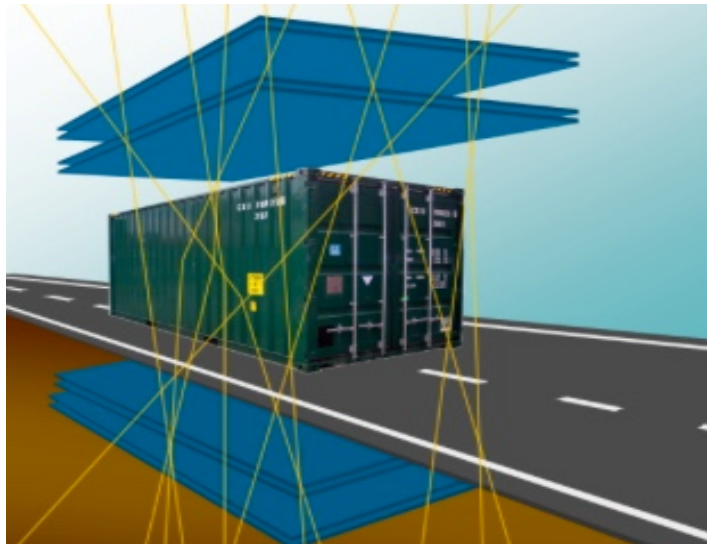


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*OSSERVATORIO ASTROFISICO DI CATANIA*

# SiPM characterization report for the Muon Portal Project

Device: SiPM type N on P - S/N. SPM10H5-60N-Y226144-wf19 ST Microelectronics



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Rapporti interni e tecnici  
N.06/2013

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# SiPM CHARACTERIZATION REPORT

OSSERVATORIO ASTROFISICO DI CATANIA  
LABORATORIO RIVELATORI



Catania Astrophysical **O**bservatory, **L**aboratory for **D**etectors

Misure eseguite da Giuseppe Romeo

<b>DATE</b>	<b>May 2, 2013</b>
<b>SiPM</b>	<b>ST Microelectronics</b> SiPM type: <b>N on P</b> $V_{BD}=27.87 \text{ V @ } T=25^{\circ}\text{C}$
<b>OP. MODE</b>	<b>Photon Counting with CAEN PSAU and Tektronix counter</b>
<b>SER. N.</b>	<b>SPM10H5-60N - Y226144-wf19</b>



# CONTENTS

1.0 Electrical Characteristics from Data sheet.....	3
2.0 Breakdown Voltage .....	4
3.0 Staircase and Cross-talk versus Over-Voltage SiPM SPM10H5-60N substrate medium doping .....	5
4.0 Electro-optical characterization .....	6
4.1 Characterization at $V_{ov} = 4V$ .....	6
4.1.1 Staircase @ $OV=4V$ .....	6
4.1.2 DCR @ $OV=4V$ at different Gate Time from 30 ns to 120 ns .....	6
4.1.2 DCR @ $OV=4V$ vs Time.....	7
4.1.4 System linearity to evaluate the best operating conditions .....	7
4.1.5 PDE measurements at Over-Voltage 4V .....	8
4.2 Characterization at $V_{ov} = 5V$ .....	9
4.2.1 Staircase @ $OV=5V$ .....	9
4.2.2 DCR @ $OV=5V$ at different Gate Time from 30 ns to 120 ns .....	9
4.2.3 DCR @ $OV=5V$ vs Time.....	10
4.2.4 System linearity to evaluate the best operating conditions .....	10
4.2.5 PDE measurements at Over-Voltage 5V .....	11
4.3 PDE comparison.....	12



### 1.0 Electrical Characteristics from Data sheet

The layout of this device is shown in Fig. 4. Its main features are reported in Table 3.

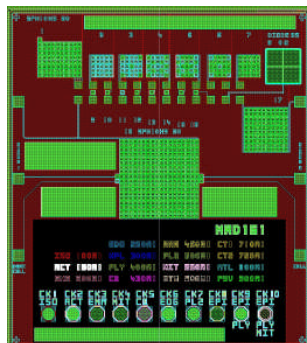


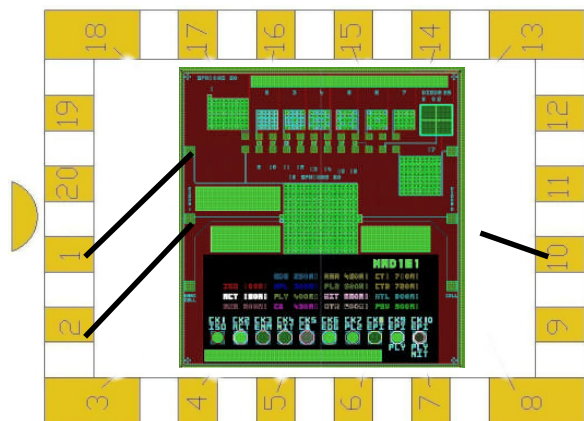
Fig. 1 SPM10H5-60: chip layout.

Table 3 Features of the SPM10H5-60 device.

Parameter	Unit	Value
<b>Sensitive area size</b>	$\mu\text{m}^2$	<b>1080 × 1080</b>
<b>Cells matrix dimension</b>		<b>18 × 18</b>
<b>Number of cells</b>		<b>324</b>
<b>Cell fill factor</b>	%	<b>67.4</b>
<b>Cell size</b>	$\mu\text{m}^2$	<b>60 × 60</b>
<b>Quenching resistor squares number</b>		<b>28</b>
<b>Quenching capacitor area</b>	$\mu\text{m}^2$	<b>26</b>
<b>Cell active area</b>	$\mu\text{m}^2$	<b>2427</b>
<b>Cell perimetral area</b>	$\mu\text{m}^2$	<b>844</b>
<b>Bonding pad area</b>	$\mu\text{m}^2$	<b>150 × 150</b>
<b>Metal grid area (2 pads included)</b>	$\mu\text{m}^2$	<b>161802</b>

### NRD16 – Multichip – SPM10H5\_60 BONDING

Electrode	Pin
Cathode	1
Cathode Diode	2
Anode (Back)	10





## 2.0 Breakdown Voltage

The  $V_{BD}$  was measured from the voltage-current measurements and tracing the intercept between the line of best fit (range from 1mA to 2mA) and the x-axis.

Here follows the plot of the I-V characteristic

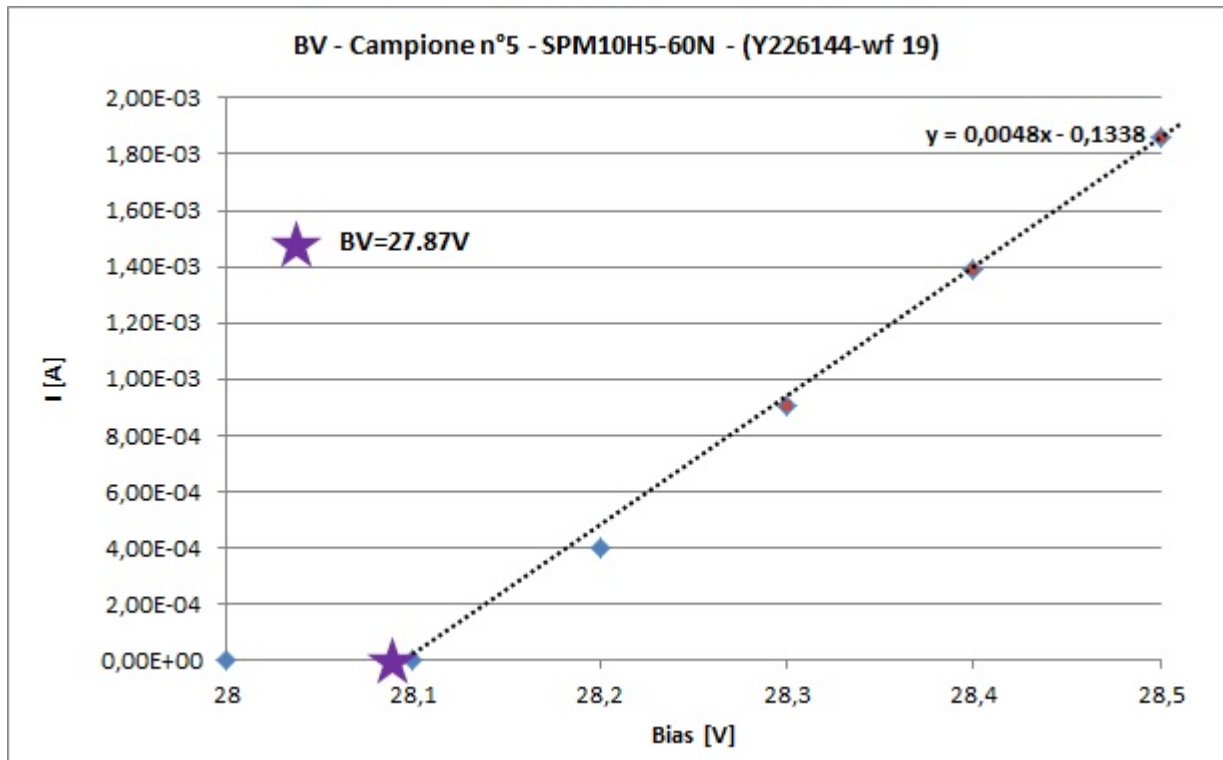


Fig. 1 – BreakDown Voltage @  $T=25.0^{\circ}C$ .

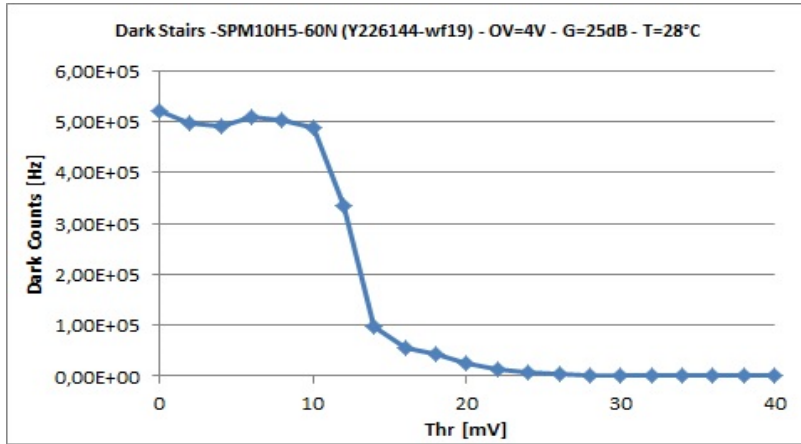
Then the break-down voltage for this SiPM is 27.87 V.



### 3.0 Staircase and Cross-talk versus Over-Voltage SiPM SPM10H5-60N substrate medium doping

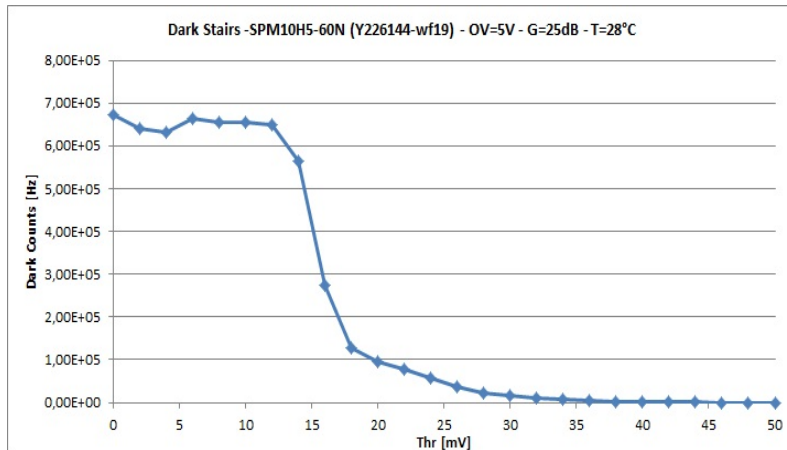
The Crosstalk is evaluated by the ratio of the DCR at 1.5 pe- and at 0.5 pe-.

**Vov=4.0V**



From the data we derive:  
**Xtalk=0.46%**  
**Dark= 500 KHz @0.5 pe**

**Vov=5.0V**



From the data we derive:  
**Xtalk=0.95%**  
**Dark= 650 KHz @0.5 pe**



## 4.0 Electro-optical characterization

We characterize the SiPM at two different Over-voltages 4V and 5V.

The characterization includes the following steps:

1. the Staircase to select the appropriate threshold,
2. the Dark Count Rate (DCR) at different gate time in order to select the best hold-off time
3. the system linearity to evaluate the best illumination conditions (avoid the saturation)
4. PDE measurements taking into account the results of the previous steps.

### 4.1 Characterization at $V_{ov} = 4V$

Here will follow the characterization at  $V_{ov}=4V$ .

#### 4.1.1 Staircase @ $OV=4V$

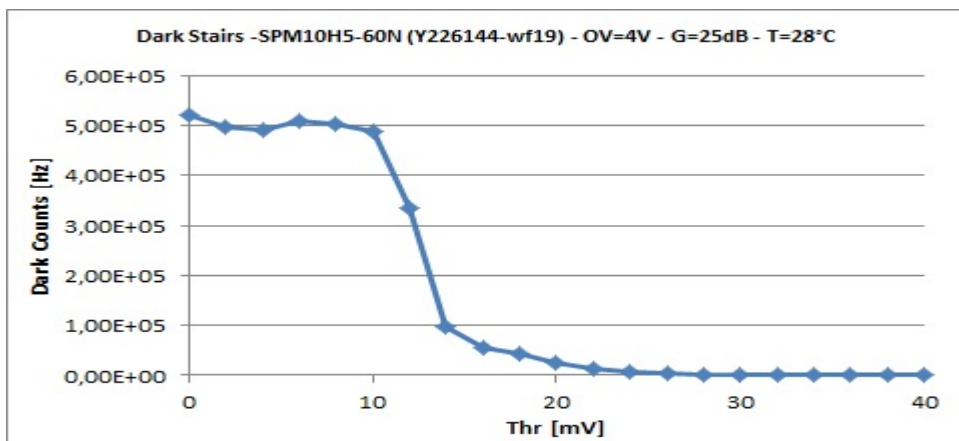


Fig. 1 – Dark Stair versus  $V_{thr}$  @  $T=28.0^{\circ}C$ .

From this plot we derived a  $V_{thr}$  of  $-6\text{ mV}$ .

#### 4.1.2 DCR @ $OV=4V$ at different Gate Time from 30 ns to 120 ns

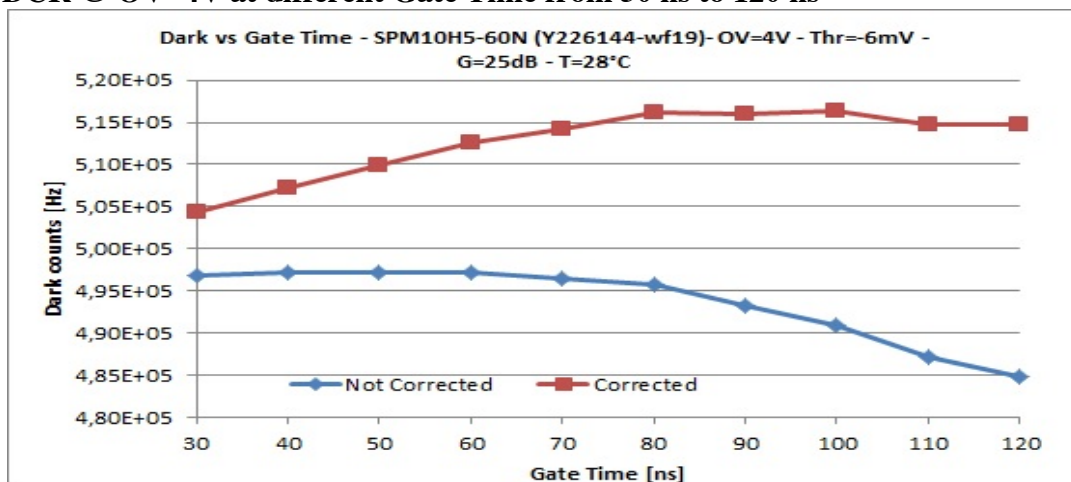


Fig.2 - DARK vs GATE TIME  $V_{ov}=4V$  -  $Thr=-6\text{ mV}$  -  $T=28^{\circ}$ . Measurements were performed at gate times from 30ns to 120ns. The upper curve is obtained correcting for dead time the lower curve. Temperature compensation for gain stabilization is also adopted

We select as optimal Gate Time - :  $\rightarrow \tau = 90\text{ ns}$





### 4.1.2 DCR @ OV=4V vs Time

By selecting the above the threshold level and the gate time obtained in the previous subsections, a measure of dark versus time is carried out.

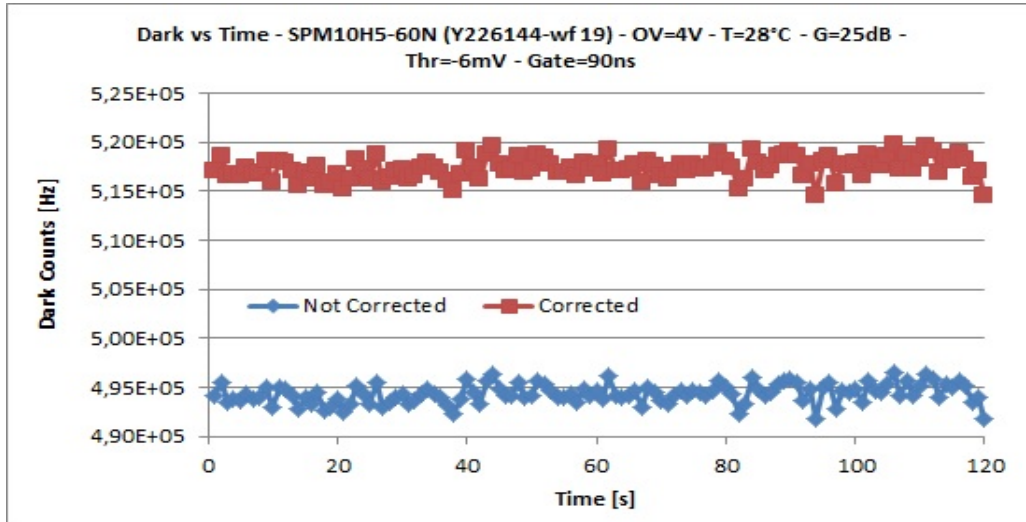


Fig.3 - DARK vs Time  $V_{ov}=4V$  -  $Thr=-6\text{ mV}$   $T=28^\circ$  The upper curve is obtained correcting for dead time the lower curve. Temperature compensation for gain stabilization is also adopted.

From this plot we derive that at a  $V_{ov}=4V$  and with a threshold of 0.5 pe the effective **DCR @  $28^\circ\text{C}$  is 500 KHz.**

### 4.1.4 System linearity to evaluate the best operating conditions

To characterize the SiPM by using the best illumination conditions, that means avoiding the system saturation and maintaining a sufficient signal on the NIST calibrated photodiode, linearity measurements were carried out. Furthermore the non-linearity conditions were tested by using the PDE measurements at a selected wavelength.

Here will follow the obtained plots of the signal count rate versus the photodiode current @500 nm and the PDE versus the signal count rate @500 nm.

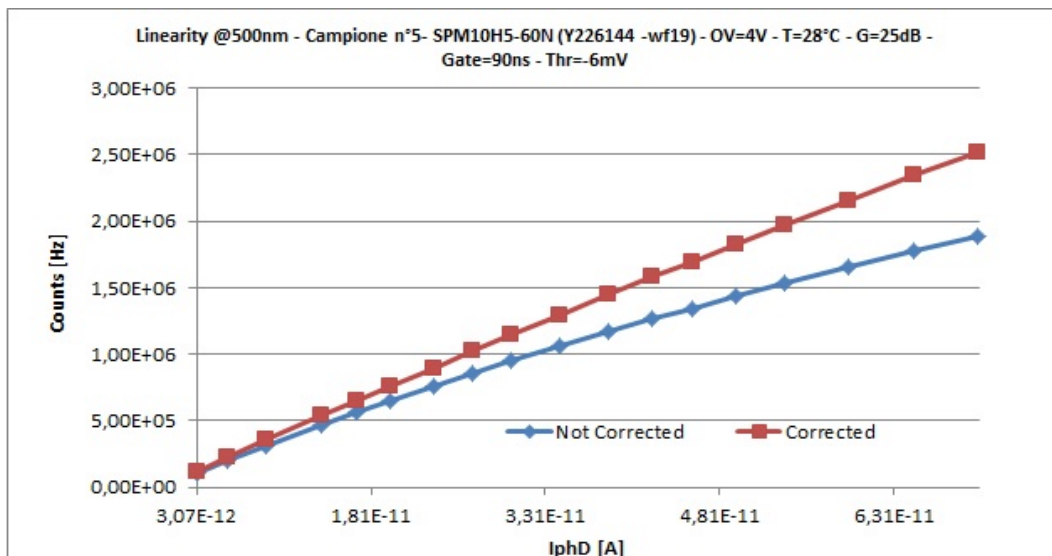


Fig. 4 – Linearity at 500 nm with and without the dead time correction.



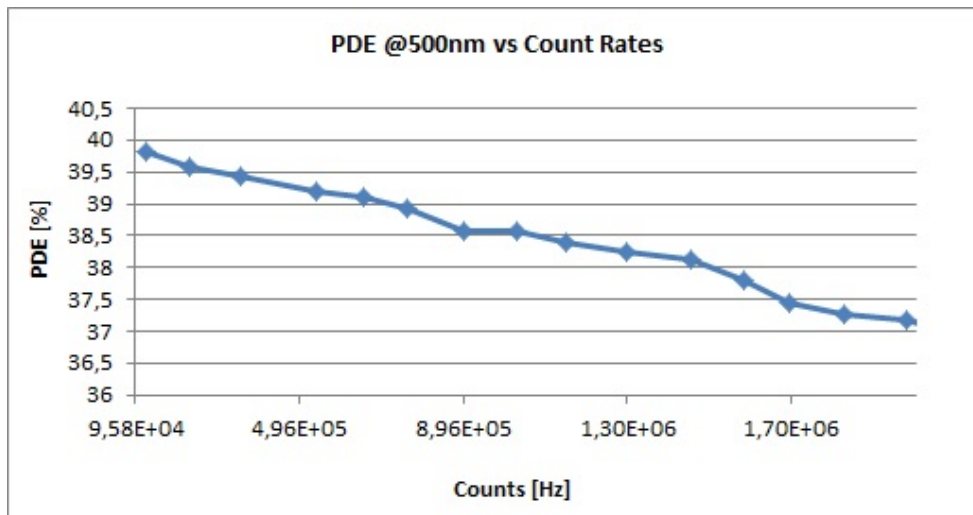


Fig.5 – PDE measurements at 500nm versus counts, from 95 KHz to 1700KHz operating the SiPM at  $V_{ov}=4V$ ,  $T=28^{\circ}C$ ,  $V_{thr}=-6\text{ mV}$ , Gate time=90 ns

From these plots we derive that the system shows a not-linearity behavior at rates greater than 900 KHz uncorrected corresponding at about 1100 KHz corrected for dead time. And the PDE is about 39-39.8 % in the range of 95 KHz – 650 KHz without dark counts (Fig.5)

Then, to be conservative, the PDE measurements have to be carried out with **uncorrected signals and without DCR subtraction not higher than 1.2 MHz corresponding to 1.5 MHz corrected for dead time.**

#### 4.1.5 PDE measurements at Over-Voltage 4V

Measurements were performed at  $V_{OV} = 4V$  and gate time 90ns. The plot reports the PDE with values corrected for the Dead Time.

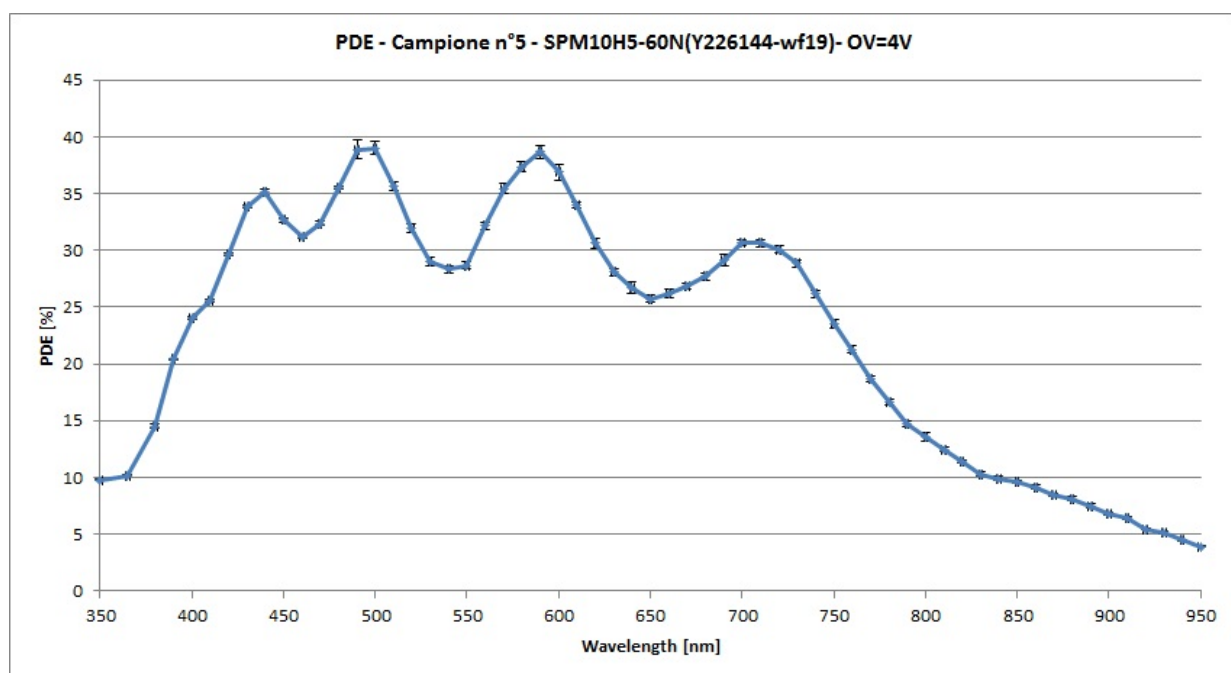


Fig.6 – PDE measurements operating the SiPM at  $V_{ov}=4V$ ,  $T=28^{\circ}C$ ,  $V_{thr}=-6\text{ mV}$ , Gate time=90 ns



## 4.2 Characterization at $V_{ov} = 5V$

Here will follow the characterization at  $V_{ov}=5V$ .

### 4.2.1 Staircase @ $OV=5V$

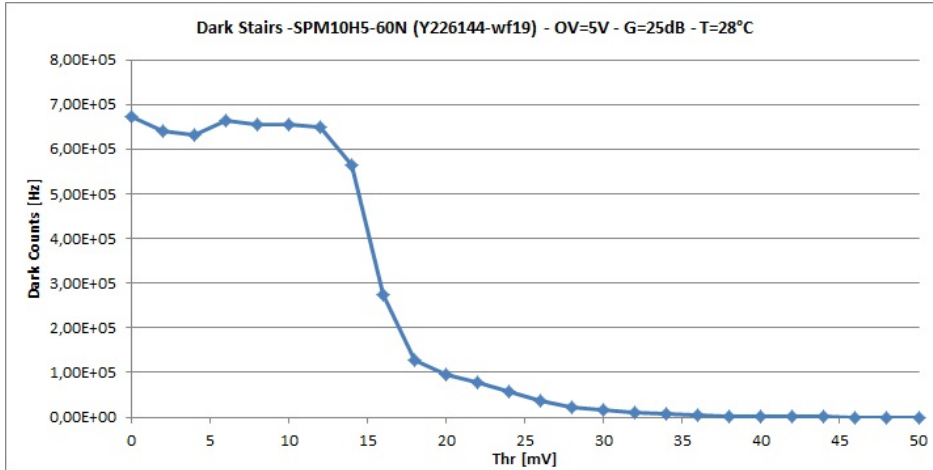


Fig. 7 – Dark Stair versus  $V_{thr}$  @  $T=28.0^{\circ}C$ .

From this plot we derived a  $V_{thr}$  of  $-10\text{ mV}$ .

### 4.2.2 DCR @ $OV=5V$ at different Gate Time from 30 ns to 120 ns

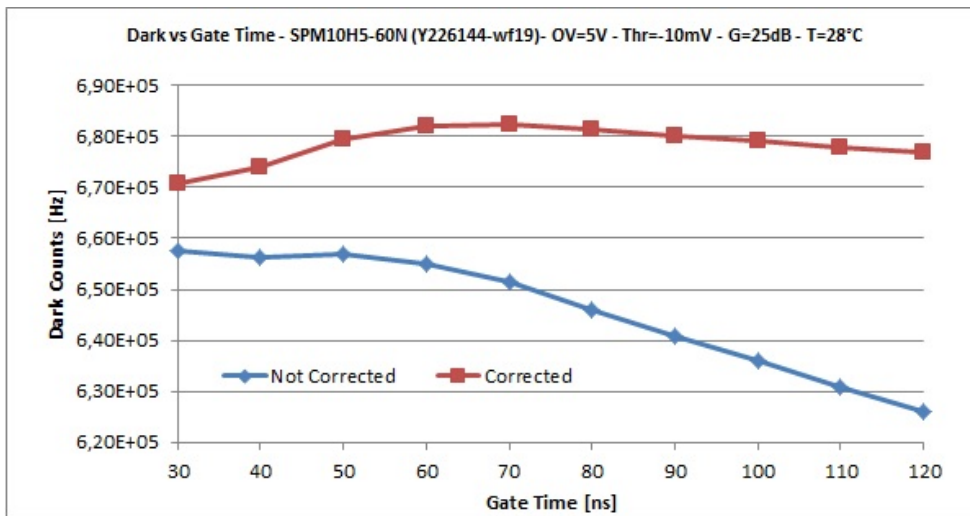


Fig.8 - DARK vs GATE TIME  $V_{ov}=5V$  -  $Thr=-10\text{ mV}$   $T=28^{\circ}$ . Measurements were performed at gate times from 30ns to 120ns. The upper curve is obtained correcting for dead time the lower curve. Temperature compensation for gain stabilization is also adopted.

We select as optimal Gate Time - :  $\rightarrow \tau = 90\text{ ns}$



### 4.2.3 DCR @ OV=5V vs Time

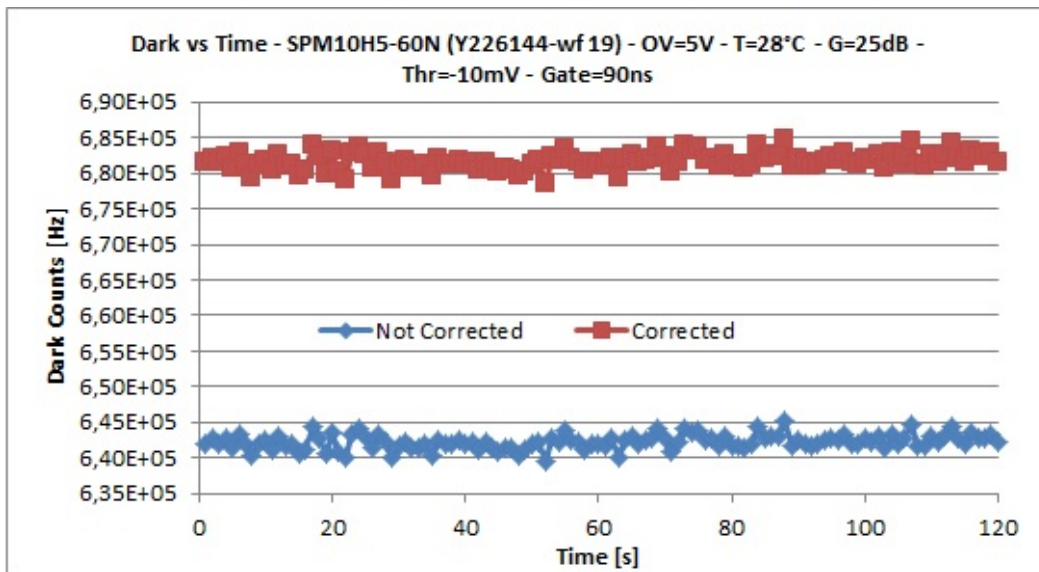


Fig.9 - DARK vs Time  $V_{ov}=5V$  -  $Thr=-10\text{ mV}$   $T=28^\circ$ . The upper curve is obtained correcting for dead time the lower curve. Temperature compensation for gain stabilization is also adopted.

From this plot we derive that at a  $V_{ov}=5V$  and with a threshold of 0.5 pe the effective **DCR @  $28^\circ\text{C}$  is 680 KHz.**

### 4.2.4 System linearity to evaluate the best operating conditions

To characterize the SiPM by using the best illumination conditions, that means avoiding the system saturation and maintaining a sufficient signal on the NIST calibrated photodiode, linearity measurements were carried out. Furthermore the non-linearity conditions were tested by using the PDE measurements at a selected wavelength.

Here will follow the obtained plots of the signal count rate versus the photodiode current @500 nm and the PDE @500 nm versus the signal count rate.

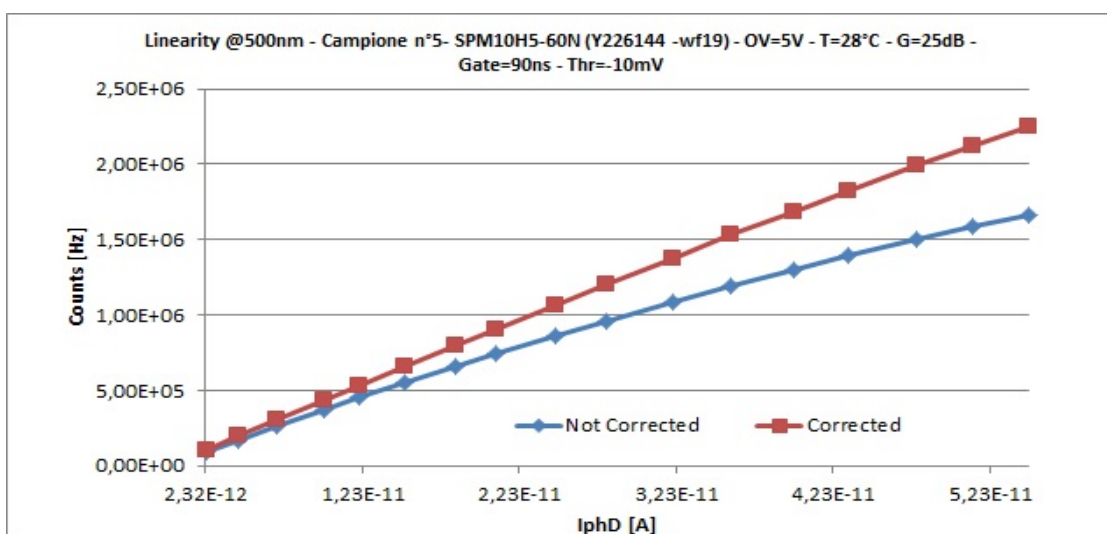


Fig. 10 – Linearity at 500 nm with and without the dead time correction.

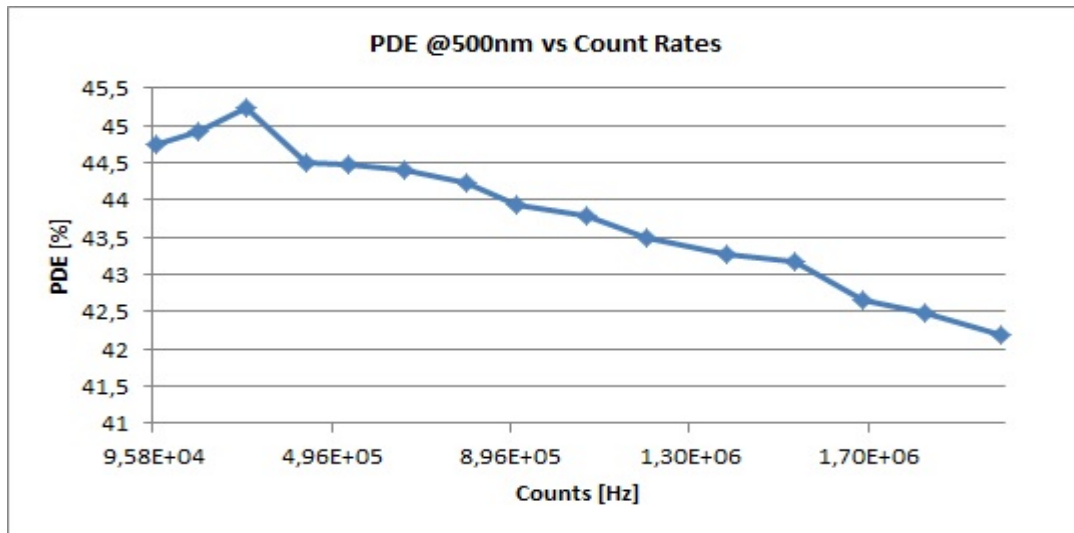


Fig.11 – PDE measurements at 500nm versus counts, from 96 KHz to 1700KHz operating the SiPM at  $V_{ov}=5V$   $T=28^{\circ}C$ ,  $V_{thr}=-10$  mV, Gate time=90 ns

From these plots we derive that the system shows a not-linearity behavior at rates greater than 900 KHz uncorrected corresponding at about 1100 KHz corrected for dead time. And the PDE is about 45-44 % in the range of 96 KHz – 900 KHz without dark counts (Fig.11)

Then, to be conservative, the PDE measurements have to be carried out with **uncorrected signals and without DCR subtraction not higher than 1.4 MHz corresponding to 1.8 MHz corrected for dead time.**

#### 4.2.5 PDE measurements at Over-Voltage 5V

Measurements were performed at  $V_{OV} = 5V$  and gate time 90ns. The plot reports the PDE with values corrected for the Dead Time.

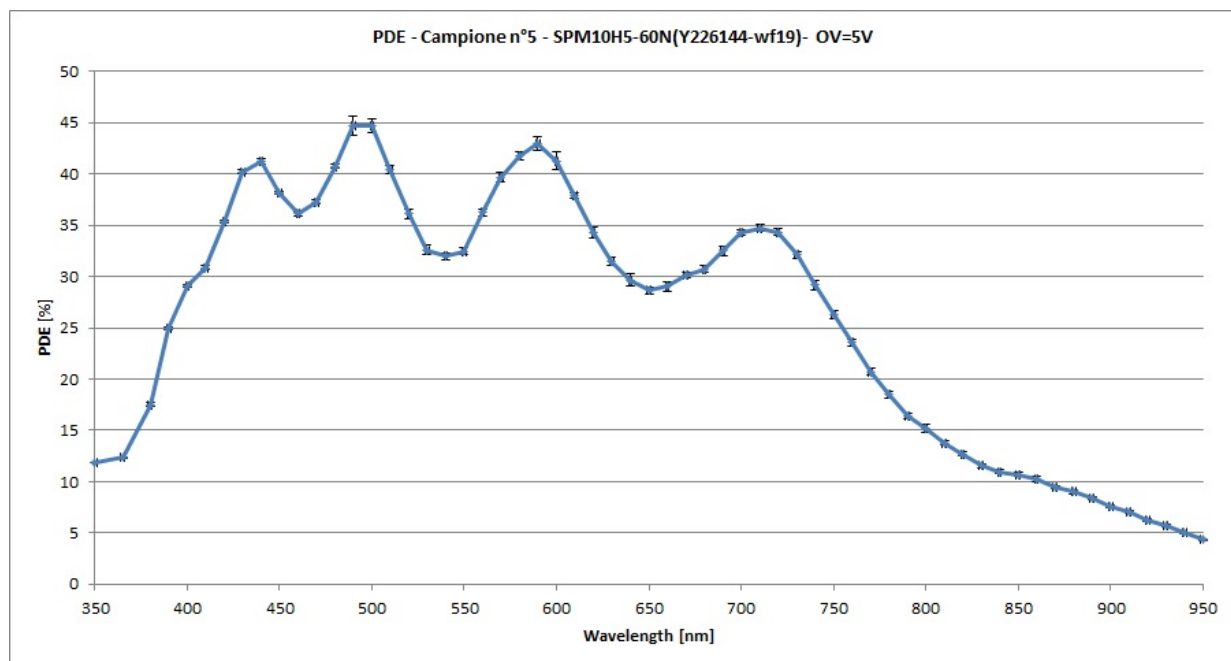


Fig.12 – PDE measurements operating the SiPM at  $V_{ov}=5V$ ,  $T=28^{\circ}C$ ,  $V_{thr}=-10$  mV, Gate time=90 ns



### 4.3 PDE comparison

PDE measurements at the various Over Voltages are here compared.

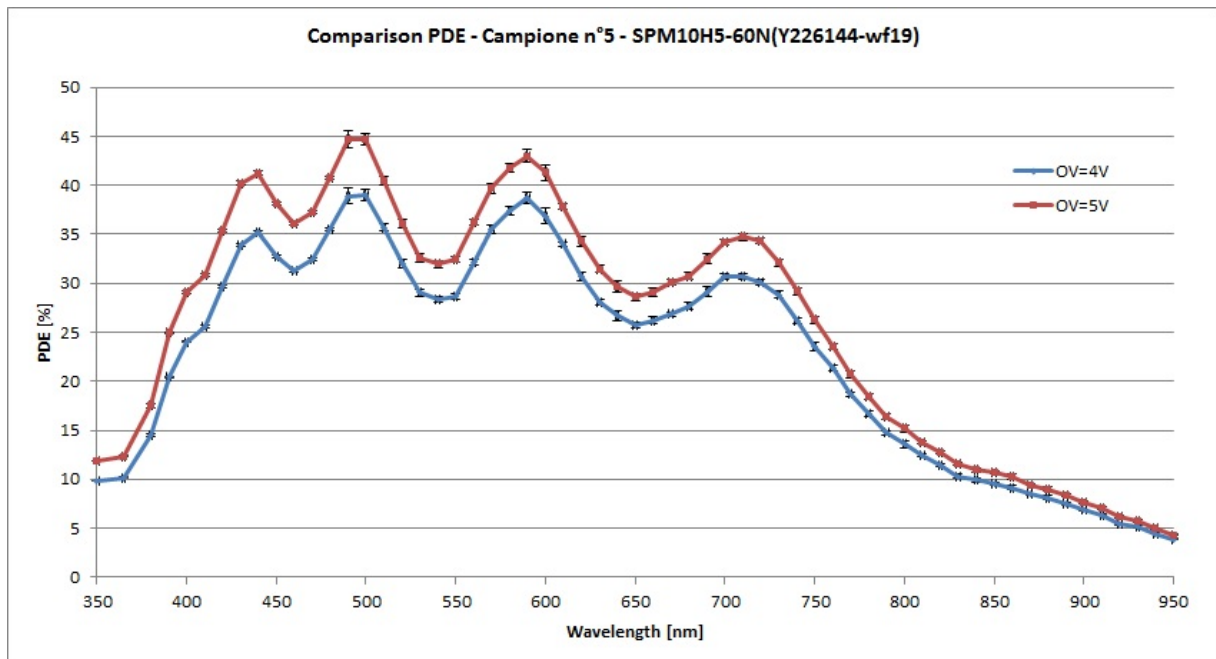


Fig.13– PDE measurements comparison at  $V_{ov}=4.0V$  and  $V_{ov}=5.0V$  @  $T=28^{\circ}C$ .