

# A.1.1 SiPM Characterization

SG6011



## Purpose of the experiment

*Characterization of a SiPM detector using an ultra-fast pulsed LED.  
Estimation of the main features of the detector at fixed bias voltage.*


## Fundamentals

Silicon Photomultipliers (SiPM) consist of a high-density (up to  $\sim 10^4/\text{mm}^2$ ) matrix of diodes connected in parallel on a common Si substrate. Each diode is an Avalanche Photo Diode (APD) operated in a limited Geiger-Müller regime connected in series with a quenching resistor, in order to achieve gain at level of  $\sim 10^6$ . As a consequence, these detectors are sensitive to single photons (even at room temperature) feature a dynamic range well above 100 photons/burst and have a high Photon Detection Efficiency (PDE) up to 50%. SiPM measure the light intensity simply by the number of fired cells. However, this information is affected and biased by stochastic effects characteristic of the sensor and occurring within the time window: spurious avalanches due to thermally generated carriers (a.k.a. Dark Counts), delayed avalanches associated to the release of carriers trapped in metastable states (a.k.a. Afterpulses) and an excess of fired cells due to photons produced in the primary avalanche, travelling in Silicon and triggering neighboring cells (a phenomenon called Optical Cross Talk).

The typical SiPM response to a light pulse is characterized by multiple traces, each one corresponds to different numbers of fired cells, proportional to the number of impinging photons. Because of the high gain compared to the noise level, the traces are well separated, providing a photon number resolved detection of the light field.

## Equipment

SP5600E - Educational Photon Kit

Model	SP5600	DT5720A	SP5601	SP5650C
Description	Power Supply and Amplification Unit	Desktop Digitizer 250 MS/s	LED Driver	Sensor Holder for SP5600 with SiPM
				
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### Related Experiment

A.1.2

G.2.1

D.1

### Ordering Options

#### Equipment

Code	Description
WK5600XEAAA	SP5600E - Educational Photon Kit

or the all inclusive Premium Version

WK5600XANAA	SP5600AN - Educational Kit - Premium Version
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Currently the Silicon Photomultipliers are the new technology used in many important physics experiments. The Cherenkov Telescope Array (CTA) is one of these experiments. The CTA project is an initiative to build the next generation ground-based very high energy gamma-ray instrument. It will serve as an open observatory to a wide astrophysics community and will provide a deep insight into the non-thermal high-energy universe. The aims of the CTA can be roughly grouped into three main themes, serving as key science drivers:

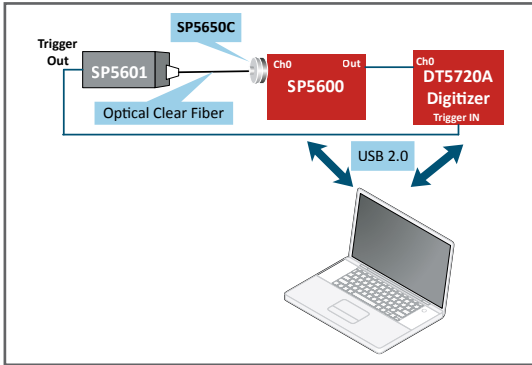
- Understanding the origin of cosmic rays and their role in the Universe
- Understanding the nature and variety of particle acceleration around black holes
- Searching for the ultimate nature of matter and physics beyond the Standard Model

<https://www.cta-observatory.org/>



### Requirements

No other tools are needed.



Experimental setup block diagram.

### Carrying out the experiment

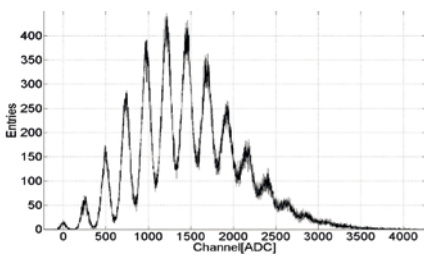
The light pulse from the SP5601 ultra-fast LED-Driver is driven through an optical clear fiber into the SP5650C SiPM holder housing the sensor under test and connected to the SP5600. The output signal (from the SP5600) is connected to the input channel of the DT5720A Desktop Digitizer equipped with the charge integration firmware, and triggered by the SP5601 LED-driver. The SP5600 and the DT5720A are connected to the PC through the USB. Use the default software values or optimize the bias voltage and discriminator threshold. The horizontal axis of the acquired spectrum is the ADC channels, therefore ADC channel conversion ( $ADC_{c.r.}$ ) factor can be calculated to perform the experiment and determine the main features of the SiPM.

### Results

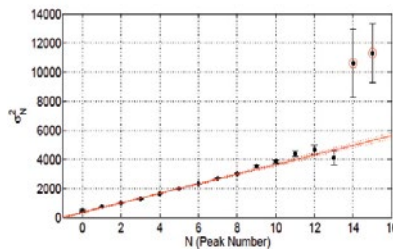
The gain of the SiPM is evaluated from the output charge of the sensor. After the estimation of the ADC channel conversion factor ( $ADC_{c.r.}$ ) and the distance between adjacent peaks ( $\Delta PP(ADC\_ch)$ ), the SiPM gain can be calculated according to the following equation:

$$Gain = \frac{\Delta PP(ADC\_ch) * ADC_{c.r.}}{e}$$

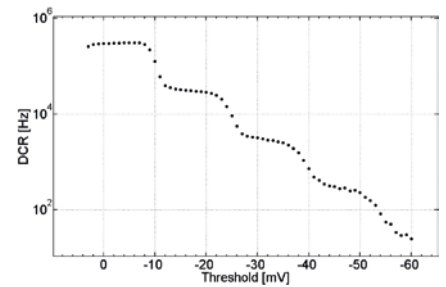
The resolution power of the system can be evaluated plotting the  $\sigma$  of each peaks versus the number of peaks. The counts frequency, in absence of light, at 0.5 p.e. threshold represents the DCR. The ratio between the dark count at 1.5 p.e. threshold ( $DCR_{1.5}$ ) and the value at 0.5 p.e. threshold ( $DCR_{0.5}$ ) give the crosstalk estimation of the detector.



Spectrum of Hamamatsu S10362-11-100C.



Peak  $\sigma$  versus peak number for Hamamatsu S10362-11-100C.



Sensor Dark Count frequency versus discrimination threshold.