15th Pisa Meeting on Advanced Detectors - La Biodola, Isola d'Elba (Italy), 22-28 May 2022

Comparison of new SiPM models for applications in High-Energy physics

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Introduction

Silicon Photo-Multipliers (SiPMs) are widely used as light detectors for the new generation of experiments dedicated to high energy physics. For these reasons, we tested several recent devices from different manufacturers: Hamamatsu 13360-1350; Ketek PM1125; ONsemiconductors FC10035 and AdvanSid NUV4S-P. Particular emphasis has been put on measurements of dark counts and gain, performed at different temperatures by means of a climatic chamber (F.lli Galli model Genviro-030LC) with a temperature range from −60 ◦C to +60 ◦C, housing the SiPM under test. This latter also allowed evaluating the temperature coefficient of all models.

Experimental apparatus

The setup consists of a Climatic chamber (F.lli Gallii model Genviro-030LC) with a temperature range from -60ºC to +60ºC that houses the SiPm t to be tested .

The inner part of the chamber can be connected to the external world by means of electrical and optical (optical fiber) feedthrough.

A CAEN SP5600 Power Supply and Amplification Unit is used to provide the bias to the SiPM placed inside the climatic chamber. The SiPM under test is welded on a custom PCB which is then connected to a CAEN SP560C Sensor Holder providing the electrical connections.

The output signal is then sent to a Desktop Digitizer (CAEN DT5720A, 250 MS/s).

A LabView graphical user interface is used to control both the SP5600 and the DT5720A through USB connections, allowing for the recording of the photon spectrum and for the direct measure of Dark Count Rate.

A CAEN SP5601 Led Driver is optically coupled to the SiPM under test via optical fiber, to provide light pulses needed to collect the photon spectrum.

Fig. 1: Climatic Chamber with the SP5600 Power Supply and the DT5720A digitizer on top of it.

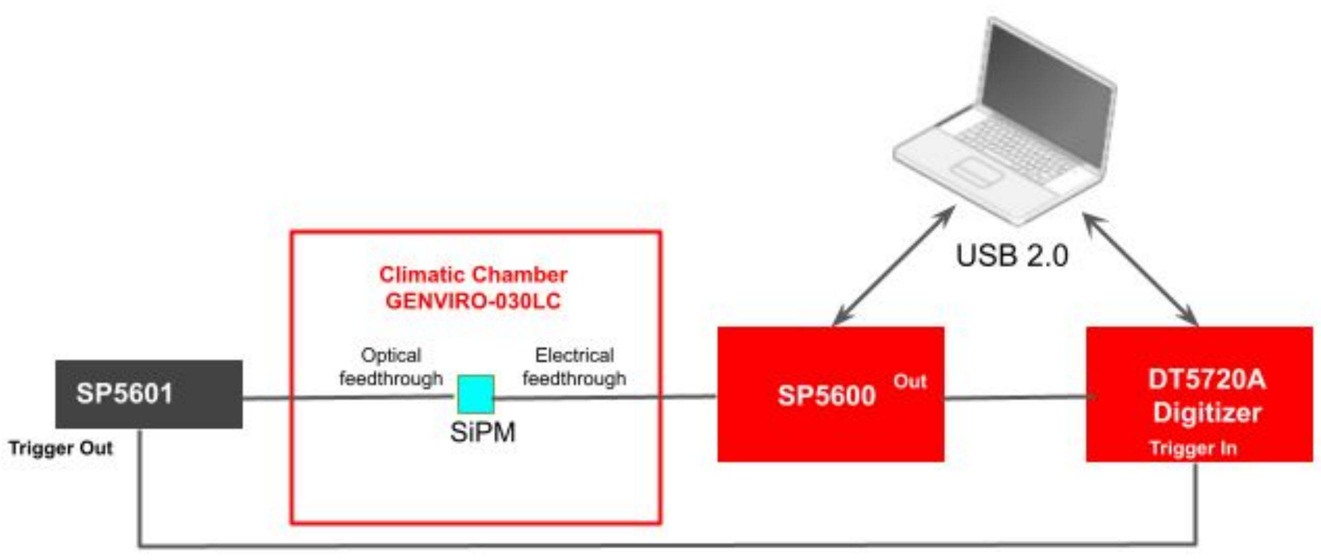


Fig. 2: Sketch of the experimental set-up.

Devices under test

We decided to test the three following small active area SiPMs: Ketek PM1125 (1x1 mm^2, 25 um cell); ONsemiconductors FC10035 (1x1 mm^2, 35 um cell); Hamamatsu S13360-1350 (1.3 x1.3 mm^2, 50 um cell). Moreover the recent AdvanSiD NUV4S-P (4x4 mm^2, 40 um cell) was added to the measurements. A picture of tested devices is presented in Fig. 3.

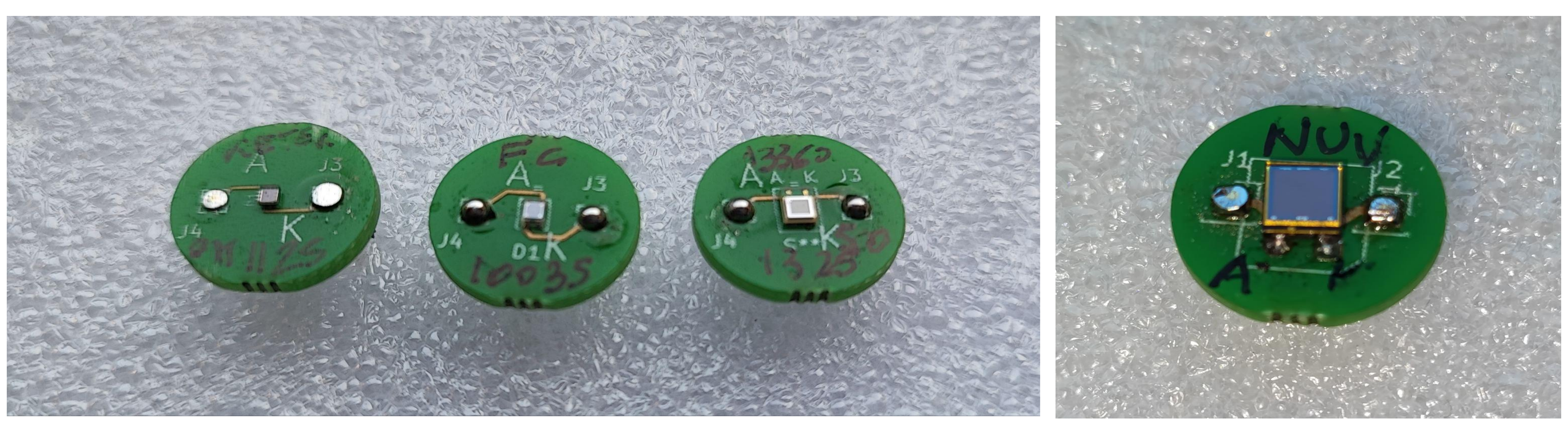


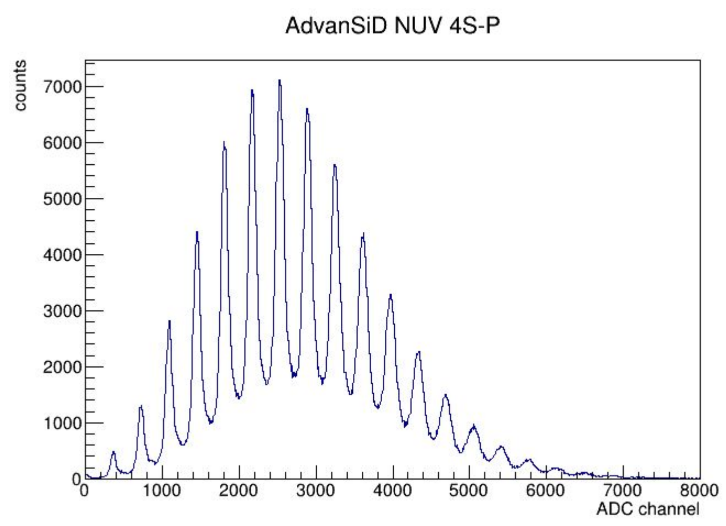
Fig. 3: Picture of the four SiPMs mounted on a custom PCB adapter.

Results

Several measurements have been carried out at four different temperatures: T = −40 ◦C; T = −20 ◦C; T = 0 ◦C; T = +20 ◦C. Here preliminary results are shown as a function of the temperature in terms of gain, breakdown voltage and dark current.

The gain of the SiPMs was evaluated from the output photon spectrum of the sensor. After a conversion taking into account a calibration factor (CAL) including the digitizer specifications and the amplification of the SP5600, the gain is calculated by measuring the distance between adjacent peaks (ADC_ch) according to:

$$GAIN = (ADC\_ch \times CAL) / e$$



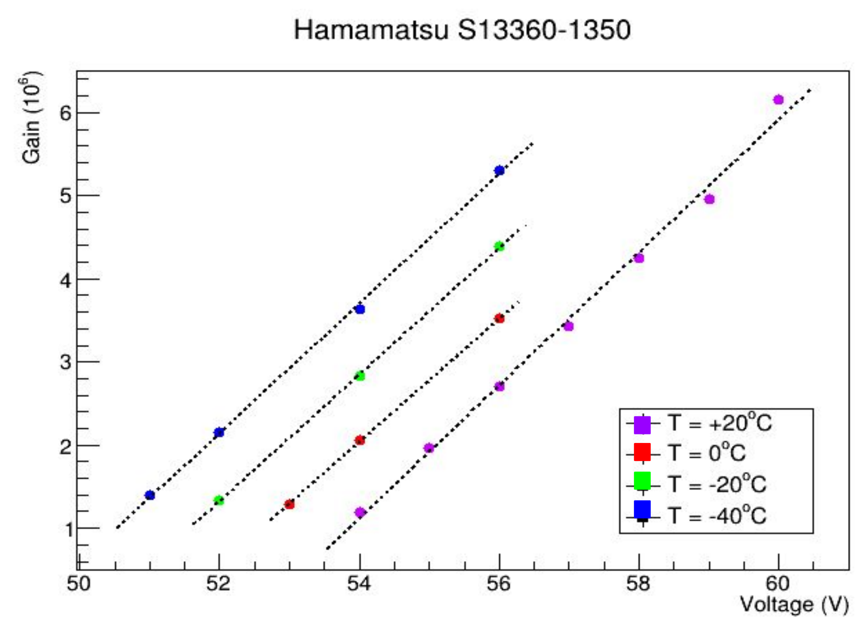


Fig. 4: Gain results. Left: example of photon spectrum for AdvanSiD NUV 4S-P taken at room temperature and at 2V overvoltage. Right: Gain vs Overvoltage of Hamamatsu S13360-1350. As expected, the gain is increasing by lowering the temperature. Gain measurements at room temperature is in agreement with the supplier specifications.

The breakdown voltage was extrapolated from a fit of the gain as a function of the bias, by evaluating the voltage for which the gain was equal to zero. This allowed evaluating the temperature coefficients for all devices under tests (see fig. 5), which were found to be in agreements with specifications.

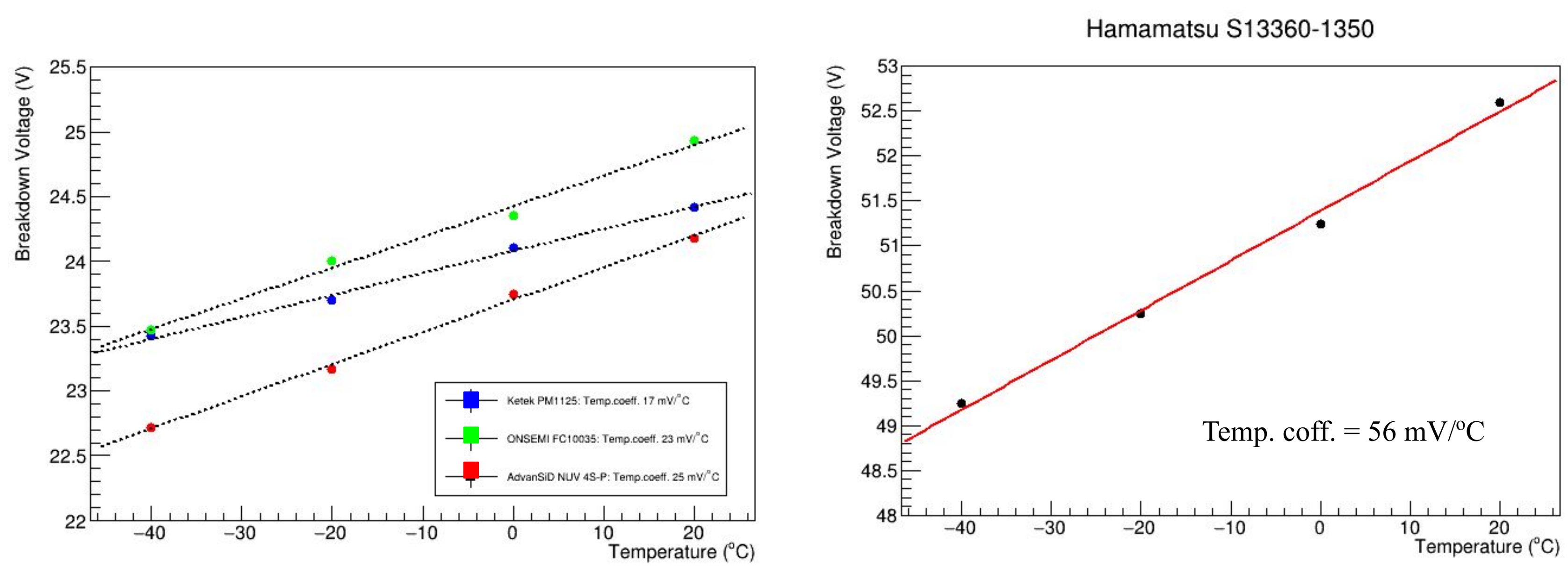


Fig. 5: Breakdown voltage as a function of the temperature. Left: Ketek PM1125 (blue), ONSEMI FC10035 (Green) and AdvanSiD NUV-4S-P (Red). Right: Hamamatsu S13360-1350.

The Dark Count Rate (DCR) has been evaluated from the so called "staircase" plot, in which the DCR is represented as a function of the applied threshold. Setting the threshold at 0.5 photo-electron and counting the number of pulses that exceed this value gives the number of times that one or more photons are detected. All devices are behaving as expected.

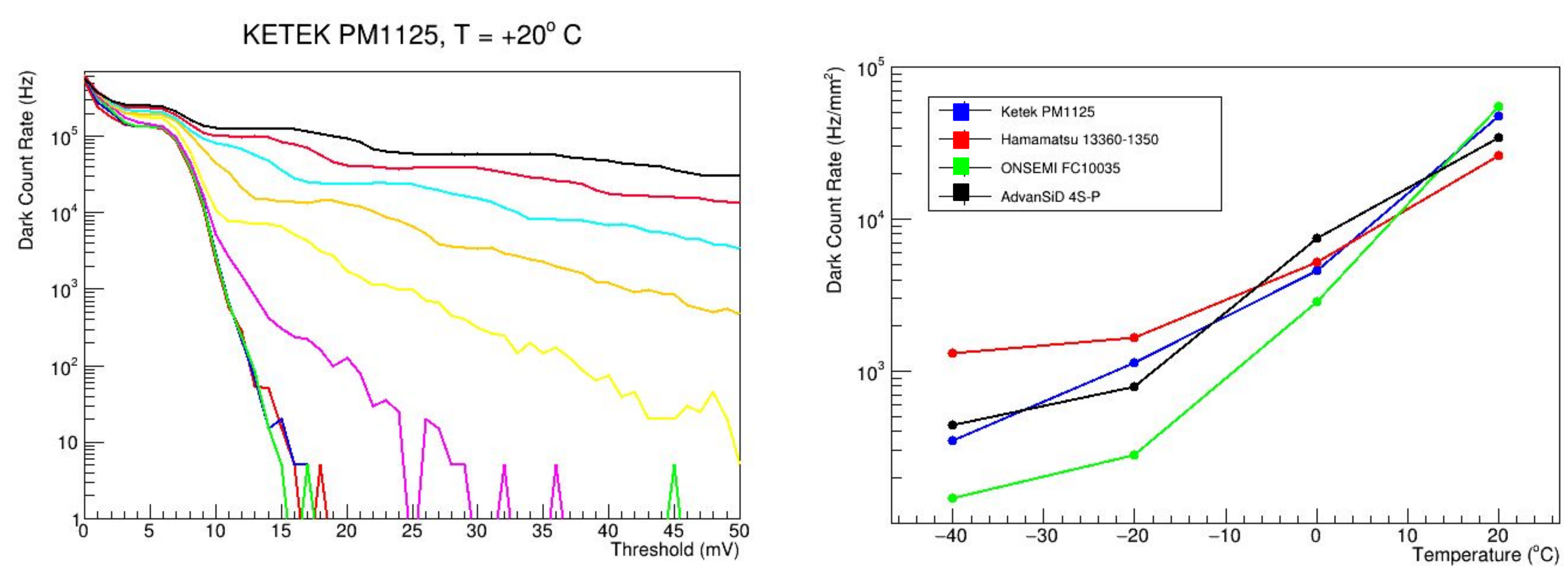


Fig. 6: Dark Count Rate. Left: example of staircase plot taken at room temperature with Ketek PM1125 for several bias voltages. Right: DCR (Hz/mm^2) as a function of the temperature.

Conclusions

The tested SiPMs have good performances in terms of gain, breakdown voltage and dark current once tested in cryogenic conditions. Therefore, they are suitable to be used for novel design scintillation light detectors dedicated to High Energy Physics experiments.

References

V. Arosio et al., "*An Educational Kit Based on a Modular Silicon Photomultiplier System*", https://doi.org/10.48550/arXiv.1308.3622