QA of pre-production Mu2e SiPMs

MUSE General Meeting

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Luca Morescalchi

Mu2e SiPM technical specs (docdb-7052)

- R1) a relative spread in Vop (operational voltage) between the sensor cells < 0.5%.
- R2) a relative spread in the dark current at Vop between the sensor cells < 15%.
- R3) a gain (measured in a gate of 150 ns) at Vop > 106 for each cell.
- R4) a PDE at Vop > 20% for 315 nm, evaluated using a reference-device.
- R7) a recovery time τ < 100 ns on a load greater than 15 Ω.

Sensors that don't meet the requirements are discarded.

What we measured

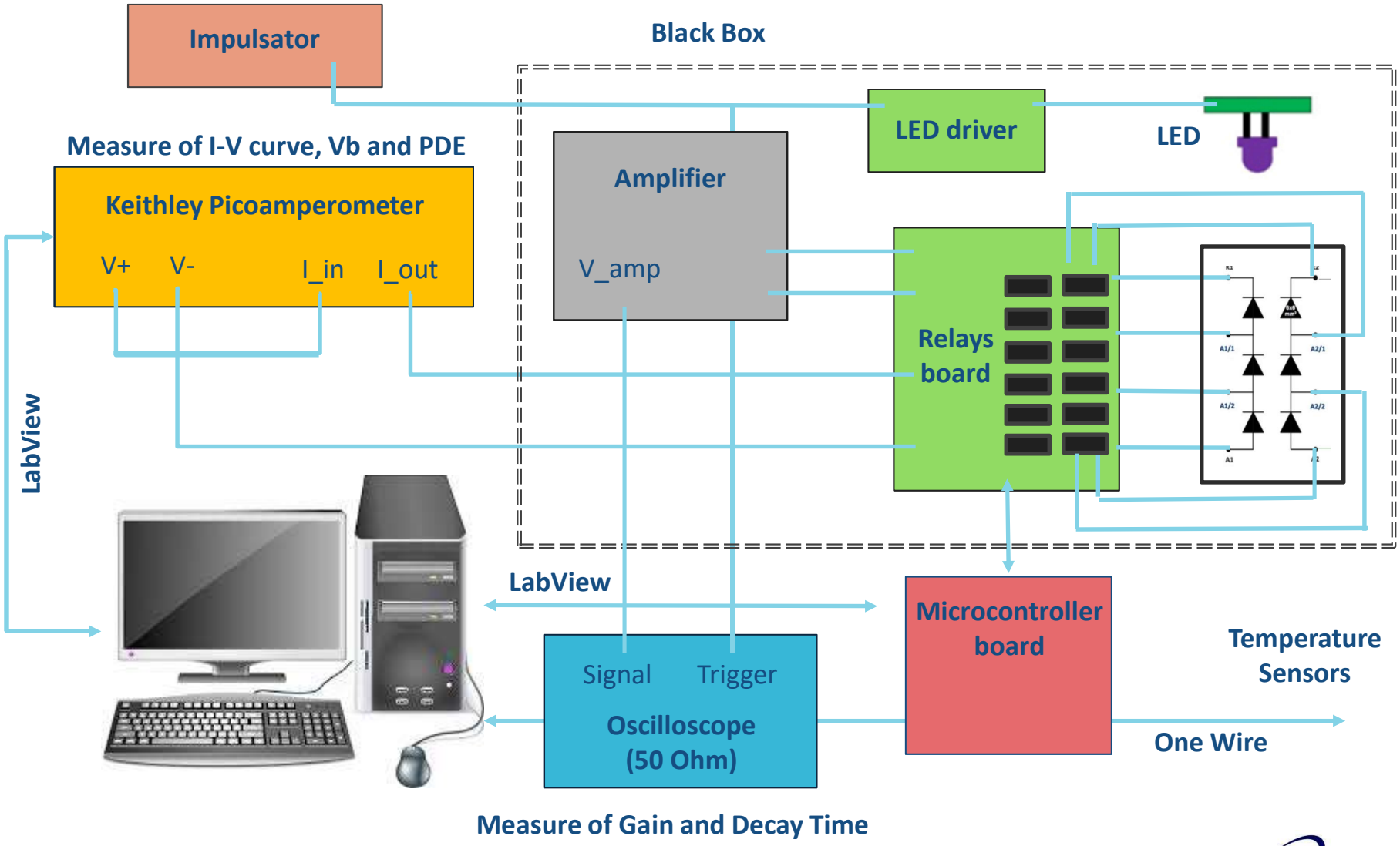
The test involved 105 photosensors from the pre-production, 35 from each of the three vendors: Hamamatsu, SensL and Advansid-FBK.



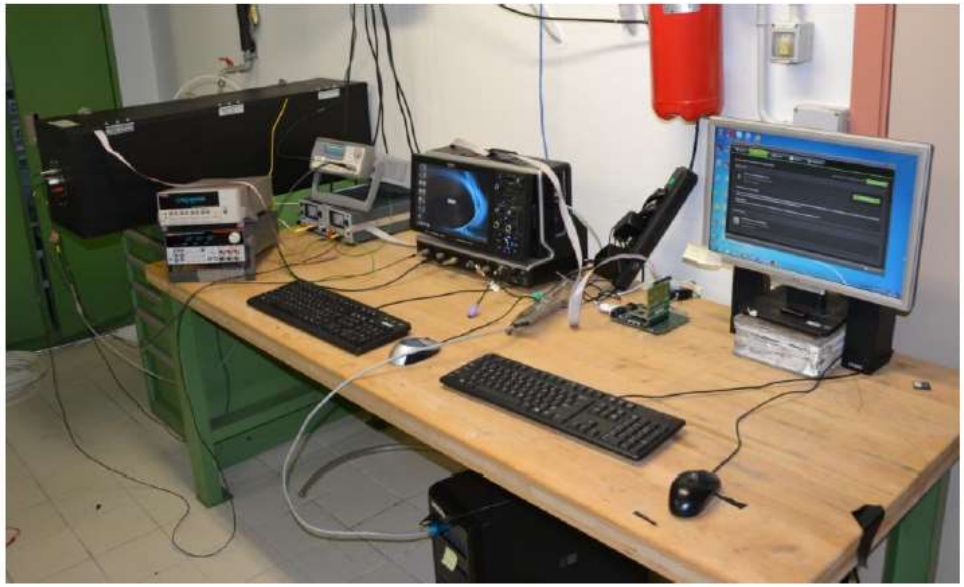
The QA procedure has been performed in a temperature controlled station at 20 that provides for each cell:

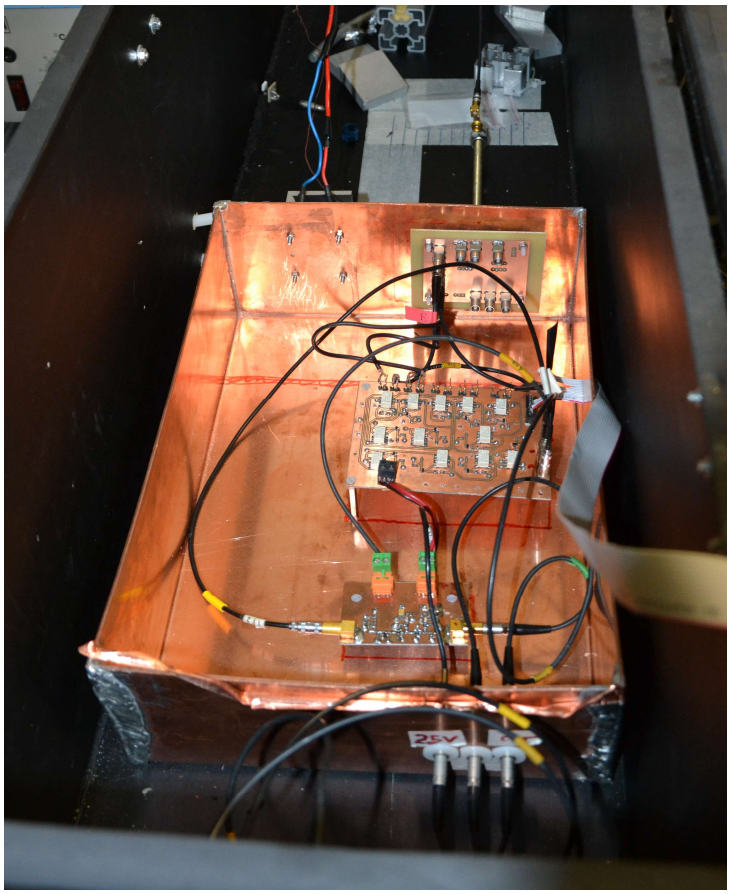
(i) the I-V dark curve from which the breakdown voltage is extracted
(ii) the Gain at Vop using the photo peaks method
(iii) the PDE by uniformly flashing the cell with 315 nm few-photons light pulses.

Experimental setup for pre-production QA



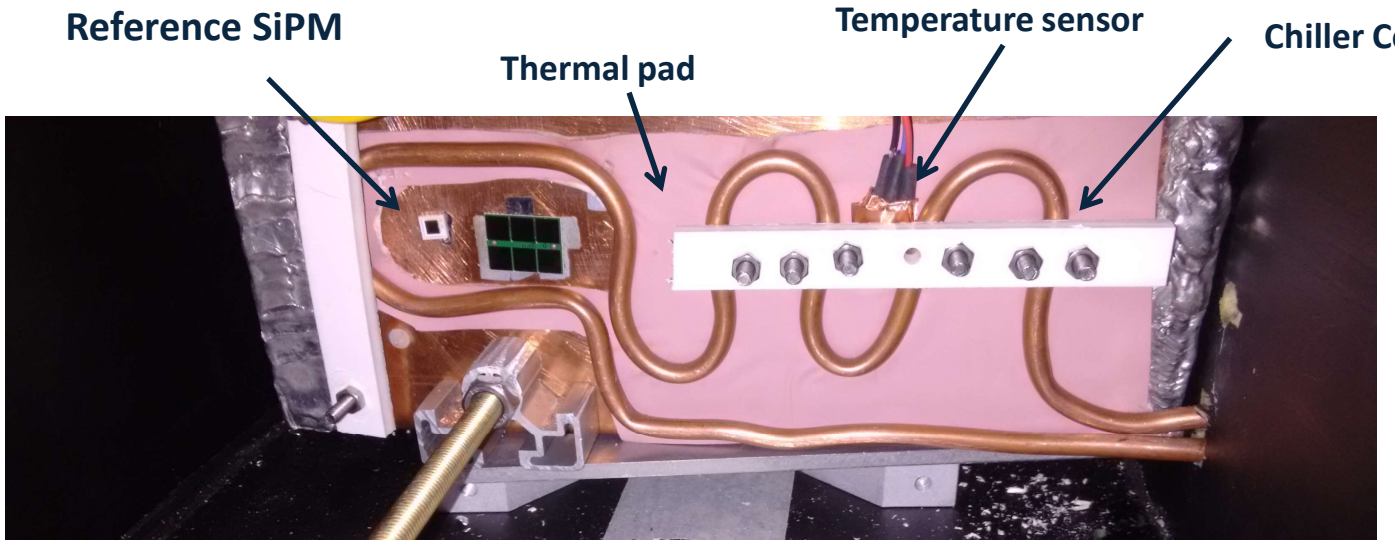
Experimental setup for pre-production QA



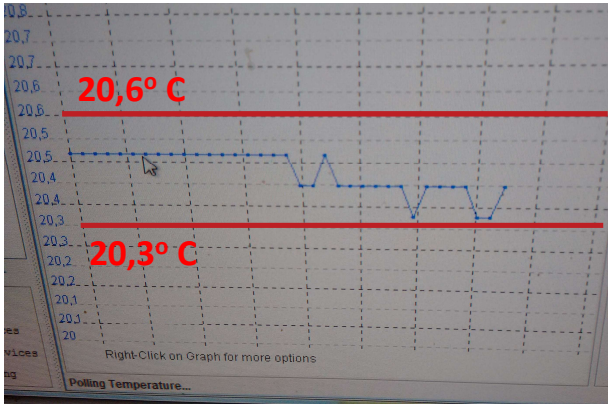


- The relays board and the amplifier are located inside a copper box, which acts as a Faraday cage.
- The UV led emitting at 315 nm is placed at the end of a metal bar bolted to the copper box.

Temperature control

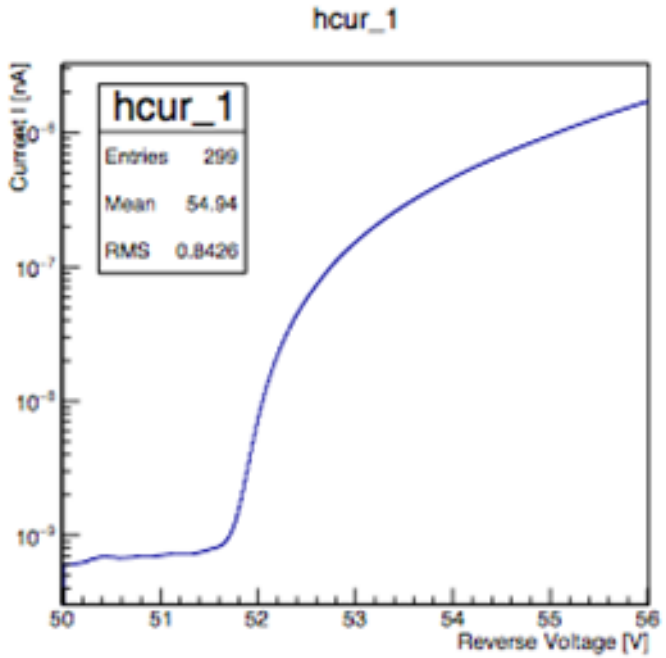


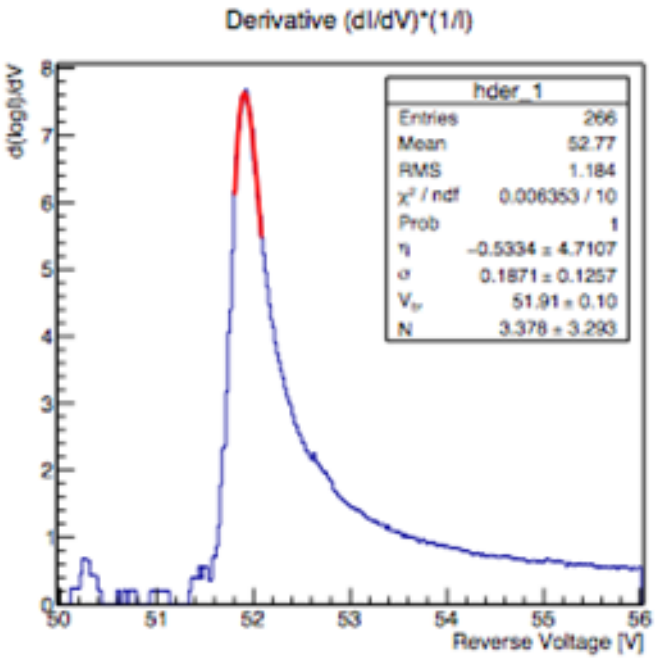
- An external chiller keeps the temperature stable around 20.5°C.
- The temperature is monitored by a one-wire DS18S20 system with an accuracy of 0.3 °C.



R1: Operative Voltage

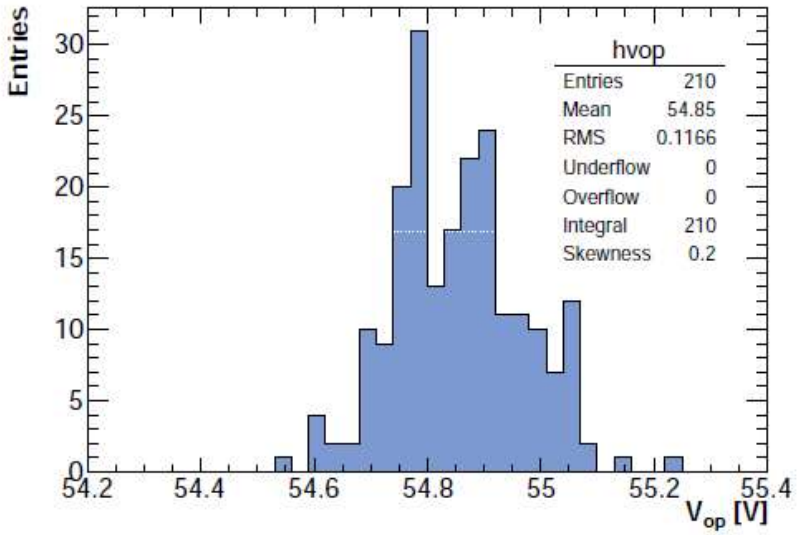
- The operative voltage has been defined as Vop = Vb + 3 V.
- We acquired the **I-V dark curve** in a range that varies among the vendors:
  - Hamamatsu [50, 56] V, SensL [24, 30] V, Advansid [26, 32] V
- For each cell we find the peak of **dlog(I)/dV - V** curve to determine the **V_b**



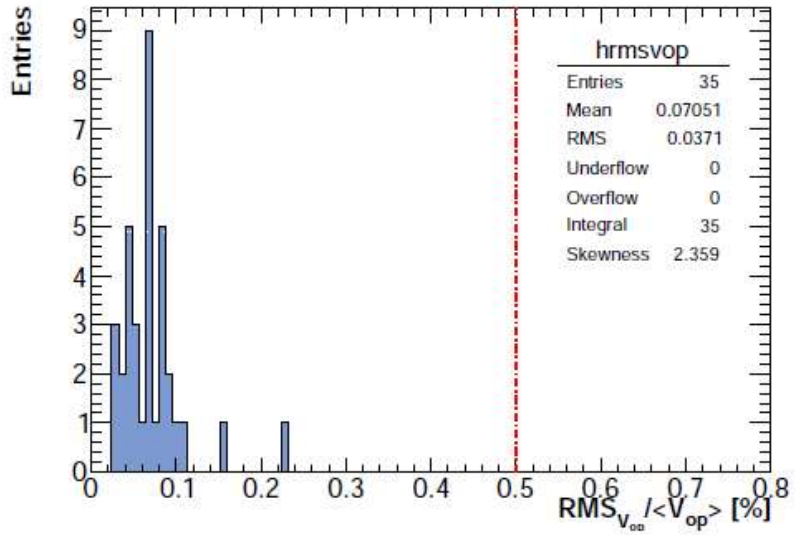


R1: Operative Voltage - Results

Measured Vop



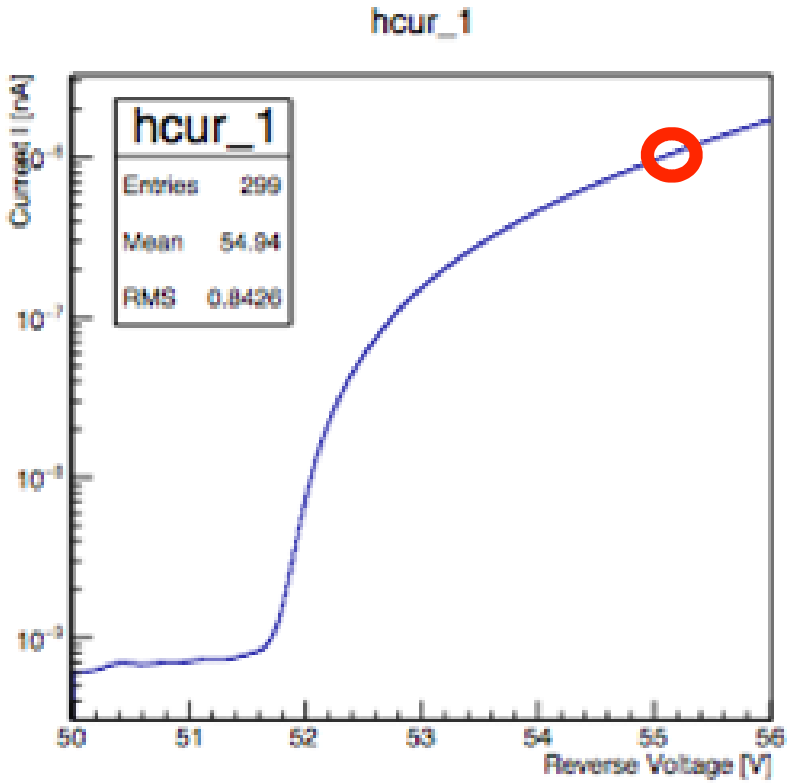
RMS Vop



Example of results from one vendor

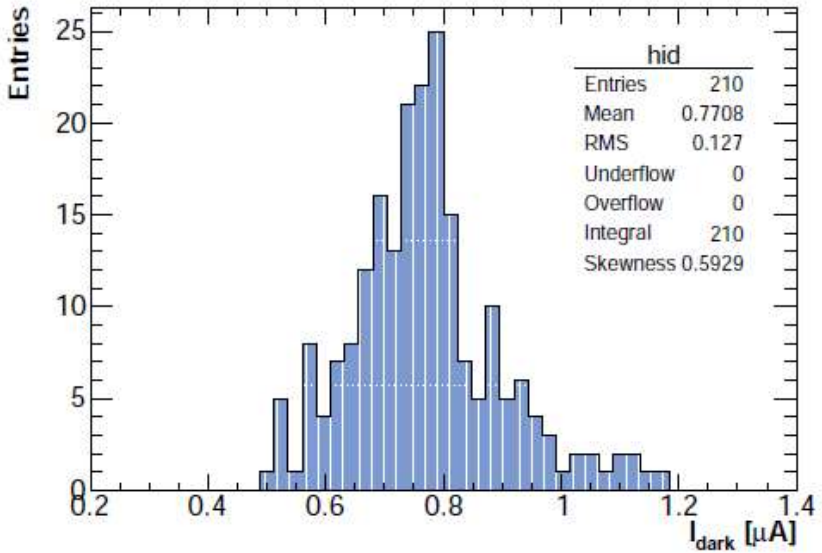
R2: Dark Current at Vop

- From the same I-V scan we obtain also the I_{dark} value at **Vop** for each cell.

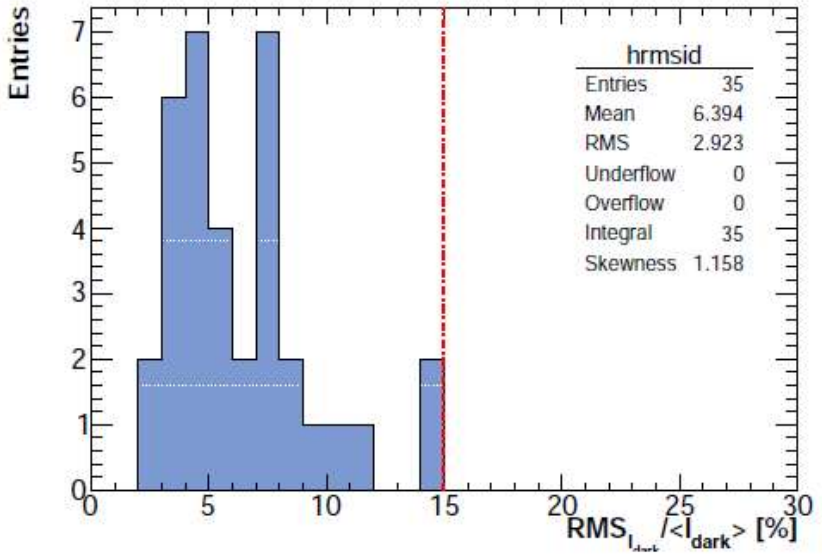


R2: Dark Current at Vop - Results

Measured Id



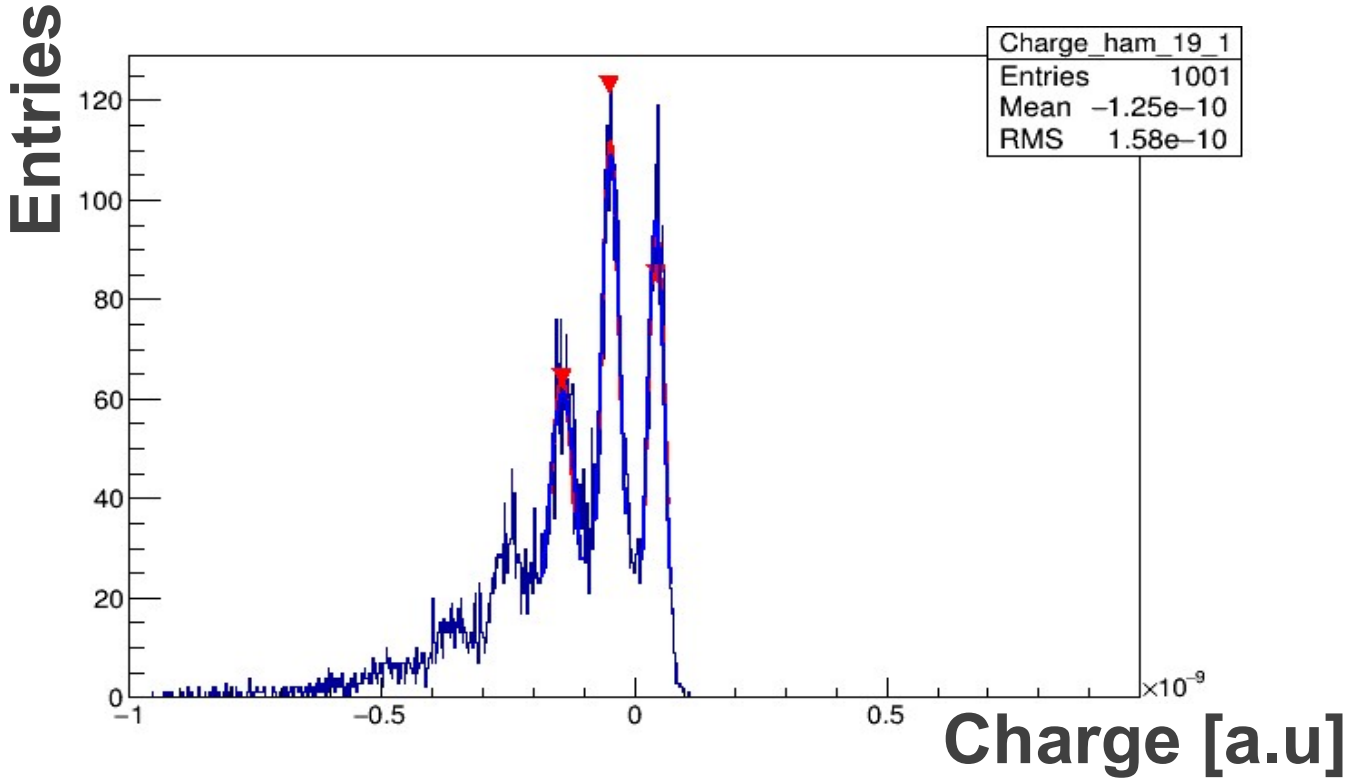
RMS Id



Example of results from one vendor

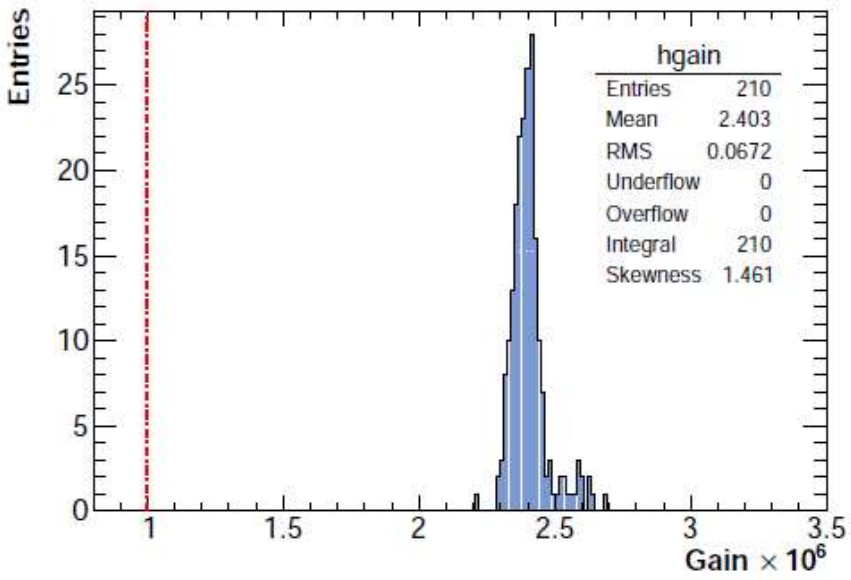
R3 - Gain at Vop

- The LED is powered by 20 ns wide pulses at a frequency of 100 kHz.
- The amplified pulses is integrated in a **gate of 150 ns** (BID requirement).
- Each charge peak corresponds to 0, 1, 2 .. n photons hitting the sensor.
- The gain is therefore obtained from G = DQpeak/e*Gamp.

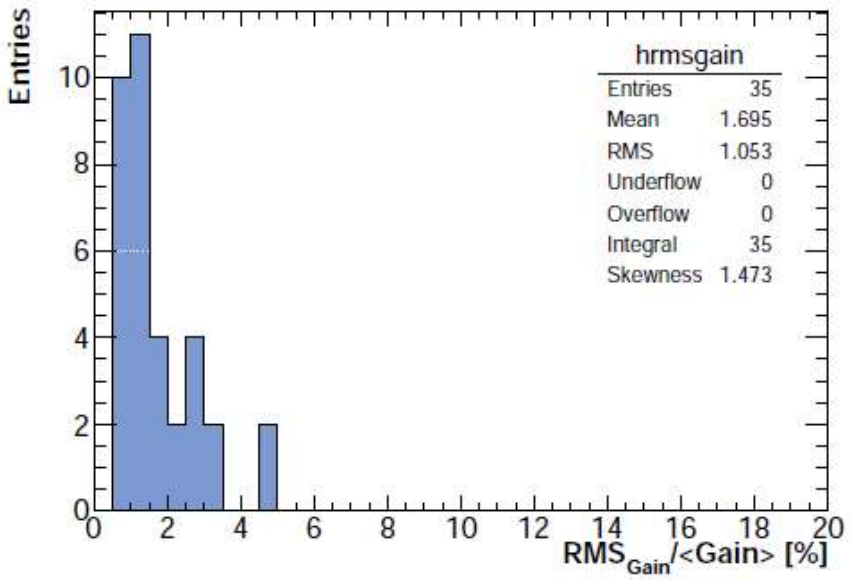


R3 - Gain at Vop - Results

Measured Gain



RMS Gain



Example of results from one vendor

R4 - Relative PDE at Vop [1/3]

- The PDE is defined as npe, the average number of detected photoelectrons, and Ngamma, the average number of incident photons on the sensor.
- The probability P(n) of detecting n photons by the sensor is given by the Poisson distribution:

$$P(n, n_{pe}, n_{dark}) = \frac{(n_{pe} + n_{dark})^n \cdot e^{-(n_{pe}+n_{dark})}}{n!}$$

- Inverting the Poisson equation, it is possible to obtain npe:

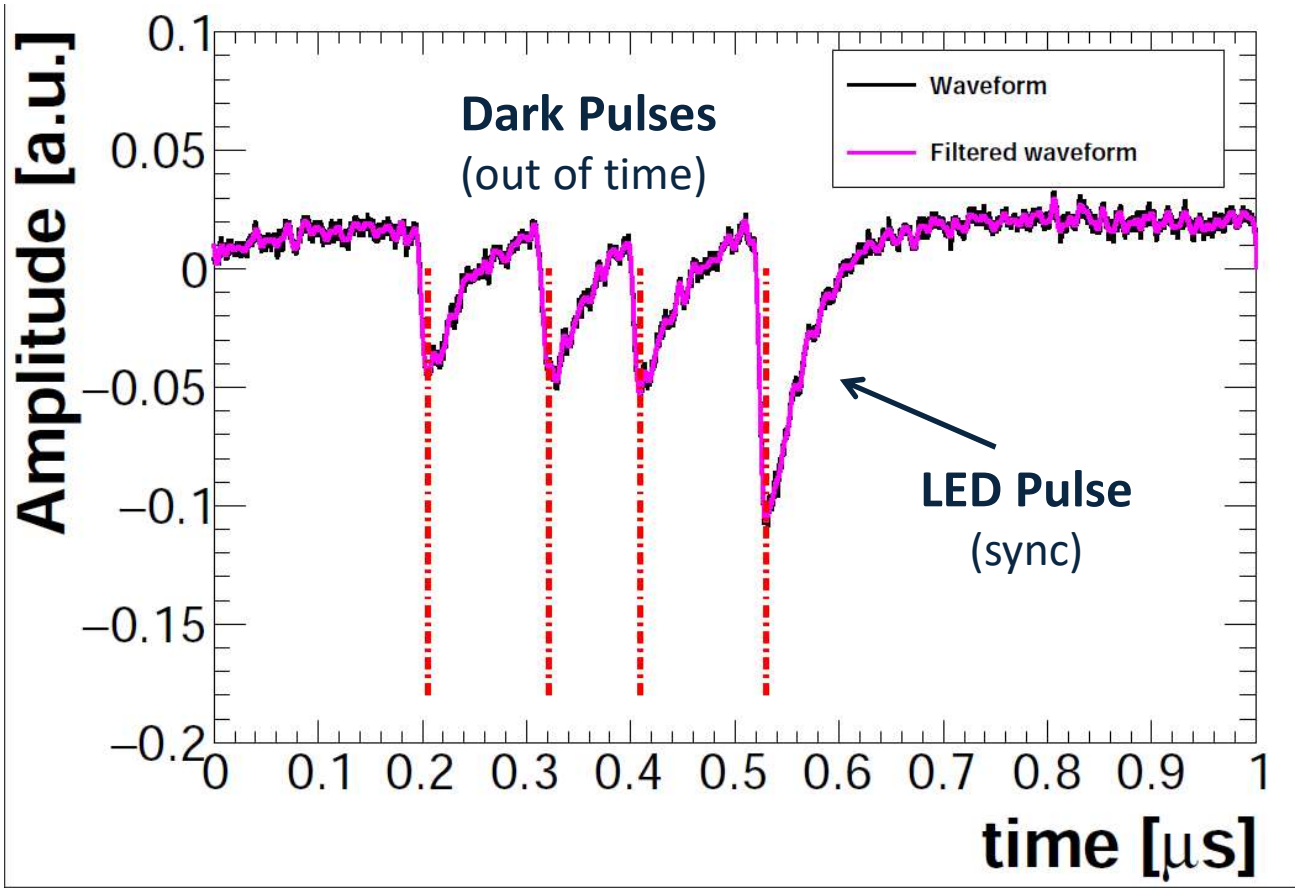
$$n_{pe} = -ln(P(0, n_{pe}, n_{dark})) + ln(P(0, n_{dark}))$$

- And express the two probability in quantities measurable by analyzing the signal waveforms, Nn>1 and Nd:

$$n_{pe} = -ln(1 - \frac{N_{n\geq 1}}{N_T}) + ln(1 - \frac{N_D}{N_T})$$

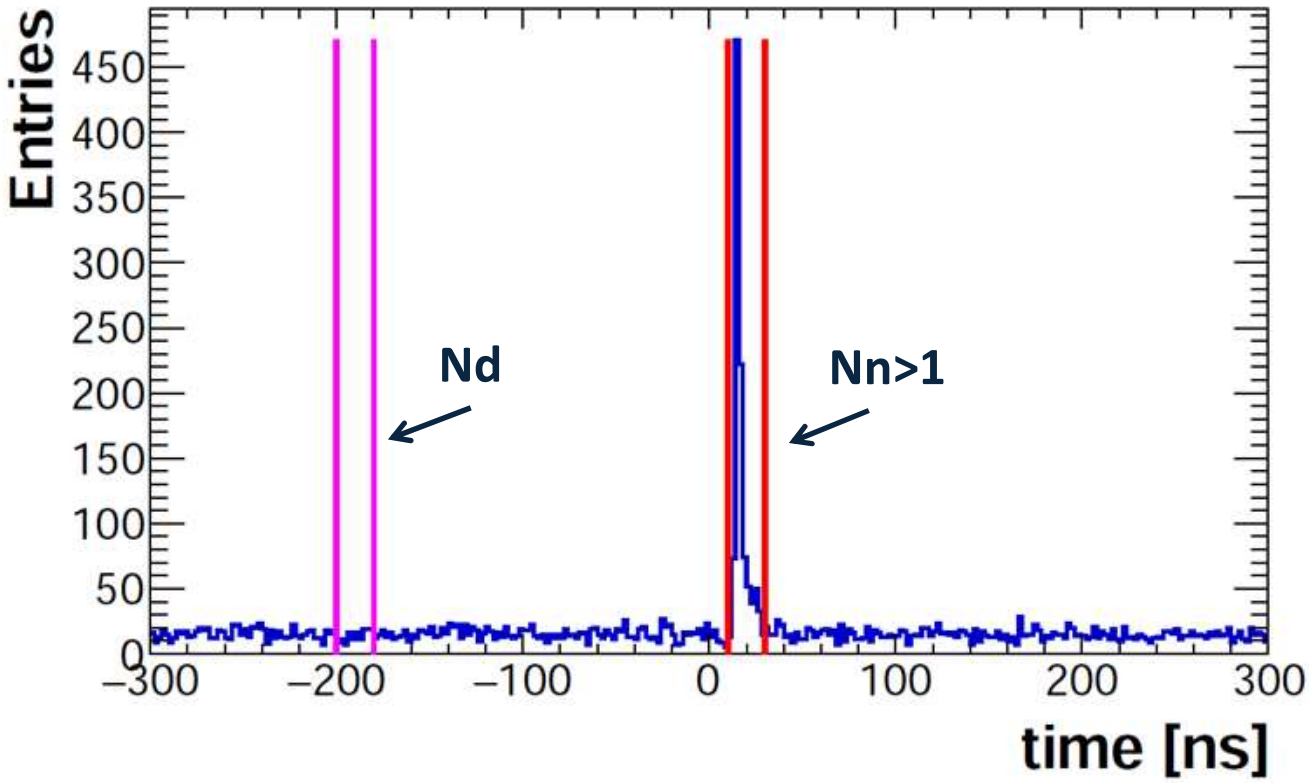
R4 - Relative PDE at Vop [2/3]

- The LED is powered by 20 ns wide pulses at a frequency of 100 kHz.
- Triggering on the light pulse, a waveform of 1 s is acquired.
- The peak time of each pulse is stored.



R4 - Relative PDE at Vop [3/3]

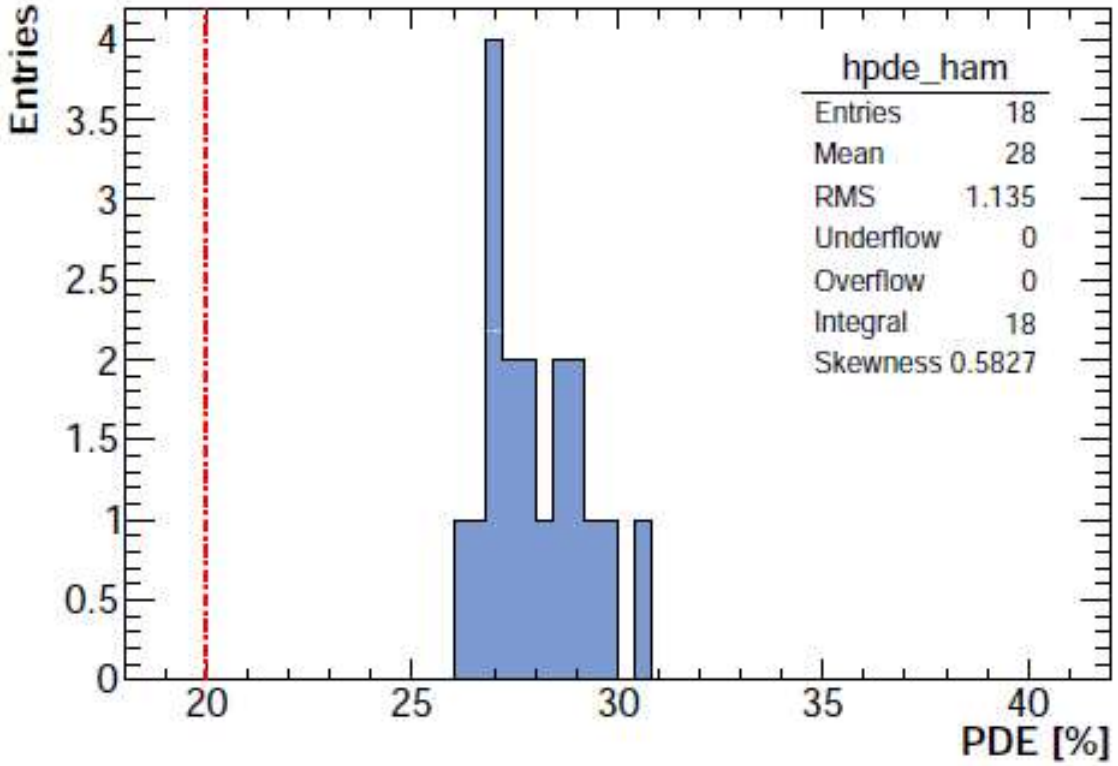
- To evaluate Ndark and Nn>1, we look at the distribution of the peak times, fixing two time gates of 20 ns each.



- To simplify Ngamma, the obtained PDE has been rescaled relatively to a reference sensor of well known PDE of 22%.

R4 - Relative PDE at Vop - Results

Measured PDE



Example of results from one vendor

R7 – Recovery Time

- The measurements have been performed in Frascati, using a load of 50 Ohm and after rescaling the time to a 15 Ohm load.