CAEN Educational

Erasmus Mundus Program

Activity Report

24/07/2019

Title: Characterization of SiPMs.

Abstract:
In this report the characterization of a Silicon Photo-Multiplier (SiPM) detector was done in order to estimate the main features of the detector. The breakdown voltage, the gain, the dark Count Rate as well as the optical crosstalk of the detector were successfully obtained.

Purpose of the experiment:
The first aim of the experiment was to calculate the Breakdown Voltage that corresponds to the value at zero gain to study the dependence of the main SiPM properties to the bias voltage. For this reason, the peak to peak distance from the photoelectron spectrum of the LED source spectrum was calculated. The mean value of the peak to peak distance was plotted as a function of the bias voltage, in order to derive the Breakdown Voltage of the SiPM by applying a linear fit. For the estimation of the Gain, with the same electronic chain, the analysis of the spectrum was done by following the software instructions. Next goal of the experiment was to estimate the Dark Count Rate and the Optical Crosstalk of the detector.

Material:
This experiment was based on a Silicon Photomultiplier detector (SiPM), which consists of a high-density matrix of Avalanche Photodiodes (APDs) operated in a limited Geiger-Muller regime and connected in parallel on a common Si substrate. The SiPM's advantages include: high detection efficiency (single photo-electron discrimination), compactness and robustness, low operating voltage and power consumption, low cost and withstanding to magnetic fields. This detector is integrated in a module with a power supply and an amplification unit (SP5600). The analog output signal is digitized using a Desktop Digitizer of 250 MS/s (DT5720A) and the light source comes from a LED Driver (SP5601). The light from the LED Driver is directed to the detector with an optical clear fiber cable, the other connections are made using LEMO and CMX cables and the communications with the PC are driven by a USB cable.

Measurements:
We set up and connected the devices, started the software and verified the connection. With the preset bias voltage of the Set SiPM, we activated the detector and, by observing the acquired histogram and the waveform tab, adjusted the digitizer parameters (gate, pre-gate, baseline). For the first part, we obtained spectra for 4 values of bias voltage and, for each of them, identified the mean value of each peak (ADC Channel) and estimated the Peak to Peak Distance (DPP). With this information we estimated the value for the breakdown voltage. For the second part, we set the bias voltage to 55 V and analysed the spectrum with the software to estimate the SiPM Gain value and the Resolution Power. For the last part, we removed the light source, covered the window of the detector and verified again the connection. We ran the "Frequency Scan" tab to identify the 0.5 phe and 1.5 phe threshold values and used them to evaluate the Dark Count Rate (DCR) and the Optical Crosstalk (OCT) values with the "Counting" tab of the software.

Data Analysis:

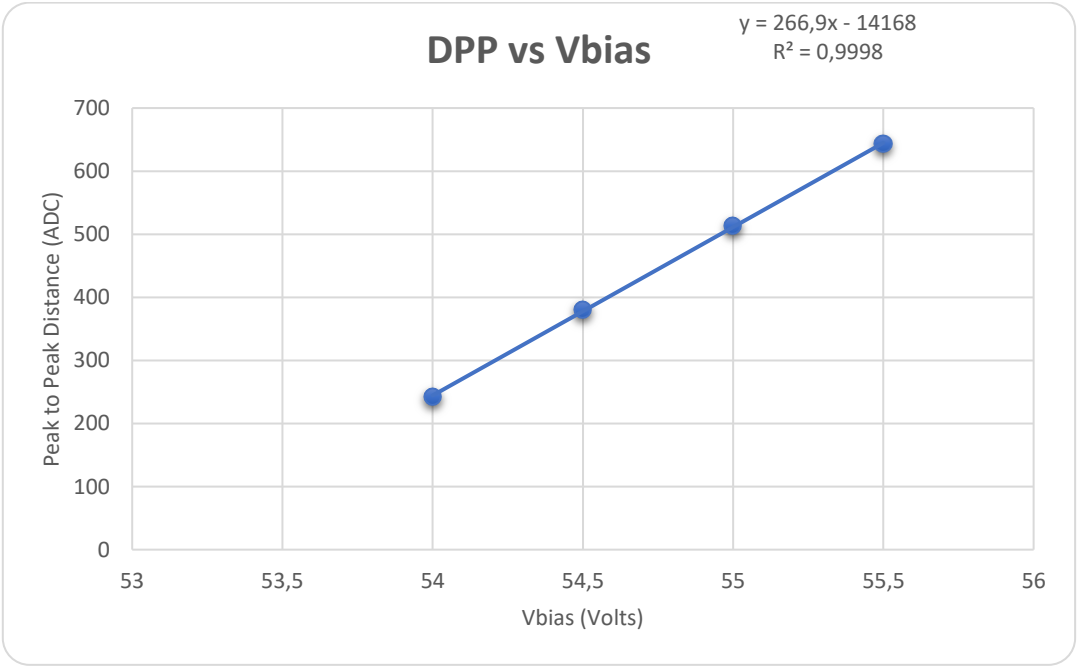
Firstly, we obtained the average value of the peak to peak distance for different values of the bias voltage between 54 V and 55.5 V. The results are presented in the following table I:

Table I

DPP (channels)	242.5	380	513	643
Vbias (V)	54	54.5	55	55.5

plotted the data from Table I were plotted with a linear fit as it can be seen in figure 1 together with the corresponding error bars. The values of the errors are very small thus are not visible.

Figure 1



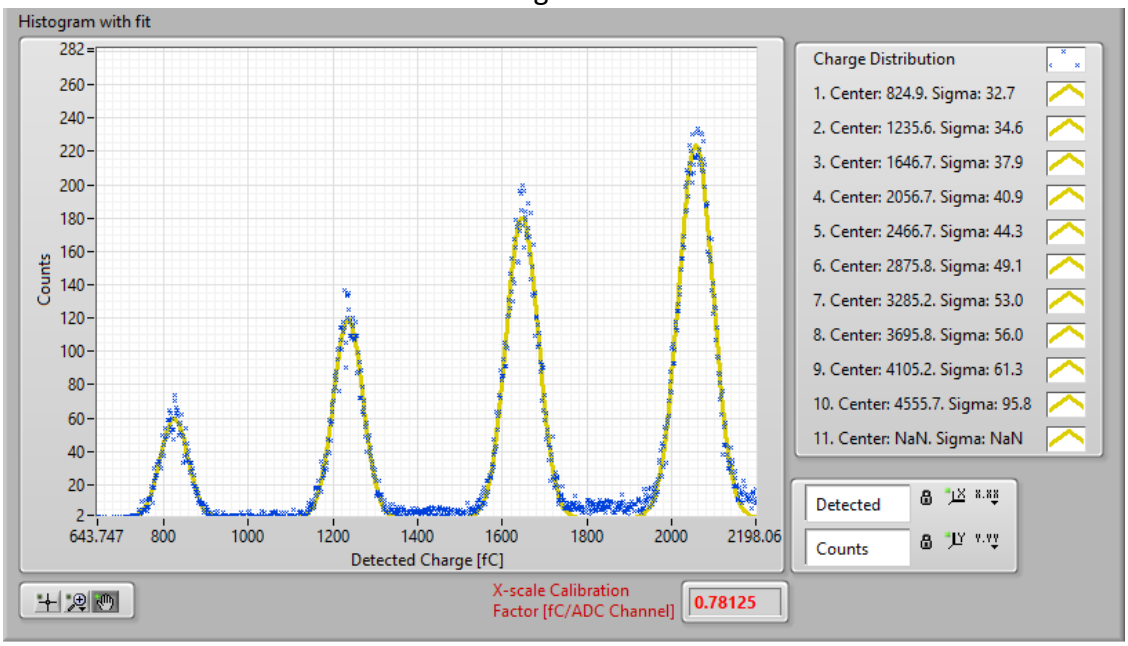
From the linear fitting the breakdown voltage was obtained. From the Equation (1) for DPP=0 we get the Breakdown Voltage.

$$\text{DPP}=m \times x + q \qquad (1)$$

$$V_{breakdown} = -\frac{q}{m} = 53.06 \pm 0{,}68\ V$$

In the second task of the experiment, we measured the gain following the instructions of the software. The program made a gaussian fit of the peaks of the photoelectron spectrum as it can be observed in the following figure 2:

Figure 2



According with the fitting the Gain was automatically calculated by the program giving the following values as it can be seen in figure 3.

Figure 3

DPP Mean [fC]	St. Dev. [fC]
414.54	13.5
SiPM Gain	**SiPM Gain Error**
2.591E+6	40.8E+3

The Program was also able to measure the resolution power on the multi-photon peak spectrum using the formula in figure 4

Figure 4

Resolution Power

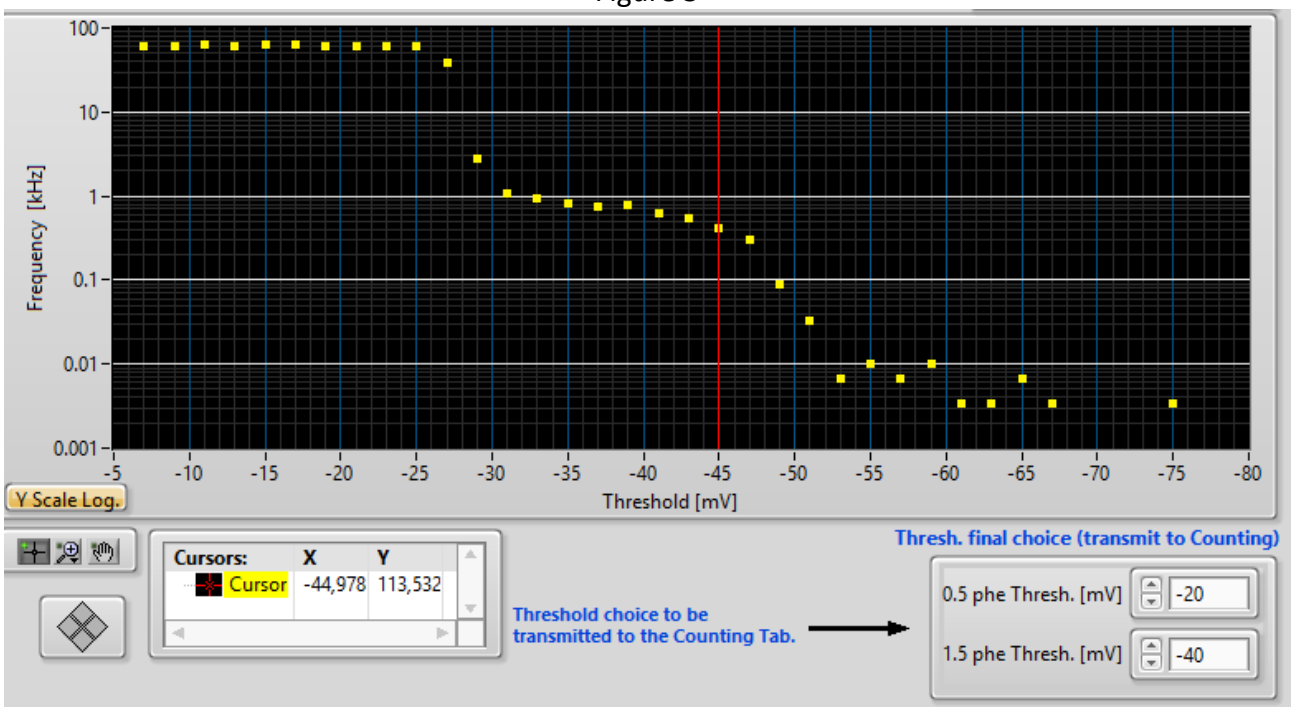
$$R = \frac{\Delta pp}{\sigma_{gain}} \qquad \sigma_{gain} = (\sigma_1^2 - \sigma_0^2)^{1/2}$$

- R= Resolution Power
- Δpp = difference between the first two peaks
- σ_{gain}= single cell gain fluctuations

Resolution Power	Res. Power Error
26.27	0.21

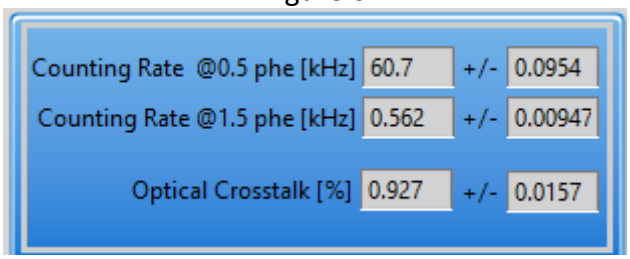
The next step of the experiment involved the calculation of the Dark Count Rate and the Crosstalk. In the following figure 5 we see the Dark Count frequency versus the discrimination threshold.

Figure 5



The program gave the following results as it can be seen in figure 6 for the counting rate for the 2 thresholds. The optical crosstalk can be calculated by dividing the 2 values.

Figure 6



Results & Conclusion:

In the first part of the experiment, we estimated a value of 53.06 V for the breakdown voltage of the detector, which is very accurate comparing with the value of 53 V presented in the datasheet of the Hamamatsu device (MPPS S13360-1350CS). The gain and the resolution power obtained were $2.591 \times 10^6 \pm 40.8 \times 10^3$ and 26.27 ±0.21, respectively. The threshold values of the 0.5 phe and 1.5 phe were -20mV and -40mV, the Dark Count Rate (DCR) for the 0.5 phe is 60.7 ±0.0954 kHz and for the 1.5 phe is 0.562±0.00947 kHz, and the ratio between these DCR, i.e. the Optical Crosstalk, was

0.927±0.0157%. In conclusion, the characterization of the Silicon Photomultipliers was executed successfully.

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