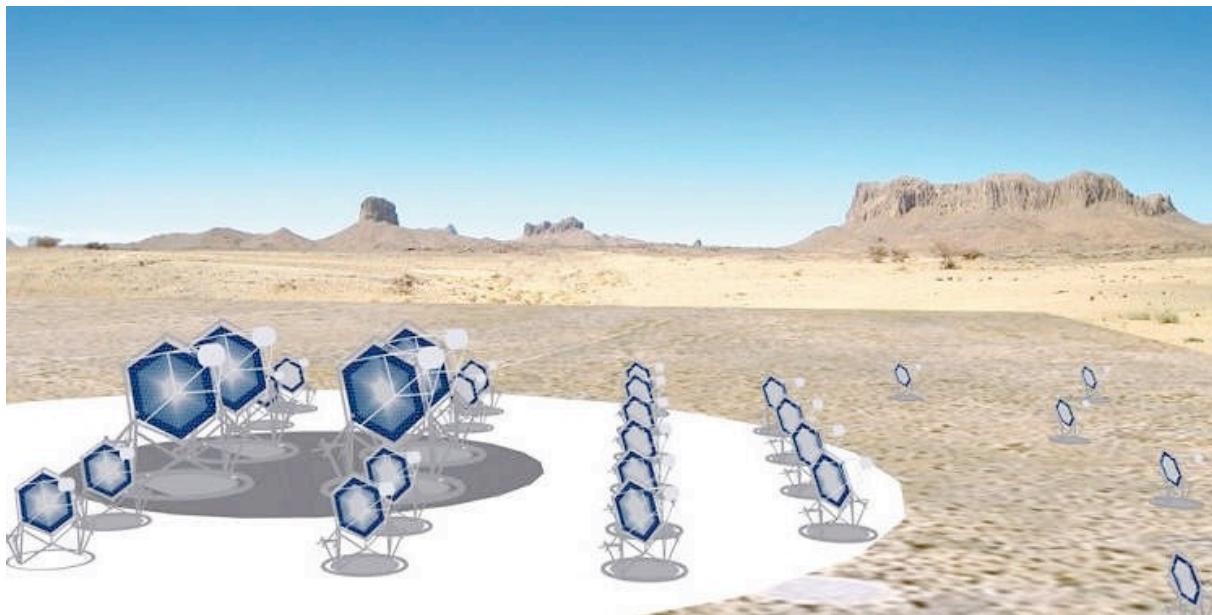


*OSSERVATORIO ASTROFISICO DI CATANIA*

# Characterization Test of SensL MicroFJ

Device: SMTPA-60035 S/N. 1 –Lot #150925



## Osservatorio Astrofisico di Catania

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(1) INAF – Osservatorio Astrofisico di Catania

Rapporti interni e tecnici  
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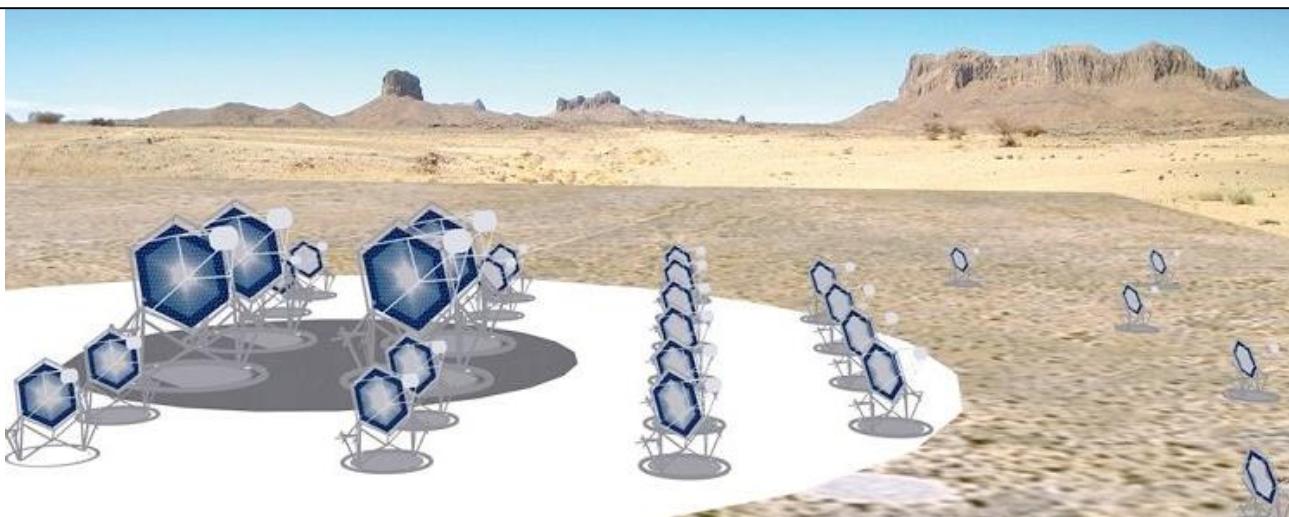
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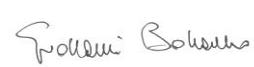
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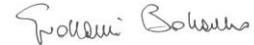
## **SensL MicroFJ-SMTPA-60035 S/N 1 Lot # 150925 Electrical Characterization Test**

G. Romeo, G. Bonanno, S. Garozzo, A. Grillo, D. Marano, M.C. Timpanaro  
INAF, Osservatorio Astrofisico di Catania



Prepared by: Name: **Giuseppe Romeo** Signature:  Date: **03/11/2015**

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Approved by: Name: **Giovanni Bonanno** Signature:  Date: **03/11/2015**



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### LIST OF ACRONYMS

OACT	Osservatorio Astrofisico di Catania
IFC	Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo
COLD	Catania astrophysical Observatory Laboratory for Detectors
PCB	Printed Circuit Board
SiPM	Silicon Photo-Multiplier
MPPC	Multi Pixel Photon Counter
SST-2M	Small-Size Telescope Dual-Mirror
PDM	Photon Detection Module
ASIC	Application Specific Integrated Circuit
FEE	Front-End Electronics
BEE	Back-End Electronics
FPGA	Field Programmable Gate Array
EASIROC	Extended Analogue Silicon-pm Integrated Read-Out Chip
CITIROC	Cherenkov Imaging Telescope Integrated Read-Out Chip
I/F	Interface
LCT	Low Cross Talk
PSAU	Power Supply and Amplification Unit



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### 1. INTRODUCTION

This document discusses on some measurement results of the SiPM most relevant characteristics: breakdown voltage, gain, dark stairs, cross-talk (XTalk) and dark count rate (DCR), carried out at the Catania astrophysical Observatory Laboratory for Detectors (COLD) on a class of recently available detectors by SensL.

## 2. Equipments

### 2.1.1 Breakdown Voltage

To measure the breakdown voltage  $V_{br}$  a typical V-I setup has been used. It consists essentially:

- A Keithley 487 picoamperometer
- An Agilent 6634B DC power supply

The schematic is sketched in Figure 1

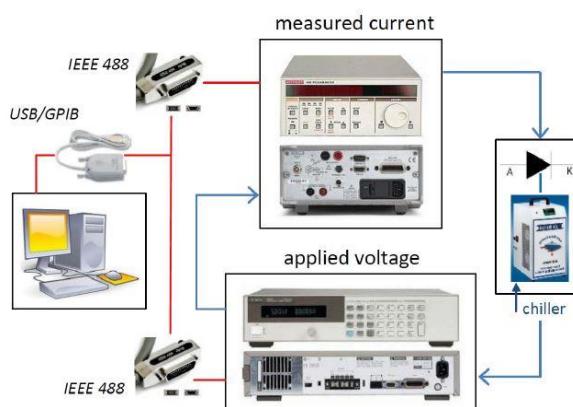


Figure 1. Experimental apparatus used for breakdown voltage measurements

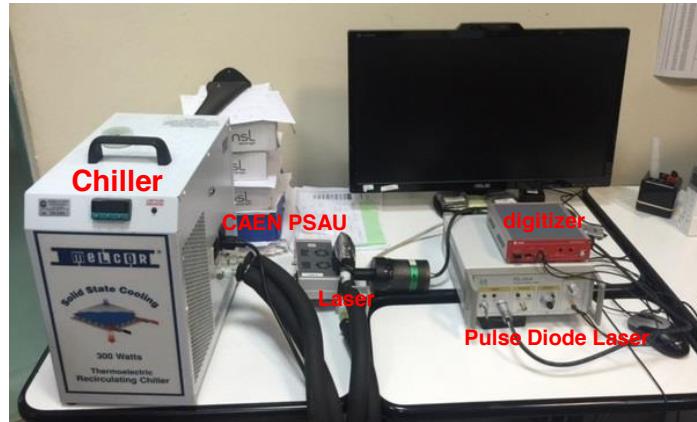
### 2.1.2 Gain

To evaluate the gain the following instruments have been used:

- A PicoQuant PDL 200-B pulsed diode laser;
- A CAEN SP5600 PSAU unit;
- A CAEN DT5720A 2-channel digitizer

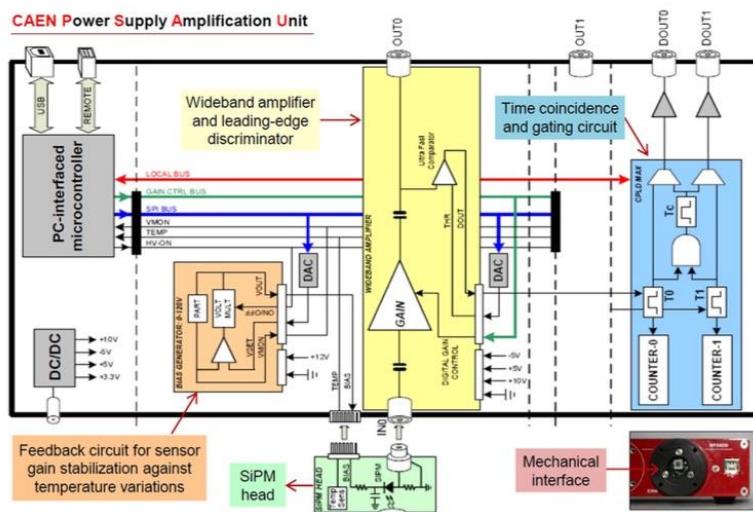
In particular a thermostatic camera has been realized to host the SiPM detector in adiabatic conditions, and a thermoelectric recirculating chiller has been exploited to cool the device and achieve the desired temperature.

The Figure 2 shows the setup used for the gain measurement.



*Figure 2. Experimental apparatus used for gain measurements*

The PSAU is an electronic system embedding a power supply and a tunable amplification unit. It provides the cathode voltage for the SiPM detector in a range of 0–120 V with a 16 bit resolution, and features a variable amplification factor up to 50 dB. It integrates a feedback circuit to stabilize the operating voltage (and, in turn, the sensor gain) against thermal variations and a leading edge discriminator feeding an internal counter. In addition, the system can provide a digital output with a tunable width from 20 ns to 320 ns. All parameters can be programmed and monitored via a standard USB interface. An additional holder interface has been implemented for the SiPM electrical board to be connected to the PSAU, and a mechanical cooling adapter has also been realized, allowing to operate the SiPM from room temperatures down to 10°C.



*Figure 3. Simplified electric schematization of the power supply and amplification unit (PSAU).*



### 2.1.3 Stair-cases

To obtain the dark stairs measurements we used a front-end electronics based on the ASIC chip CITIROC produced by Weroc that is a 32-channel fully-analog front-end specifically designed to directly interface SiPM detectors (developed following requirements suggested by INAF).

The Figure 4 shows a photograph of the CITIROC evaluation board with the black light-tight box that prevents accidental light exposure of the SiPM detectors and allows a thermal regulation by means of a cooling system mounting a thermoelectric Peltier device.



*Figure 4. CITIROC evaluation board and the black light-tight box with cooling system based on Peltier TEC.*

### 3. Measurements Results

#### 3.1.1 Breakdown Voltage

Here follows the achieved plot of the I-V characteristic at room temperature (25°C) where are also superimposed the two trends lines. The  $V_{br}$  was simply the intercept of the two trends.

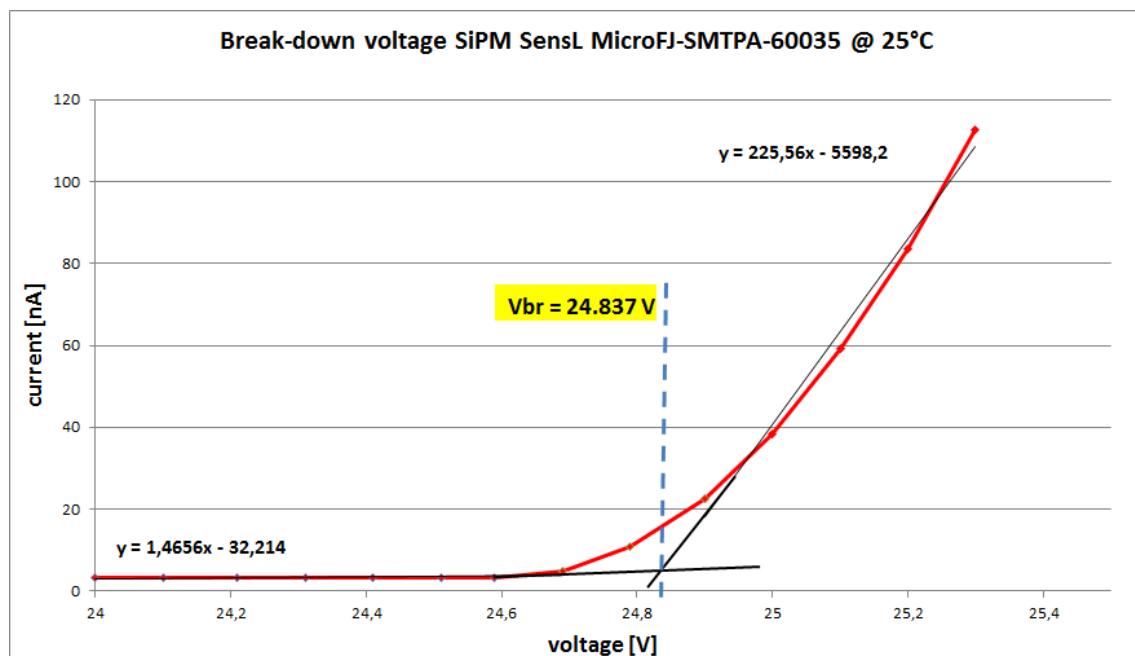


Figure 5. Breakdown Voltage measurement at 25°C for the SensL MicroFJ-SMTPA-60035 S/N 1 Lot # 150925 device.

The **breakdown** voltage for this SiPM is:

$$V_{br} = 24.84 \text{ V.}$$



### 3.1.2 Gain

Figure 6 shows seven charge pulse histograms of the device at 18 °C corresponding to seven different operating voltages. Each histogram is fitted with a series of Gaussian distributions (red line). The average spacing between two consecutive charge peaks almost linearly increases with the bias conditions.

Figure 7 shows the measured gain at various over-voltages.

The SiPM gain G is defined as the number of unit (electron) charges generated in response to a single-pixel photon absorption or thermally ignited avalanche.

In Geiger-mode operation the multiplication factor of an avalanche discharge is expected to grow linearly with the operating voltage according to

$$G = \frac{Q_{TOT}}{e} = \frac{C_{pixel}(V_{op} - V_{br})}{e}$$

where  $Q_{TOT}$  is the total charge generated by a single avalanche discharge,  $C_{pixel}$  is the overall capacitance of the SPAD microcell, and e is the elementary electron charge.

Accounting for the constant ADC rate (charge/channel):

$$ADC\ conversion\ rate = \frac{ADC\ channel}{Coulomb} = \left( \frac{V_{PP}}{R_{IN}} \frac{1}{2^{Nbit}} \Delta t \right) \frac{1}{G_{PSAU}}$$

Where:

$V_{pp} = 2V$  is the digitizer dynamic range

$R_{IN} = 50\Omega$  is the digitizer input impedance

$N_{bit} = 12$  bit is the digitizer resolution

$\Delta t = 4\text{ns}$  is the digitizer sampling period

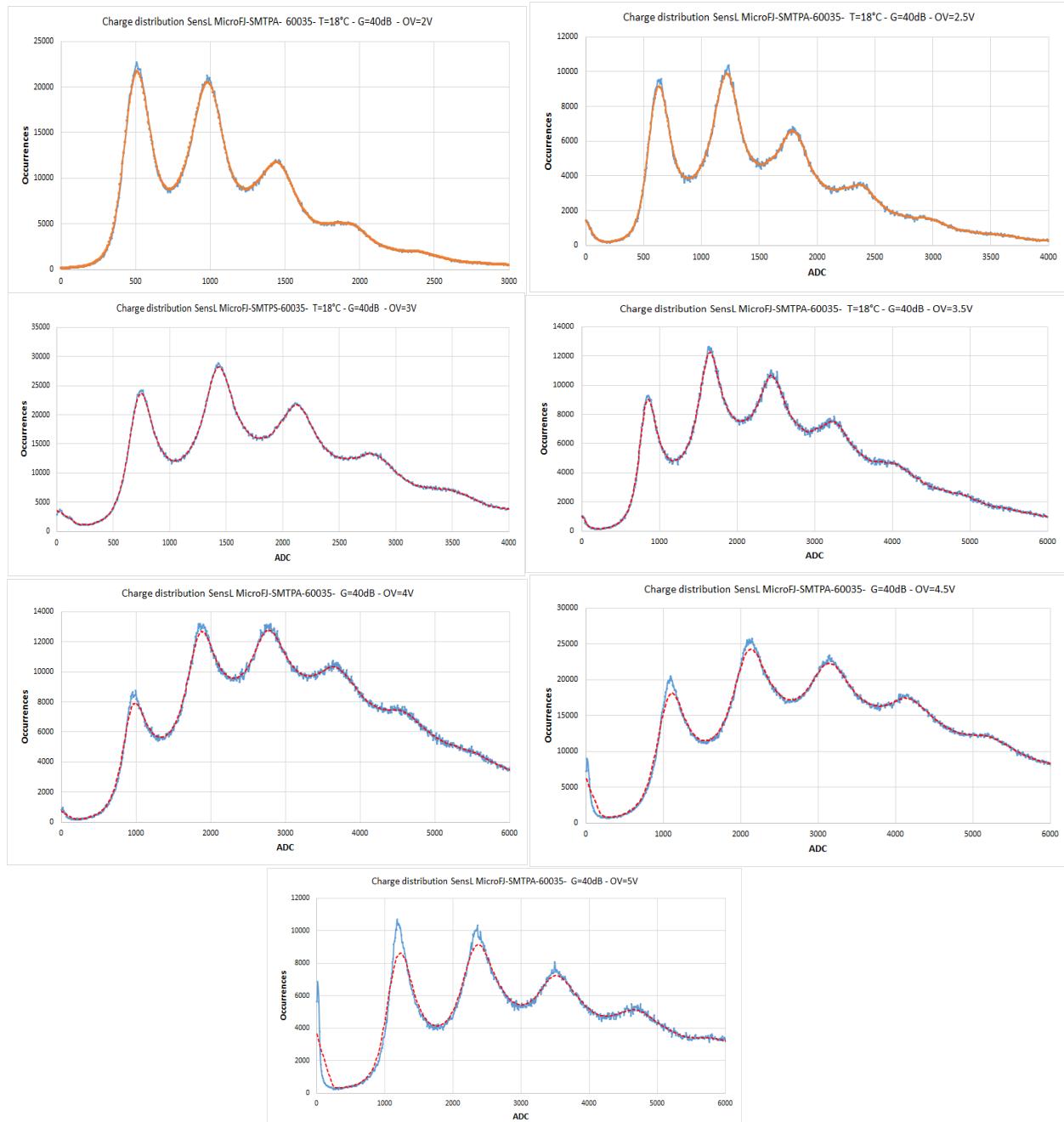
$$\frac{V_{PP}}{R_{IN}} \frac{1}{2^{Nbit}} \Delta t = 39.06 \left[ \frac{fC}{ADU} \right]$$

$$G_{PSAU} = 40dB$$

$$ADC\ conversion\ rate = 3.906 \left[ \frac{pC}{ADU} \right]$$

for a given bias voltage the SiPM gain is obtained by:

$$G_{SiPM} = \frac{(two\ peaks\ distance)[ADU] \times (ADC\ conversion\ rate)}{charge\ of\ electron}$$



*Figure 6. Charge amplitude histograms for seven different bias conditions at 18 °C with the use of the CAEN PSAU amplifier for the SensL MicroFJ-SMTPA-60035 S/N 1 Lot #150925 device.*

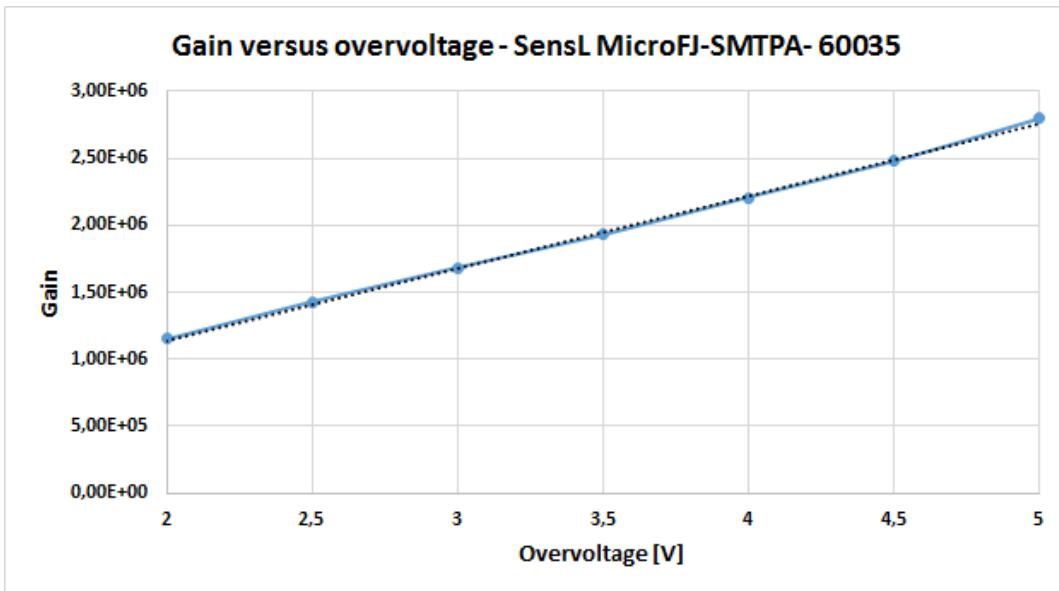


Figure 7. Gain measurements as a function of the bias voltage with the use of the CAEN PSAU amplifier for the SensL MicroFJ-SMTPA-60035 S/N 1 Lot #150925 device.

### 3.1.3 Staircase and Cross-Talk

In Figure 8 are shown the measured staircases in linear scale at different overvoltages with the use of the CITIROC front-end electronics, while in Figure 9 are reported in logarithmic scale.

The SiPM optical cross-talk probability is evaluated from the DCR as the ratio between the first and the second event count rate.

The classical (as reported in literature) approach consists in evaluating the ratio between the 0.5-p.e. and the 1.5-p.e. DCR values directly from the staircases.

The so called “derivative” method, relying on the DCR staircase derivative, is also considered.

Figure 10 shows the obtained Xtalk with respect to the overvoltage (as well as the operating voltage) for both methods. The red curve represents the classical method that in this case is the worst-case condition, while the blue curve represents the derivative method that provides lower cross-talk values.

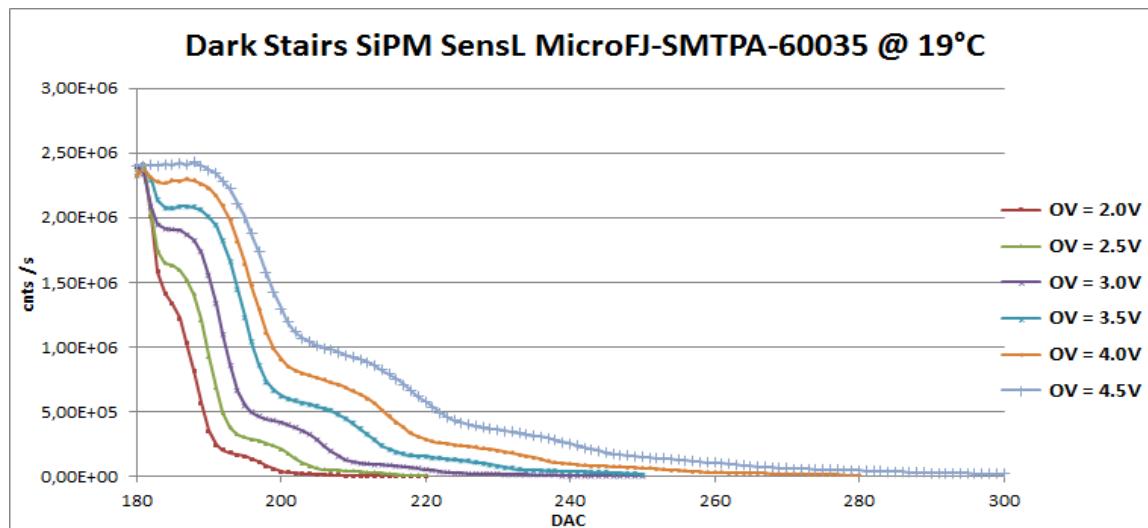


Figure 8. Staircase in the linear scale at 19°C and at different overvoltages with the use of the CITIROC for the SensL MicroFJ-SMTPA-60035 S/N 1 Lot # 150925 device.

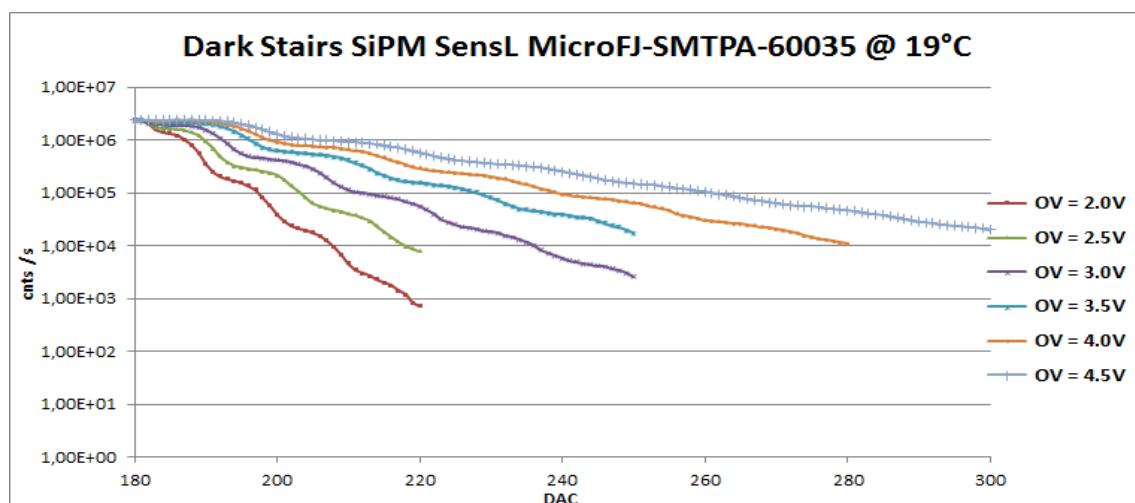


Figure 9. Staircase in the logarithmic scale at 19°C and at different overvoltages with the use of the CITIROC for the SensL MicroFJ-SMTPA-60035 S/N 1 Lot # 150925 device.

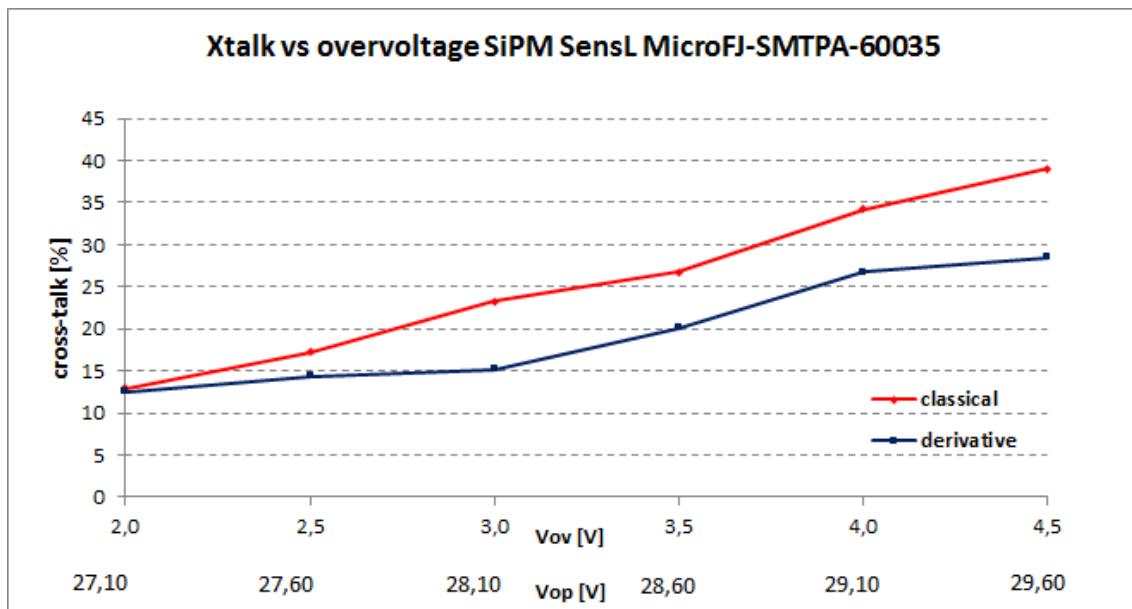


Figure 10. Cross-Talk at different overvoltages with the use of the CITIROC for the SensL MicroFJ-SMTPA-60035 S/N 1 Lot # 150925 device.

The following table reports the Xtalk obtained values by using the classical (reported on literature) method (1.5 pe / 0.5 pe) and the derivative method (2pe / 1pe).

OV [V]	Vop [V]	DCR [HZ]	worst case	best case	Vbr @25°C [V]	dV/dT [mV]
			XT Stairs [%]	XT Deriv [%]		
2,0	27,10	1,33E+06	12,91	12,54	24,84	21,5
2,5	27,60	1,63E+06	17,25	14,32		
3,0	28,10	1,91E+06	23,30	15,16		
3,5	28,60	2,09E+06	26,74	20,15		
4,0	29,10	2,27E+06	34,22	26,74		
4,5	29,60	2,40E+06	39,00	28,48		

**All files related to the experimental measurements presented in this report, are located in the database on the PC-LAB (COLD) site Astrophysical Observatory of Catania, path C:\Users\CCDLab1\Desktop\Romeo\Misure**



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### 4. CONTACTS

The team working on the electronic design of the ASTRI camera is composed by people from INAF's Catania Astrophysical Observatory and Palermo IFC. It is also referred to as the Electronics Camera Team.

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