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3x3 mm^2 SensL SiPM characterization for the New CHOD detector of the NA62 experiment at CERN

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The article presents the results of SensL SiPM characterization for the New CHOD detector in NA62 experiment at CERN. For each of 500 photosensors we have measured noise, gain and relative photon detection efficiency.

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1. Introduction

The main goal of NA62 experiment [1] is to study very rare kaon decays $K^+ \rightarrow \pi^+ \nu\tilde{\nu}$ with 10% precision. This decay mode is strongly suppressed in Standard Model (SM) and can be very precisely calculated in terms of SM parameters. Branching ratio of BR $(K^+ \rightarrow \pi^+ \nu\tilde{\nu}) = 7.81 \cdot 10^{-11}$ makes it sensitive for search New Physics beyond SM. A few candidates for the decay $K^+ \rightarrow \pi^+ \nu\tilde{\nu}$ have been observed in BNL experiments E787 and E949, but the error of measured branching ratio was too large – $BR(K^+ \rightarrow \pi^+ \nu\tilde{\nu}) = (17.3^{+11.5}_{-10.5}) \cdot 10^{-11}$ [2]. Only the measurement of the branching ratio with at least 10% accuracy can be a significant test of New Physics.

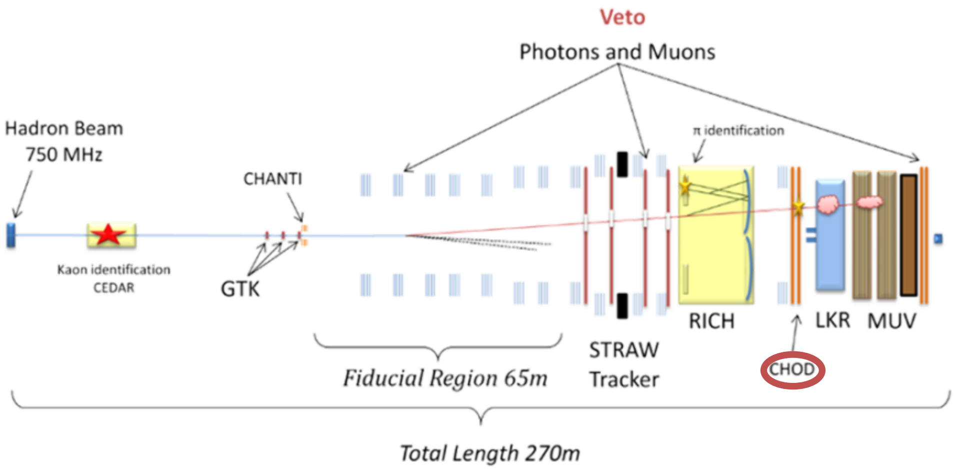

Figure 1. *Schematic view of the NA62 experiment*

The NA62 setup is comprised of many different detectors. One of them Charged-particle Hodoscope (CHOD) provides the rejection of enormous number of decays with muons. Segmented CHOD is made of plastic scintillator counters with pad structure covering the area around the beam pipe. CHOD is designed to define the aperture for charged particles for the level-0 trigger and to veto possible interactions in the RICH mirror plane (≈ 20% of radiation length).

Total number of counters is 148. Readout scheme is shown in Fig.2. Each 3 cm thick pad is read out with 16 wavelength shifting (WLS) fibers Kuraray Y11 of 1 mm diameter and four SensL SiPMs with the sensitive area of 3 x 3 mm^2 each. Each SiPM views four fibers combined in such a way to cover the whole surface of the scintillator. Pairs of SiPMs are connected in parallel so that two independent electronic channels composed of a pair of SiPMs are applied for each pad.

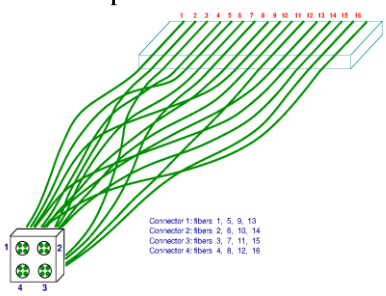

Figure 2. *Schematic view of the pad*

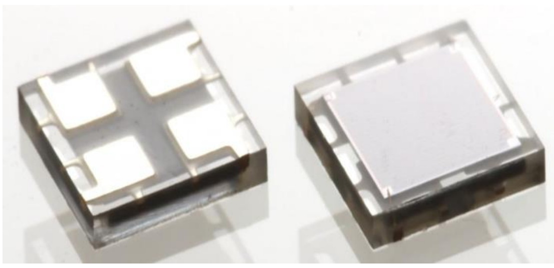

Figure 3. *SensL SiPMs MicroFC-30035-SMT*

2. SensL photosensor parameters

Front and back sides of SiPM MicroFC-30035-SMT [3] are shown in Fig. 3; the back side with electrical pads on the left and light sensitive face on the right. The device is manufactured in surface mounted package. The SiPM has 4774 pixels of 35x35μm^2 size, photon detection efficiency (PDE) is about 35% for green light according to SensL specification. Overvoltage is specified in 1-5 V range, bias voltage is set to 30 V as the operational parameter in our detector.

Before characterization of all 500 SiPMs we measured in details a few samples in relation to overvoltage. Fig. 4 shows the crosstalk level and dark rate vs overvoltage. The optical crosstalk probability is the probability that a fired pixel will initiate through secondary photons an avalanche in a neighboring pixel. Dark count rate is related to accidental pulses initiated by thermally generated electrons in SiPM p-n junction region. The PDE at 520 nm vs overvoltage is shown in Fig.5. The obtained value of PDE is smaller than specified in the SensL datasheet.

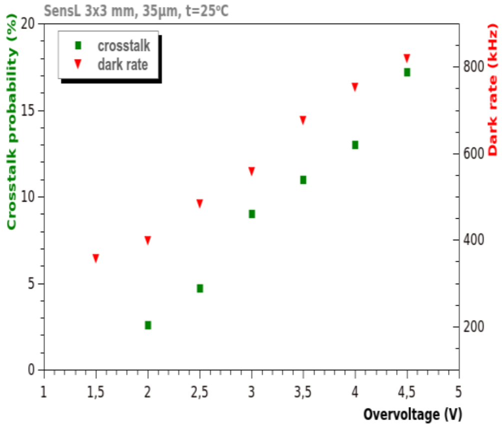

Figure 4. *Crosstalk level and dark rate vs overvoltage*

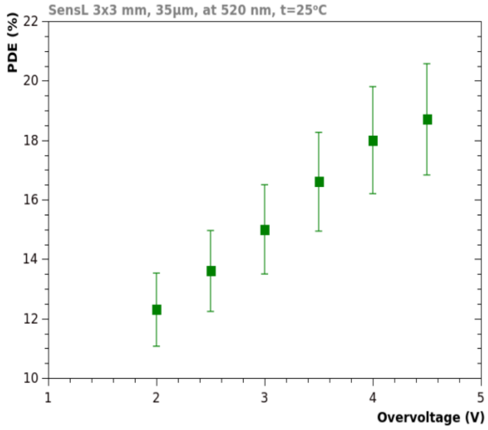

Figure 5. *PDE at 520 nm vs overvoltage*

3. Setup for measurements

All SiPMs were tested in a temperature controlled box using a green LED as a light source (see Fig. 6). Bias voltage was set to 30V as we plan to supply the same bias voltage for all photosensors in the experiment. Estimating the distribution of SiPM parameters at the same value of bias voltage was one of the goals for our measurements. The Relative gain, dark rate and the level of the crosstalk in SiPM were evaluated using a dark noise spectrum of a photosensor assuming Poisson distribution of photoelectrons (or more correctly avalanches) in the ADC spectrum.

The relative gain was measured as the average distance between the photoelectron peaks in charge spectrum. The dark rate F_{dark} was obtained by counting the number of events with no counts, or pedestal events, N_{ped}. Then the Poisson ratios give us the rate as

$$F_{dark} = -\frac{\ln\frac{N_{ped}}{N_{tot}}}{t},$$

where N_{tot} stands for the total number of events, and t for the ADC gate width which was 350 ns. From the dark noise rate measurement one can predict the fraction of events that should have one avalanche in the absence of crosstalk. The crosstalk effect changes the fraction of events with one avalanche so that counting the actual number of such events allows us to calculate the crosstalk probability.

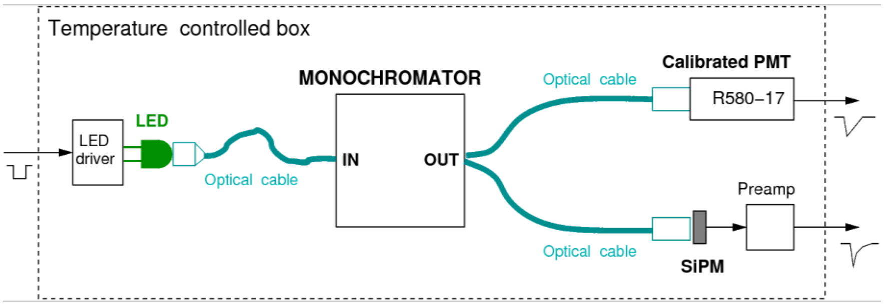

Figure 6. *Installation scheme for measurements of absolute PDE value*

For PDE measurement the LED generated 60 ns long light pulses sent to a monochromator. Selected wavelength is 520 nm to correspond the WLS fiber emission. The output light is splitted between two optical cables with the ratio close to 1:1, one cable is connected to a SiPM under test, and another cable is sent to a reference phototube. The cable ends are mounted into ferrules with the output apertures of a 0.5 mm diameter.

The reference photoreceiver is a calibrated Hamamatsu PMT R580-17 with a green-extended photocathode. The accuracy of PMT spectral calibration is estimated to be about 10%. The phototube measured the average number of photons from LED flashes, this number was adjusted to be less than 200. Then we can calculate the absolute value of PDE for tested SiPM. For characterization of 500 photosensors we measured SiPM responce to LED flashes without calibration using the PMT. The amplitude of the LED flash in photoelectrons was called as a relative PDE parameter.

Distributions of the measured parameters are presented in histograms in Fig. 7.

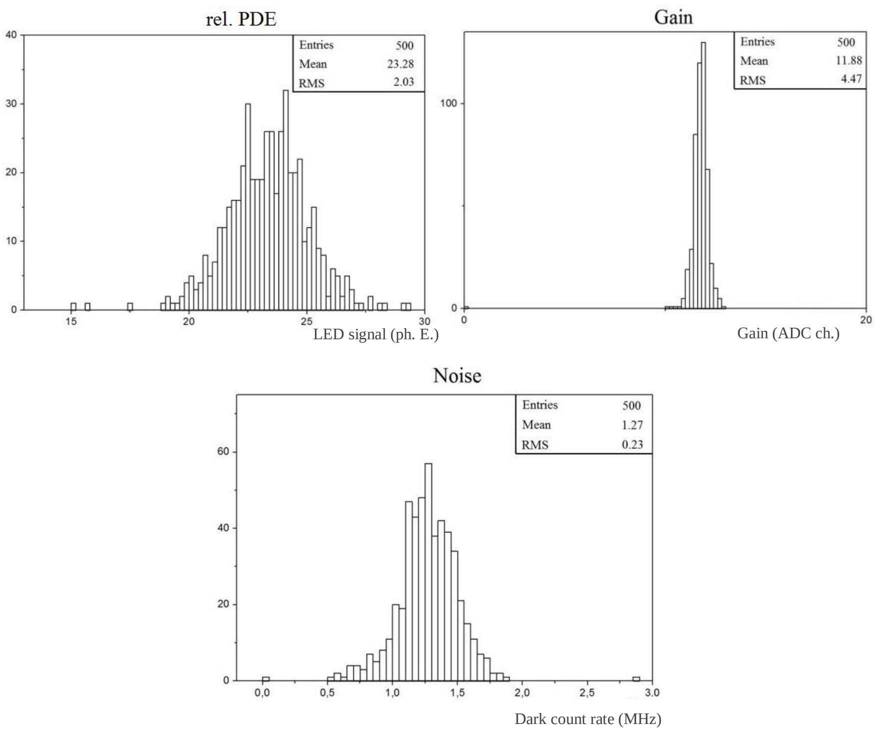

Figure 7. *Histograms of the relative Photon Detection Efficiency (PDE), gain and noise*

4. Conclusion

We have measured relative gain, relative PDE and noise at the same bias voltage for 500 SiPMs MicroFC-30035-SMT for the New CHOD detector of the NA62 experiment. We did not find broken devices. The distribution of parameters was within our specified limits except for two samples as can be seen in histograms above. We have performed measurements of absolute PDE for a few samples. PDE was found to be close to 20% at 520 nm and 4.5 V overvoltage that is notably lower than presented in SensL specification.

References

[1] F. Hahn et al, NA62 Technical Design Document, NA62-10-07 (2010).
[2] A. V. Artamonov et al. (E949 Collaboration), Phys. Rev. Lett. 101, 191802 (2008)
[3] SensL C-Series datasheet (2014). Available at: http://sensl.com/downloads/ds/DS-MicroCseries.pdf (accessed 28 September 2015).