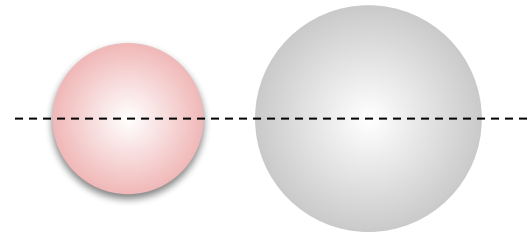




SiPMs characterization

10/11/2021

Julio Ureña



Why?

Every SiPM that is meant to be used for further experimentation in the laboratory should be previously characterized.

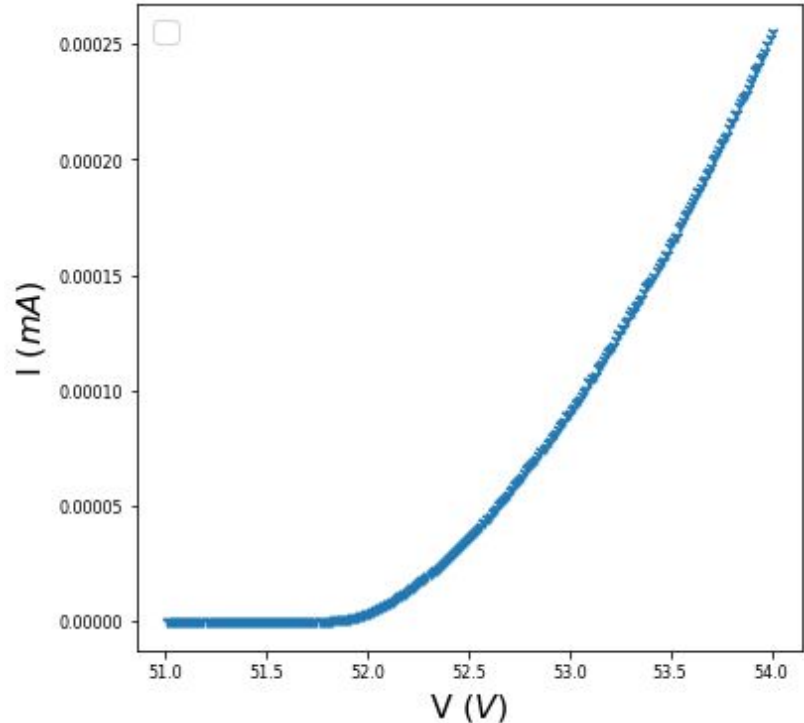
I.e. we need to measure every SiPM **breakdown voltage** (BDV) and its **gain**.

For the very next experimental setup we expect to use 5 SiPMs attached to a card. As a matter of fact, 5 SiPMs are being characterized at the moment.

Data taking for BDV

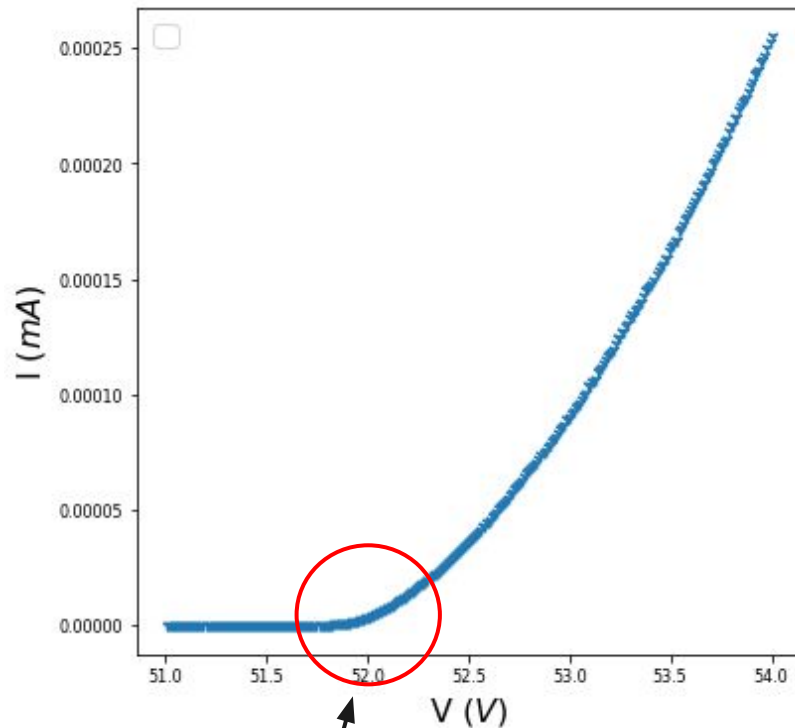
Raw data obtained from the Keithley-multiplexer setup for the I-V setup

```
data > IV_curve > 21_11_08_board00_sipm01_cold_iv_inverse.txt
262 53.600000 0.000174
263 53.610000 0.000174
264 53.620000 0.000176
265 53.630000 0.000177
266 53.640000 0.000178
267 53.650000 0.000181
268 53.660000 0.000183
269 53.670000 0.000183
270 53.680000 0.000186
271 53.690000 0.000187
272 53.700000 0.000188
273 53.710000 0.000190
274 53.720000 0.000191
275 53.730000 0.000192
276 53.740000 0.000195
277 53.750000 0.000197
278 53.760000 0.000199
279 53.770000 0.000199
280 53.780000 0.000201
281 53.790000 0.000204
282 53.800000 0.000206
283 53.810000 0.000204
284 53.820000 0.000208
285 53.830000 0.000210
```



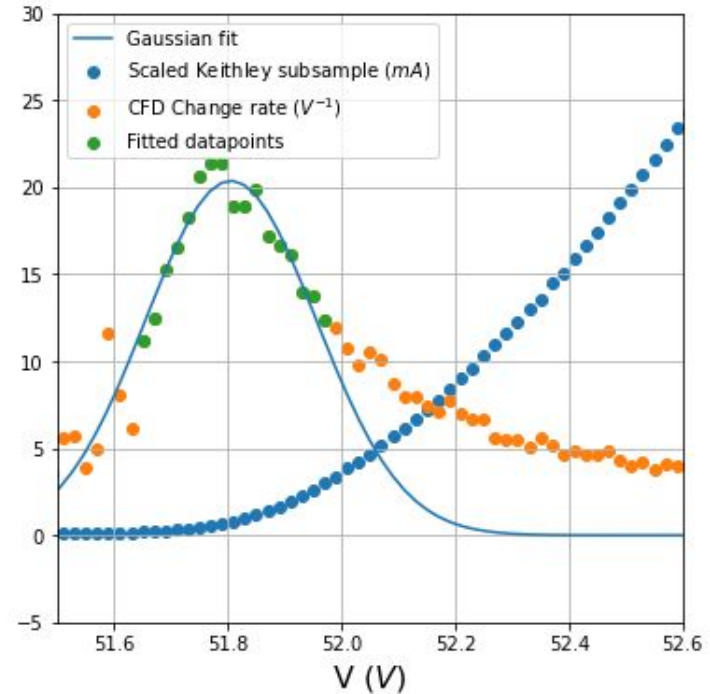
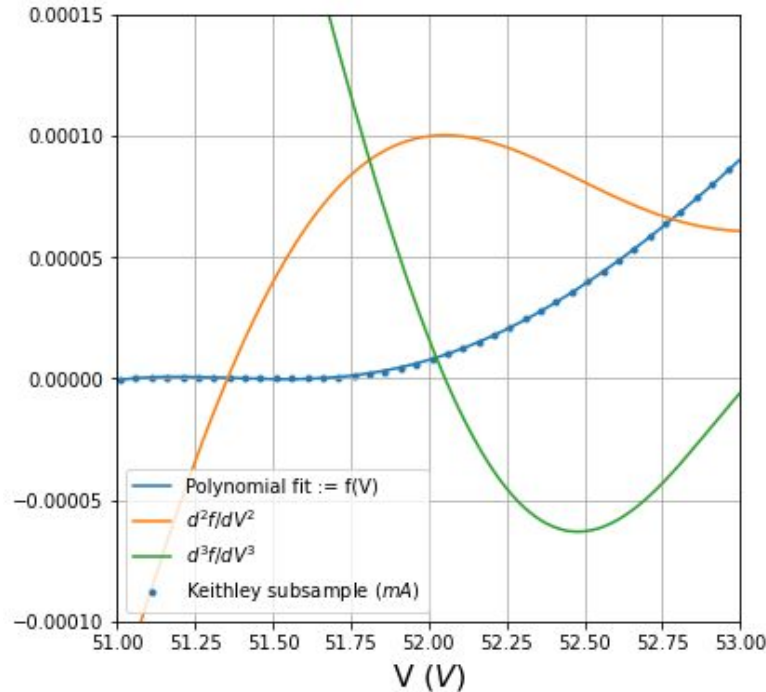
Data taking for BDV

The BDV, over which the SiPM PN junction becomes conductive, lies *somewhere over here*



BDV estimation

Two similar methods have been used to estimate the breakdown voltage (BDV) out of the I-V curve

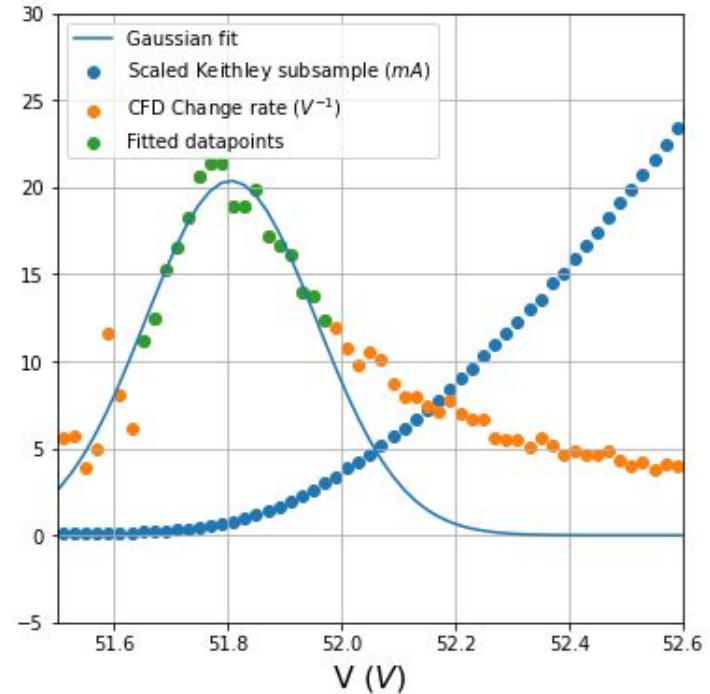


BDV estimation

One of them is based on the **current change rate**, CCR.

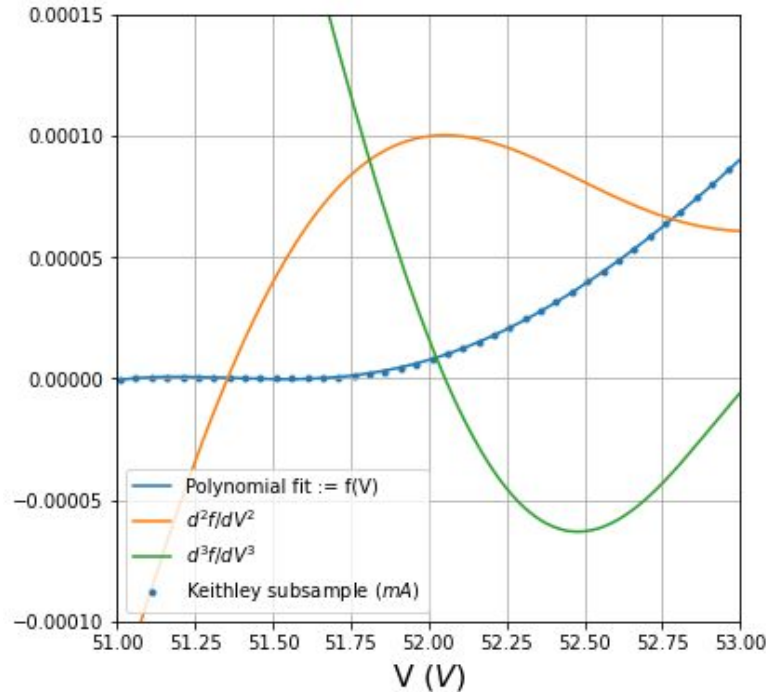
$$\text{CCR} = \frac{1}{I} \frac{dI}{dV}$$

Numerically, the CCR was estimated using the centered finite differences method, whose error is $O(h^2)$



BDV estimation

The other one is based on finding the voltage of maximum curvature for the I-V curve.



To do so, we study the maximum of the second order derivative of a polynomial model of the sampled I-V curve.

Obtained BDV

For each SiPM, the BDV has been computed as the average of the BDV's obtained via both methods

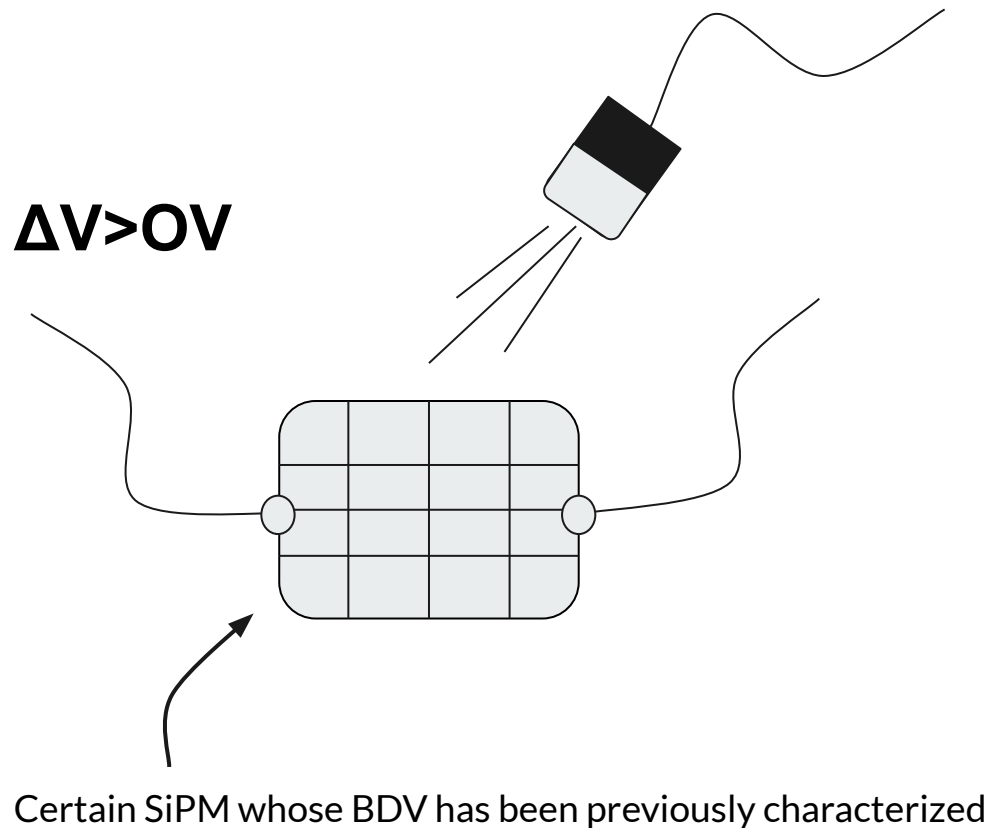
```
results > breakdown_voltages.csv
```

1	#boardNo	SDBDB(V)	CRVDB(V)	ABDV(V)	ABDVErr(V)
2	00	52.05	51.81	51.93	0.12
3	01	52.02	51.78	51.90	0.12
4	03	52.07	51.88	51.98	0.10
5	04	52.04	51.84	51.94	0.10
6	07	52.15	51.93	52.04	0.11

Gain characterization

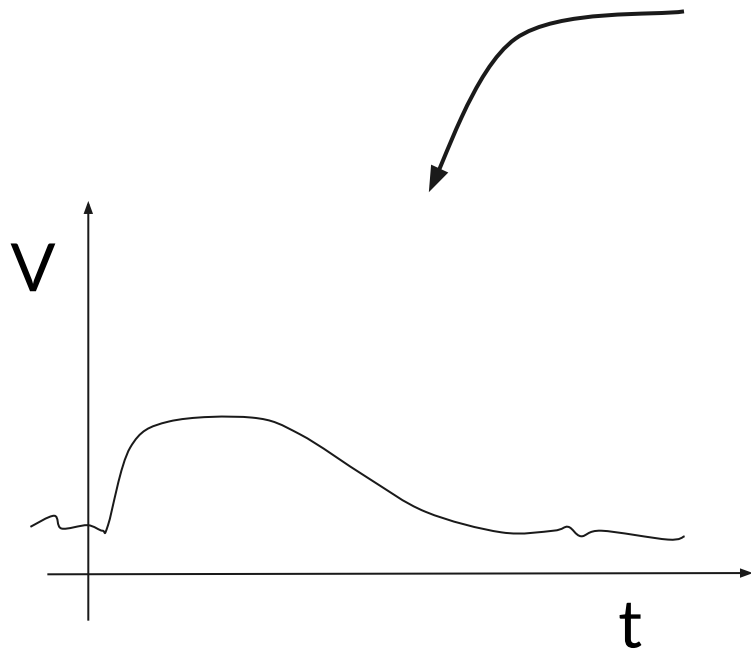
The voltage supplied to the SiPM referred to its BDV its known as Over-voltage (OV).

Supplying a certain OV to a SiPM, illuminating it and monitoring its output signal lets us characterize the SiPM gain for that OV, which is a measure of the SiPM response to the received light.

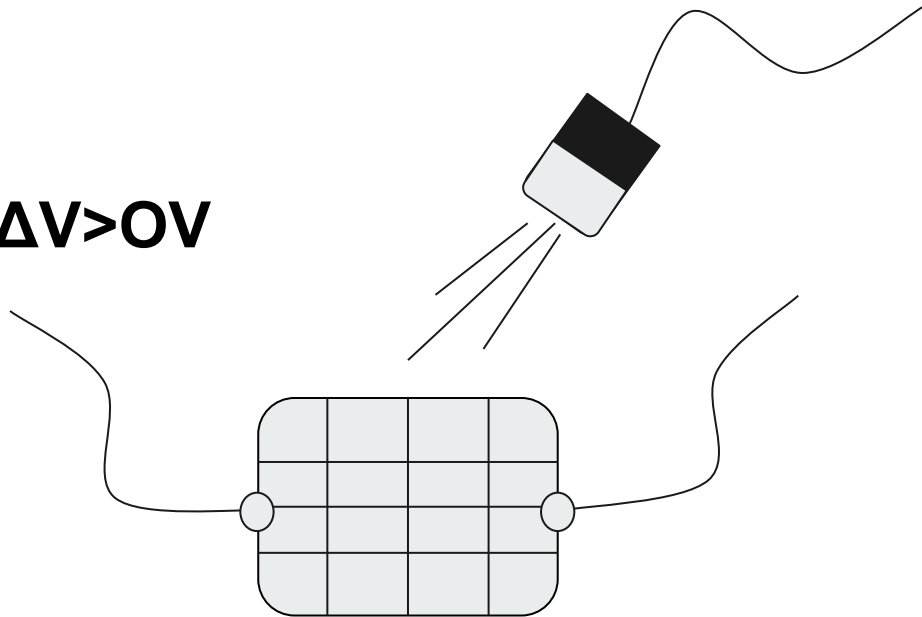


Gain characterization

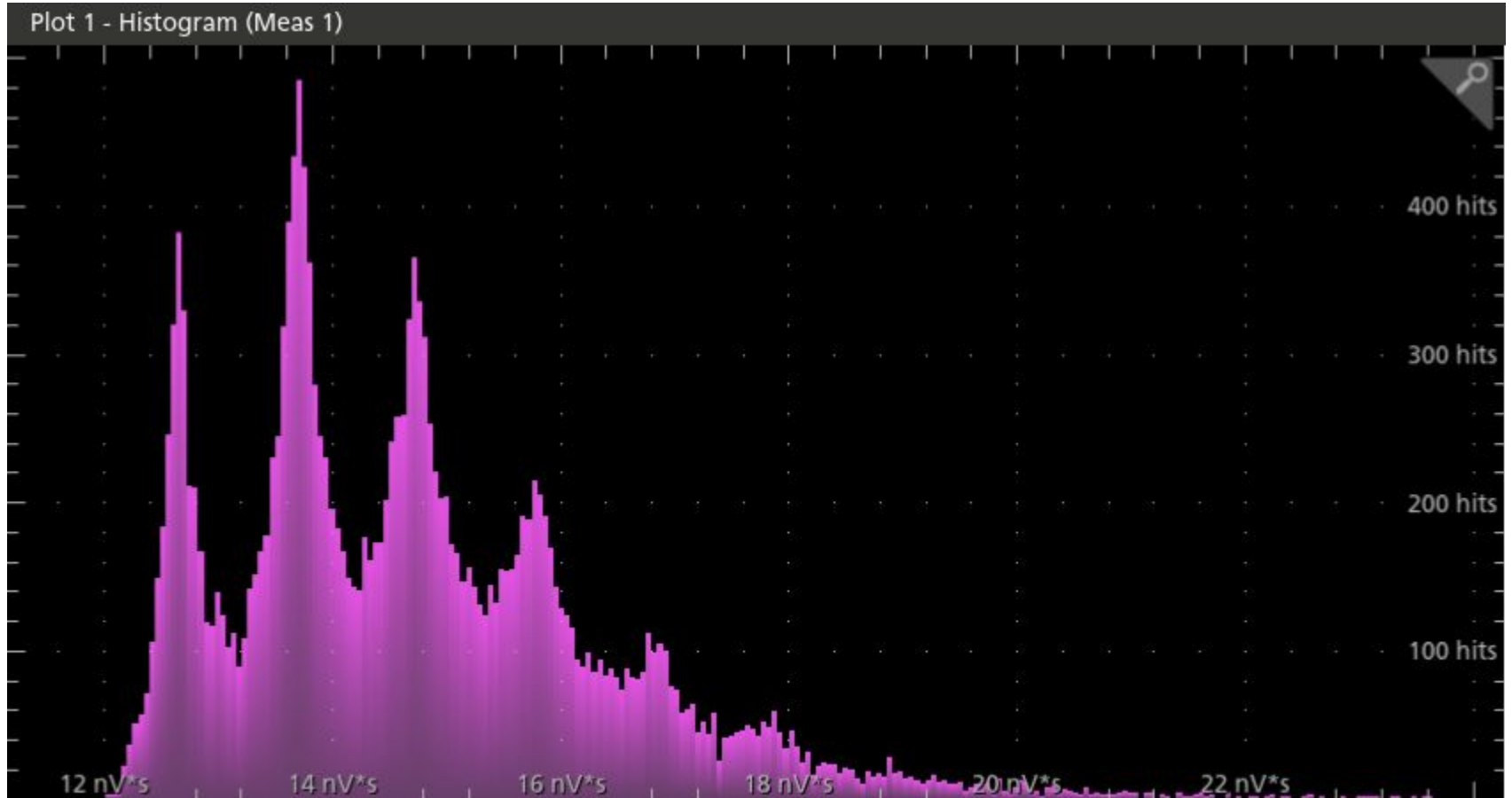
The oscilloscope perceives the SiPM response as $V(t)$ waveforms which are measured in two different ways



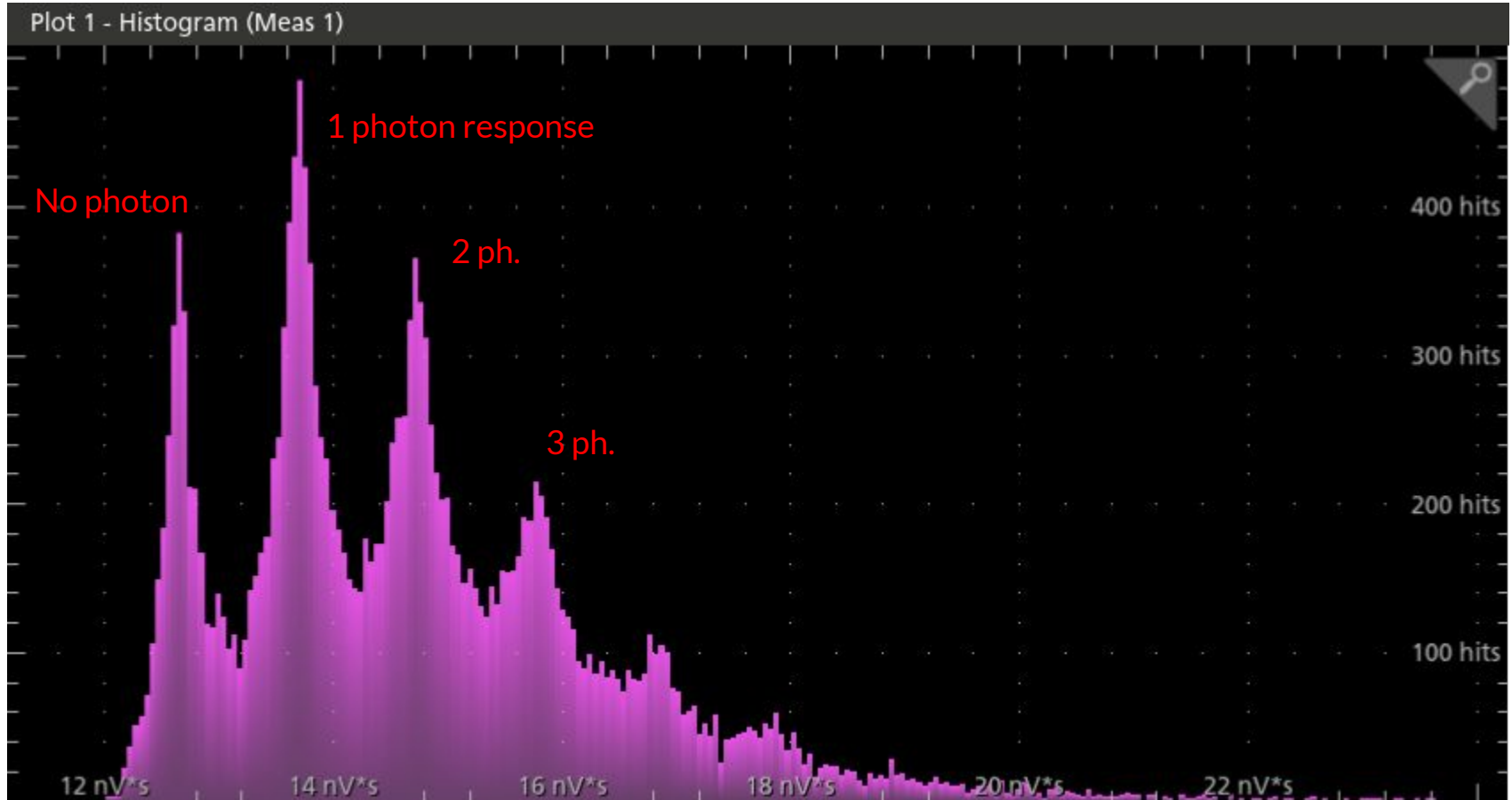
$$\Delta V > OV$$



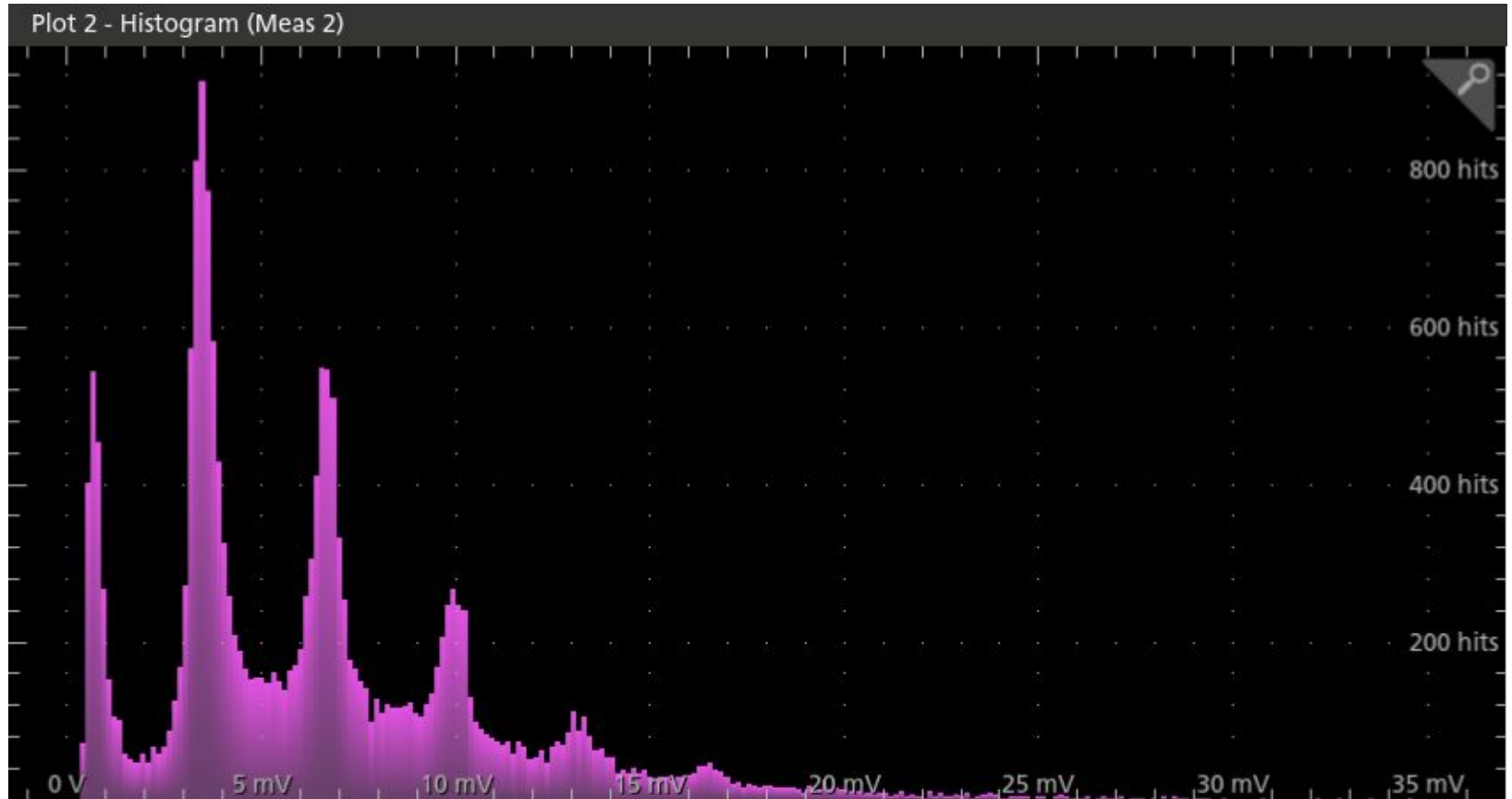
Data taking for gain: Area measurement



Data taking for gain: Area measurement



Data taking for gain: Amplitude measurement



The next thing to do is quantitatively estimating each SiPM gain for a certain OV interval.

One of these histograms are obtained for each studied OV. The gain grows linearly with the OV. The histogram that is obtained at a certain $OV=x$, lets us estimate the SiPM gain at $OV=x$ by linearly fitting the charge vs. n° photons. We have one of those $Q_{vs.N^\circ Ph.}$ datapoints for each histogram pike.