New Study for SiPMs Performance in High Electric Field Environment

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Abstract. We report on a new study for the performance of the Silicon Photo-Multipliers (SiPMs) light sensors when they are exposed to high electric field strengths in cryogenic environment. Three different SiPMs from two vendors (FBK and Hamamatsu) have been tested. The SiPMs showed very good stability, with respect to the gain and the crosstalk probability, when they are exposed to high electric fields compared to the case with the absence of the electric field.

Keywords: SiPM, Electric Field, Cryogenic Environment, Gain, Crosstalk.

1 Introduction

Although, during the past decade, substantial development in the area of SiPMs has offered what appears to be a superior alternative to conventional methods for light detection, SiPMs are still counted as relatively new technology. Hence, not all their features have been examined under the influence of extreme working conditions. While it is known that the SiPMs are stable against the change in the surrounding magnetic field [1], but little is known about their behavior under the exposure to strong variations in a surrounding electric field.

In this work, we perform new study on the SiPMs performance under the influence of the exposure to high electric field strengths. Two serious concerns will be addressed:

1. Any change in the SiPM properties (detection efficiency, gain, dark noise, crosstalks, etc.).

2. Any physical damage to the body of the sensors, due to the possible discharges caused by the high E fields.

2 Experimental setup

This study has been carried out using a LXe test station at IHEP-CAS China, with specially designed internal structure. The test station is capable of liquefying Xe, CF4 and Ar gases. In this study, four SiPMs from two different vendors, in which nEXO experiment is interested in [2], are tested (see Fig. 1). More SiPM-types can be tested in future, based on the experiment requirements. The detailed information for each device is listed in the following, except for the FBK-STD SiPM, as the range of operating voltage of this device is reduced a lot in cryogenic temperatures that leads to poor performance. Hence, the results will not be reported in this paper.

- *FBK VUV Low Field SiPM:* 2x2 array of 2.98x2.78 mm^2 SiPMs of filling factor ~ 73%, with pixel size 25x25 µm^2, forming ~ 5.96x5.56 mm^2 QUAD Chip. They are VUV sensitive, working in cryogenic environment and provided as bare chips.
- *FBK RGB-HD SiPM:* 2x6 array of 2.25 x 2.25 mm^2 SiPMs of filling factor ~ 72.5%, with pixel size 25 x 25 µm^2 and total chip size: ~15.3 x 4.95 mm^2. These SiPMs are UV sensitive, working in cryogenic environment and provided as bare chips.
- *Hamamatsu VUV3 SiPM:* one SiPM chip of size 3.4x3.4 mm^2 with pixel size 50 µm and filling factor ~ 50%. This SiPM is VUV sensitive, working in cryogenic environment but not provided as bare chips.

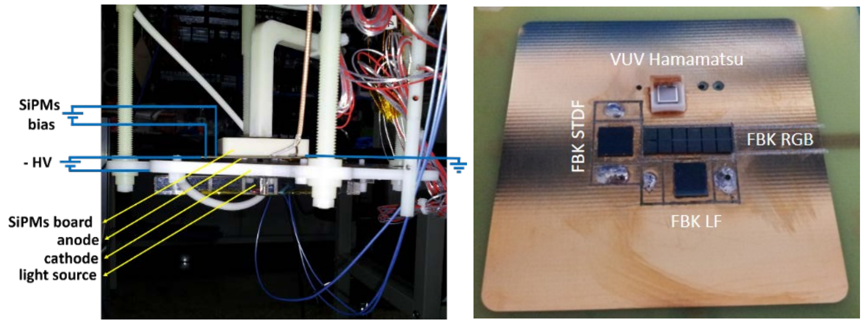

Fig. 1. (Left) The assembly of the test setup; SiPMs, cathode and the light source in the inner chamber. (Right) The four SiPMs used in this study attached to the grounded metalic sheet.

Two sets of data were collected at different electric field values; 0, 6, 12, 18, 24 and 30 kV/cm, in liquefied CF4 environment (at -125 °C). The two data sets are based on the lightning condition; the first data set collected used a blue light (~ 465 nm) LED source that is placed outside the outer chamber and driven by a pulse generator at 10 kHz frequency. The light pulse is then split into two channels and delivered by fiber cables. One fiber cable goes to a monitor PMT outside the chamber that is used to monitor the stability of the LED light. The second data set was collected in dark (i.e. at the single photoelectron level).

3 Results

3.1 Total charge vs HV for the data collected with light

The SiPM total output charge calculated from the collected wave-forms has been corrected by the total charge collected by the monitor PMT. This latter, the corrected total charge, is then normalized to the total charge collected at 0 kV/cm electric field measurement. Figure. 2 shows the relative total charge as a function of electric field strengths. The plot shows very good stability, within the statistical errors, for the relative total charge for the three SiPMs.

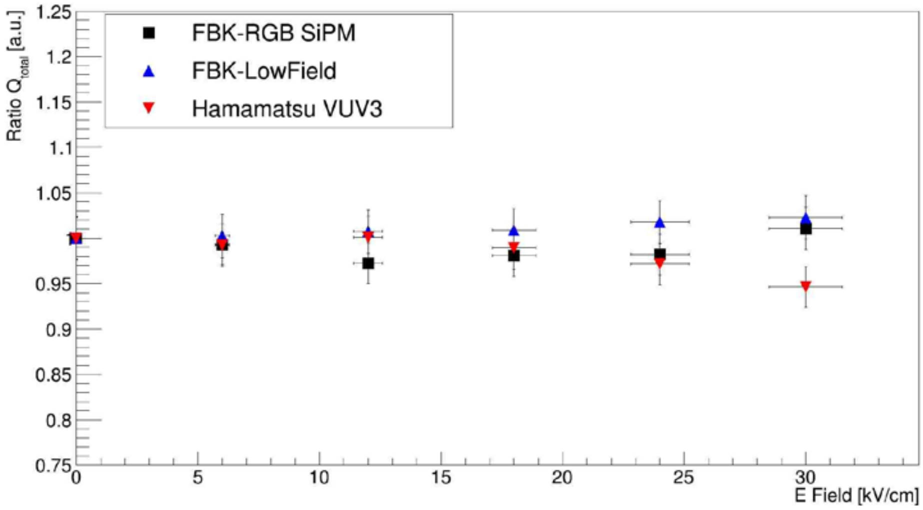

Fig. 2. The relative total charge as a function of E-field: FBK-RGB (black squares), FBK-LF (blue triangles) and Hamamatsu VUV3 (inversed red triangles).

3.2 Total charge vs HV for the data collected in dark

The relative total charge discussed in the previous section, includes the relative gain and the detection efficiency of each SiPM. At this stage, the two components are indistinguishable. Therefore, a study for the SiPMs performance in dark is essential, to examine their relative gains stability. Moreover, this examination provides direct picture on their detection efficiency stability at the different electric field values.

Figure 3 (top) shows the total charge as a function of electric field strengths, while the bottom figure shows the stability of the cross-talk probability. Both plots show excellent stability, within the statistical errors, of the SiPMs gain and correlated noise when they are exposed to different electric field values.

4 Conclusion

The results obtained from the HV tests show excellent stability in the different types of SiPMs performance when they are exposed to high electric field values up to 30 kV/cm. Also physical inspections were performed on the body of the SiPM chips. The SiPM chips used in these tests are bare chips except for the Hamamatsu one, which was in a special carrier made by the company. No evidences of strong discharges on the body of the chips were found, indicating that the SiPMs chips are safe to be used in the high electric fields environment.

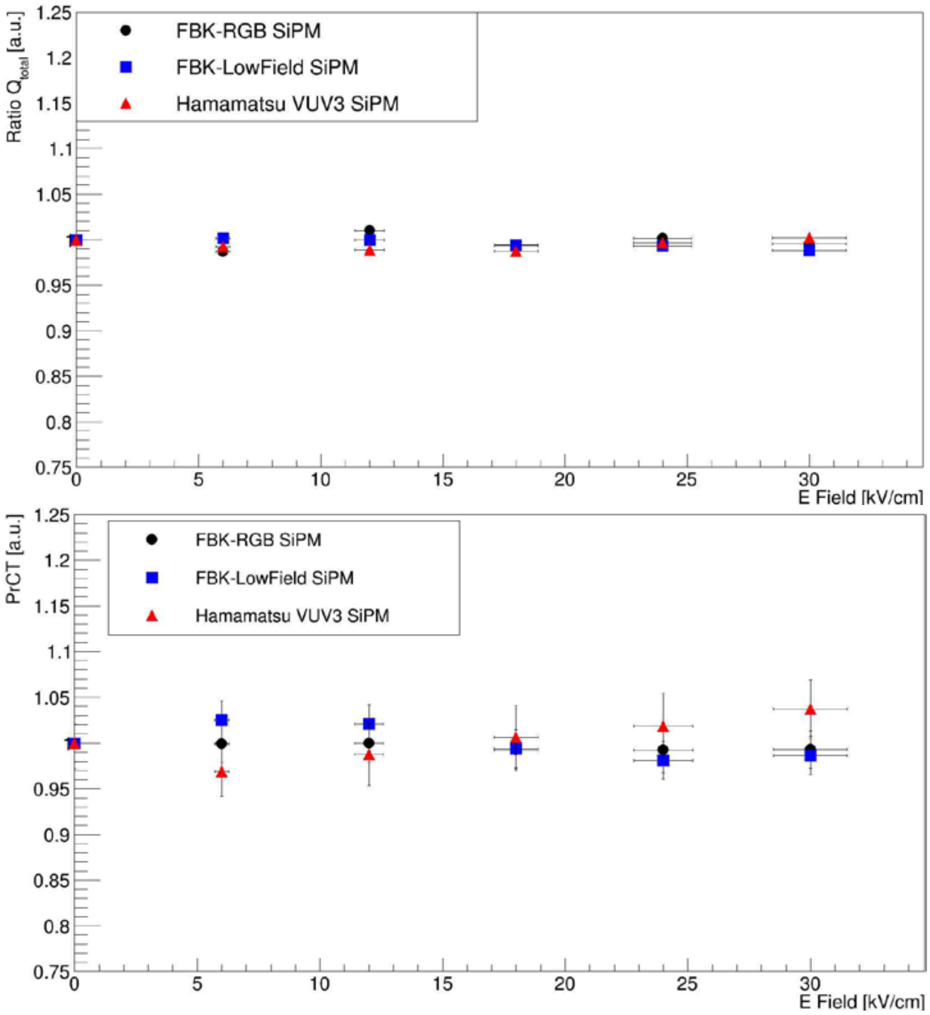

Fig. 3. (Top) relative total charge (relative gain) vs electric field strengths. (Bottom) cross-talk probablitlity vs electric field strengths.

References

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