0V
Sensitivity: **6.3 nC/cGy** - 8V



SIGNAL CHARACTERIZATION

● **p-i-n** on **Kapton** V = 0.01 mm^3

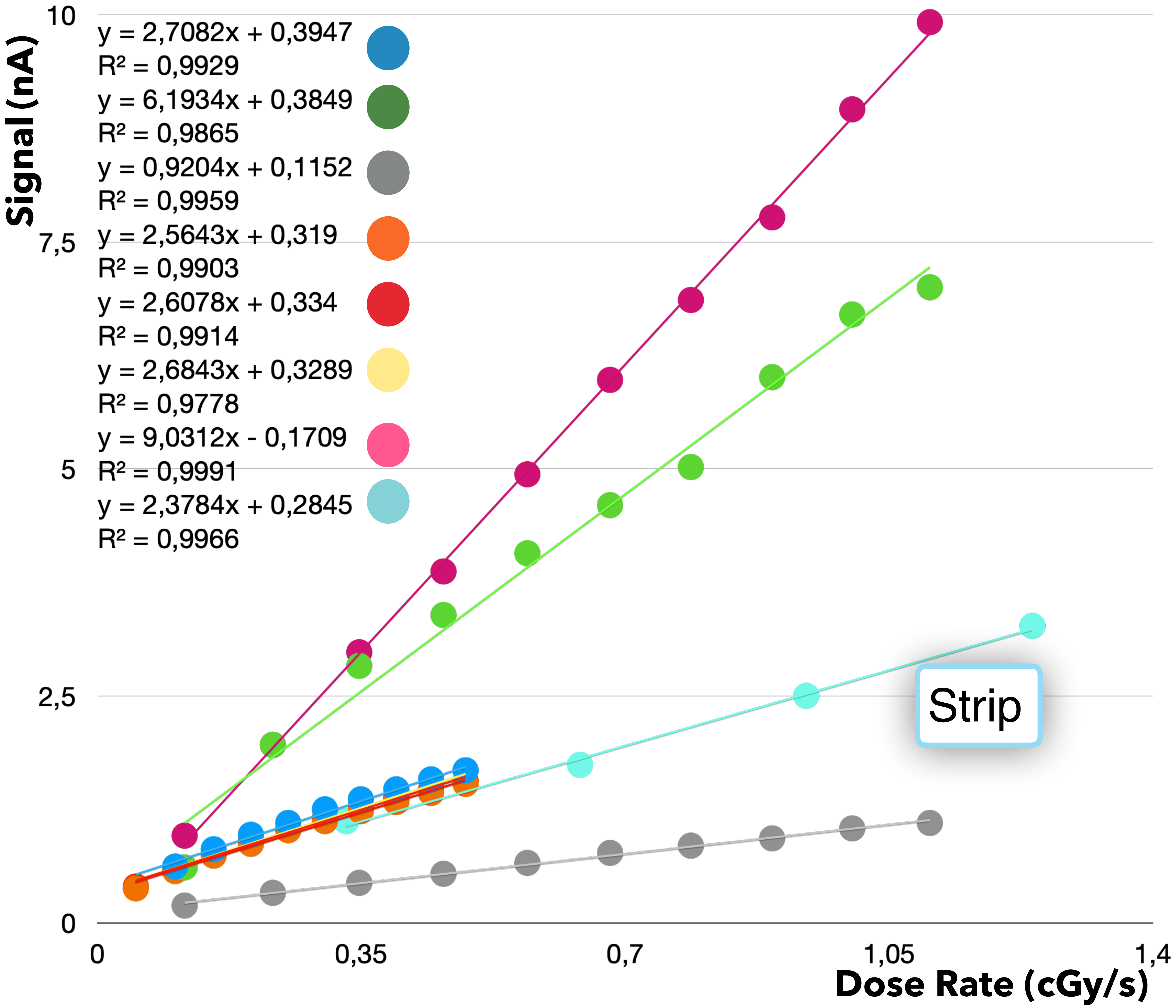
● **p-i-n** on **Kapton** V = 0.06 mm^3

● ● **p-i-n** on **c-Si** V = 0.0025 mm^3

● ●

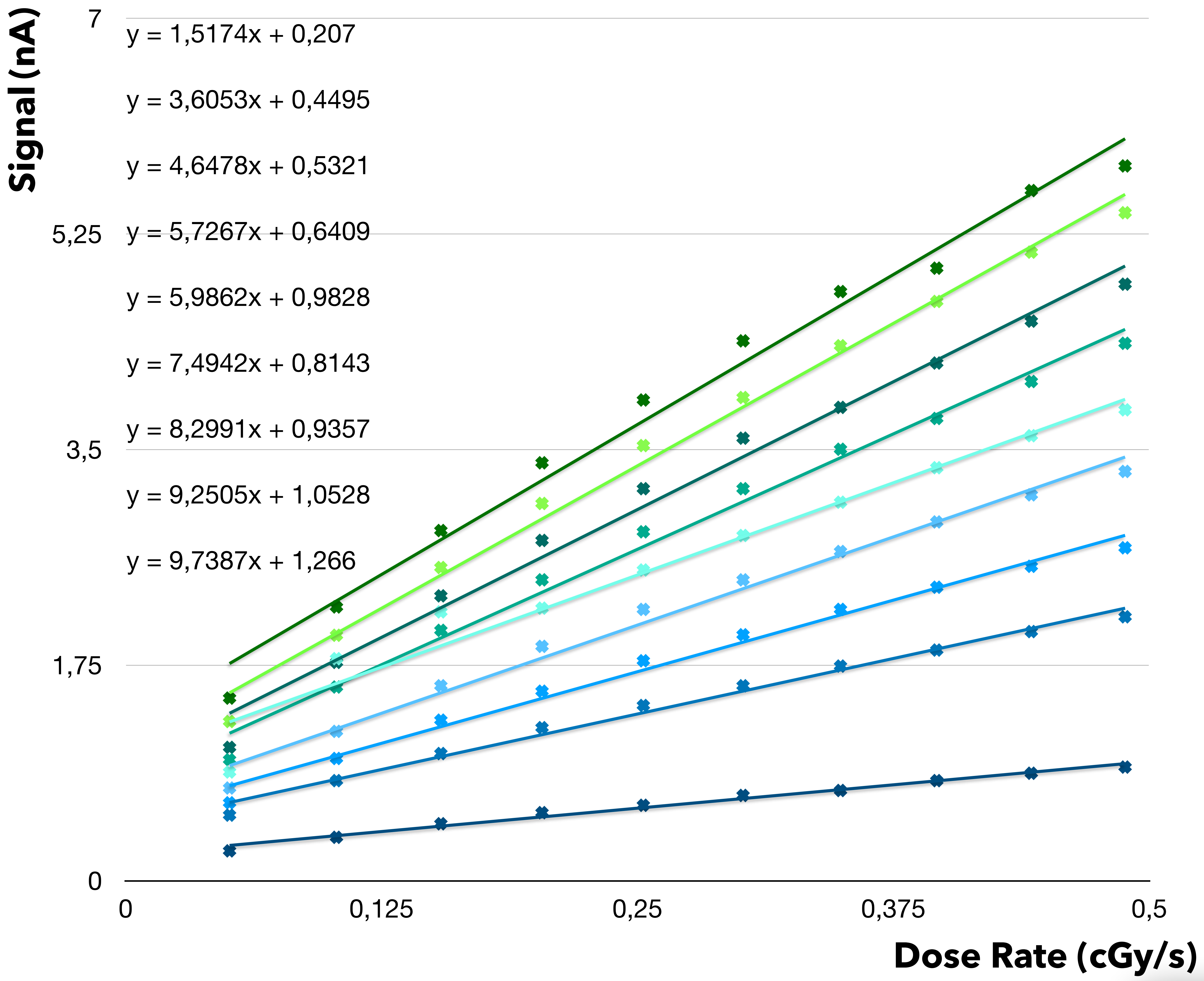
● **p-i-n** on **c-Si** V = 0.01 mm^3

● **p-i-n** on **c-Si** V = 0.01 mm^3 Don't scale with volume



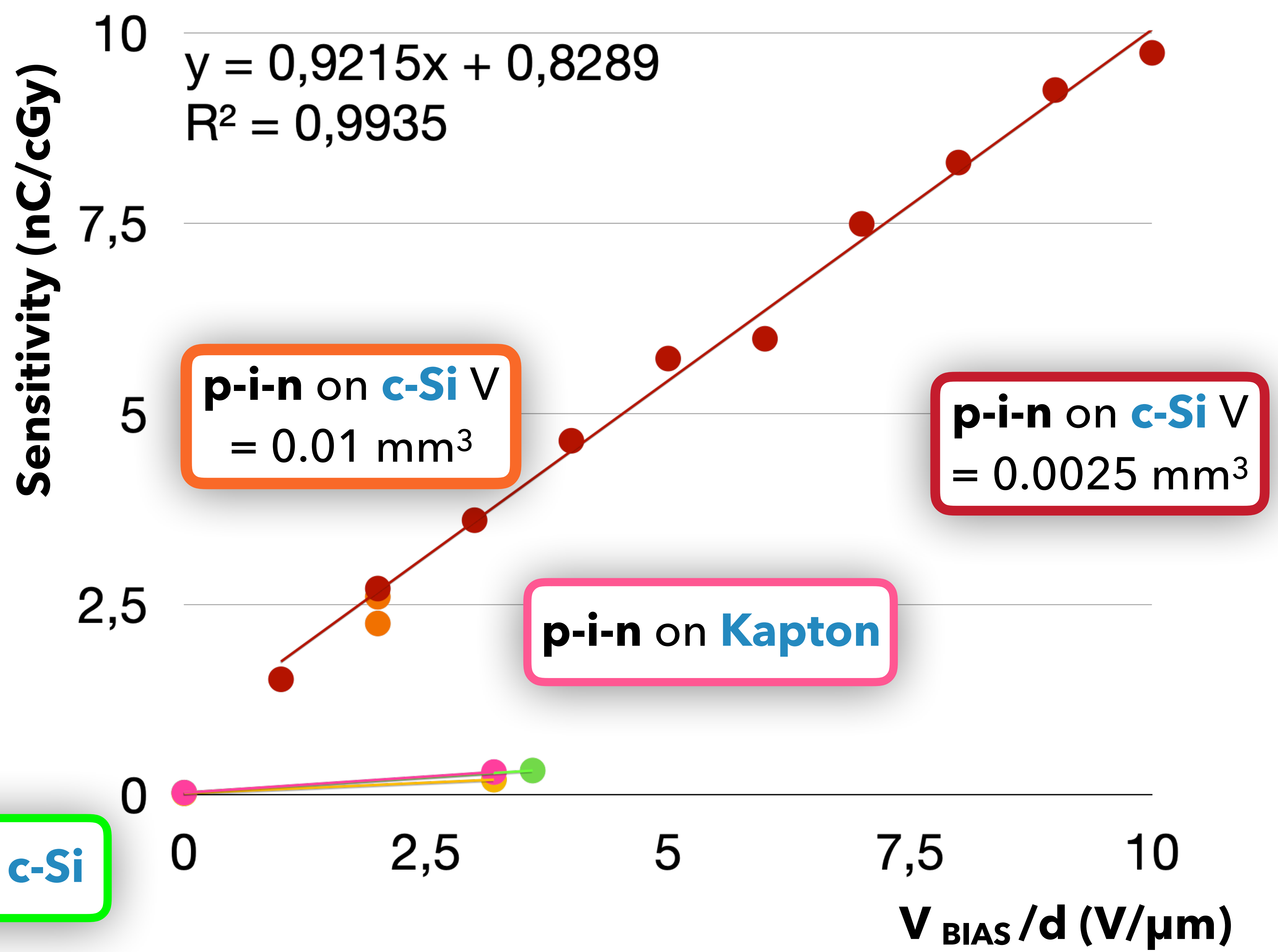
	p-i-n on **c-Si** V = 0.01 mm^3	**p-i-n** on **c-Si** V = 0.0025 mm^3	**CSC** on **c-Si** V = 0.13 mm^3	**CSC** on **c-Si** V = 0.099mm^3	**p-i-n** on **Kapton** V = 0.06 mm^3	**p-i-n** on **Kapton** V = 0.01 mm^3
Sensitivity nC/cGy	9.0±0.4	2.6±0.4	16.71±0.06	8.78±0.03	6.3±0.8	0.92±0.02
Sensitivity nC/cGy (0V Bias)	/	/	1.37±0.01	0.84±0.01	0.8±0.02	0.07±0.01
Normalized Sensitivity nC/cGy mm^3	903±40	1040±40	128±1 10.5±0.1	89±0.3 8.5±0.1	105±13 13.0±0.3	92±2 7±1

SIGNAL CHARACTERIZATION



For the p-i-n type sensors deposited on crystalline silicon, the sensitivity trend in relation to the applied bias was studied.

Here we can see the sensitivities normalized to the volume of the pins (0.0025 mm³) measured for the various types of detectors.



CONCLUSION

- We have tested different types of sensors which differ from each other in:

1. Type of contact;
1. Thickness;
2. Area;
3. Substrate;
4. Perimeter ?;

Normalizing the sensitivity to the volume of each sensor, the best sensitivity is that associated with pin-type devices deposited on c-Si.

With the same contact and area, the sensitivity scales with the thickness.

With the same thickness and type of contact, the sensors with a greater area have a greater sensitivity.

With the same contact and volume, diodes deposited on crystalline silicon have greater sensitivity.

With the same contact, area, and thickness strip have a lower sensitivity than square pad.

FUTURE WORK

- We need sensors deposited on kapton with different thicknesses and an area comparable to that of diodes on c-Si, in order to understand if the difference in the sensitivity value is due to the area or thickness;
- We must try to correlate the spectroscopic measurements to these electrical measurements to try to understand why some configurations seem to work better than others;