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Evaluation of the optical cross talk level in the SiPMs adopted in ASTRI SST-2M Cherenkov Camera using EASIROC front-end electronics

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ABSTRACT: ASTRI (Astrofisica con Specchi a Tecnologia Replicante Italiana), is a flagship project of the Italian Ministry of Education, University and Research whose main goal is the design and construction of an end-to-end prototype of the Small Size of Telescopes of the Cherenkov Telescope Array. The prototype, named ASTRI SST-2M, will adopt a wide field dual mirror optical system in a Schwarzschild-Couder configuration to explore the VHE range of the electromagnetic spectrum. The camera at the focal plane is based on Silicon Photo-Multipliers detectors which is an innovative solution for the detection astronomical Cherenkov light.

This contribution reports some preliminary results on the evaluation of the optical cross talk level among the SiPM pixels foreseen for the ASTRI SST-2M camera.

KEYWORDS: Front-end; ASIC for SiPM; Front-end Electronics for Detector; Readout Analogue Electronics Circuits; Electronic Detector Readout Concepts; Trigger Concepts and Systems; Cherenkov Telescope.

Contents

1. Introduction **1**

2. EASIROC Front-End **2**

3. Experimental Setups **3**

4. Cross Talk for physical SiPM pixel **3**

4.1 Method 1: Cross Talk evaluation from the trigger chain 3

4.2 Method 2: Cross talk from pulse height distribution 4

5. Summary and Conclusion **5**

1. Introduction

ASTRI (Astrofisica con Specchi a Tecnologia Replicante Italiana) [1], is a flagship project of the Italian Ministry of Education, University and Research led by the Italian National Institute of Astrophysics, INAF. Primary goal of the ASTRI project is the design and construction of an end-to-end prototype of the of the small-size telescopes (SST) of the Cherenkov Telescope Array (CTA)[2]. The prototype, named ASTRI SST-2M, will adopt a wide field dual mirror optical system in a Schwarzschild-Couder configuration to explore the VHE range (1-100TeV) of the electromagnetic spectrum. The camera at the focal plane is based on Hamamatsu S11828-3344m[1] Silicon Photo-Multipliers detectors which is an innovative solution for the detection of Cherenkov light that requires high sensitivity in the 300-700nm band and fast temporal response [3]. Each SiPM is a 4×4 array of physical pixels that are grouped in 2×2 logical pixels of size of 0.17° in order to match the optics angular resolution (see Figure 1).

The SiPMs adopted for the ASTRI SST-2M camera will be read by the front-end CITIROC (Cherenkov Imaging Telescope Integrated Read Out Chip) whose precursor EASIROC (Extended Analogue Silicon Photo-Multiplier Integrated Read Out Chip) has been used to perform the measurements in this paper.

EASIROC is equipped with 32-channels each with the capability of measuring charge from 0.3 to 2000 photoelectrons.

To verify that the solutions adopted for the camera electronics and the choice of the detectors are compliant with the ASTRI SST-2M requirements, a number of tests were carried out at the INAF laboratories in Palermo and in Catania [3, 4, 5, 6, 7, 8]. In this paper we present some preliminary results on the evaluation of the optical cross talk level in the SiPM pixel array foreseen for the ASTRI SST-2M camera.

[1] http://www.hamamatsu.com/sp/hpe/HamamatsuNews/HEN111.pdf

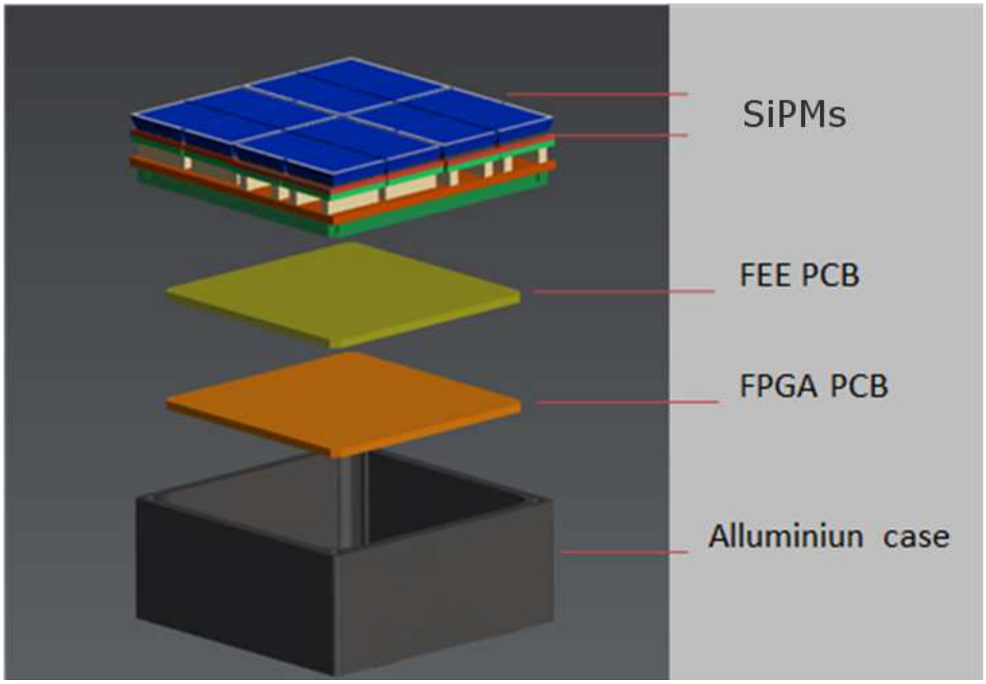

Figure 1. Exploded view of the PDM mechanical module.

2. EASIROC Front-End

EASIROC, precursor of CITIROC, was used to obtain a preliminary evaluation of the cross talk level in the SiPM adopted for the ASTRI SST-2M camera.

EASIROC [9] is a 32 channel fully analogue front end ASIC(Application Specific Integrated Circuit) dedicated to readout SiPM detectors specifically developed by the institute IN2P3-CNRS and the firm Omega Micro[2] (France). An Evaluation Board designed and realized by Omega Micro allows to test the functional characteristics and performance of the ASIC. Two separate chains, high and low gain respectively, are implemented in the ASIC in order to measure charge from 0.3 photo-electron (pe) up to 2000pe. Each of the two chains is composed by an adjustable gain preamplifier followed by a tunable shaper and a track and hold circuit. A shaping time of 50 ns has been adopted for both the low and high gain chain for the pulse height measurements. A third chain is implemented to generate a trigger using a fast shaper (15ns) followed by a discriminator with adjustable threshold set by a 10-bit DAC (Digital to Analog Converter) common to all 32 channels.

[2]http://omega.in2p3.fr

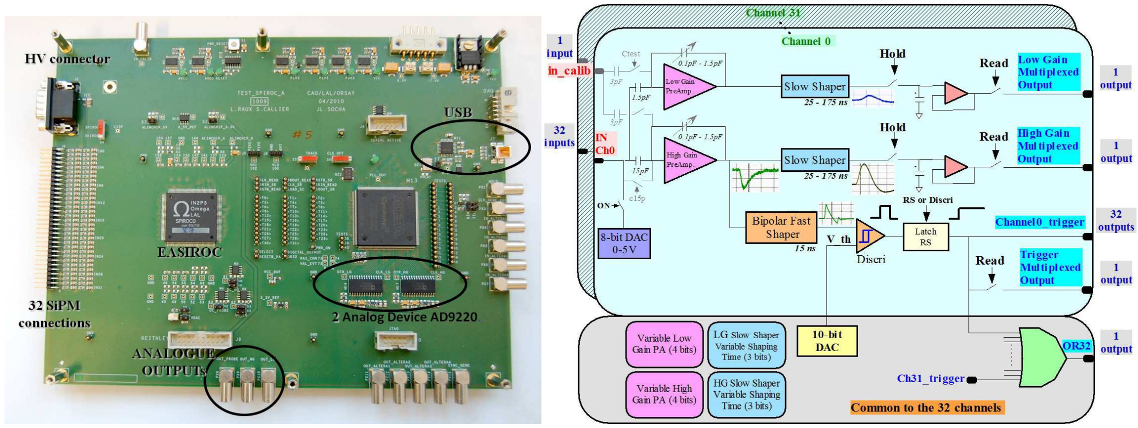

Figure 2. Architecture of the front-end EASIROC (Omega Micro courtesy)

3. Experimental Setups

In the measurements presented in this work, the physical SiPM pixel was directly connected to a channel of the ASIC; the over-voltage was set to 0.88V.

A LabView based software developed by the Omega Test group[3], provided with the evaluation board, implements all the required functions including ASIC configuration set-up and data taking.

Measurements were performed at room temperature ($\sim$24°C) without any temperature control.

4. Cross Talk for physical SiPM pixel

Two different methods were used to evaluate the SiPM cross talk level: the first method is based on a scan of the dark noise pulses at different trigger thresholds and the second one evaluates the cross talk from the pulse height distribution of the signal.

4.1 Method 1: Cross Talk evaluation from the trigger chain

This method is based on measurements of the trigger rate as a function of the discriminator threshold in dark noise regime [10]. Data were accumulated for 10s. The results are shown in the figure 3 where the characteristic staircase function is clearly evident: the count rate drops every time integer multiples of 1 pe are reached. The rate of the first plateau, that is relative to discriminator thresholds < 1pe, gives the total dark noise rate, that in our measurements is $\sim 9.8 \cdot 10^5$ Hz. Assuming a Poisson distribution, the probability to have two dark noise coincident events within a time window of 15ns is about 10^{-2}% (rate 100 Hz), negligible with respect to the dark rate measured. According to reference [10], the cross talk level is then evaluated from the ratio $P_c = \nu_{1.5pe}/\nu_{0.5pe}$, where the approximated values of $\nu_{0.5pe}$ and $\nu_{1.5pe}$ are taken from the point marked in the Figure 3 with the red arrows that are representative of the average values in the two plateaus. With these assumptions a cross talk probability of $\sim$ 24 % is obtained.

[3]http://www.lal.in2p3.fr/

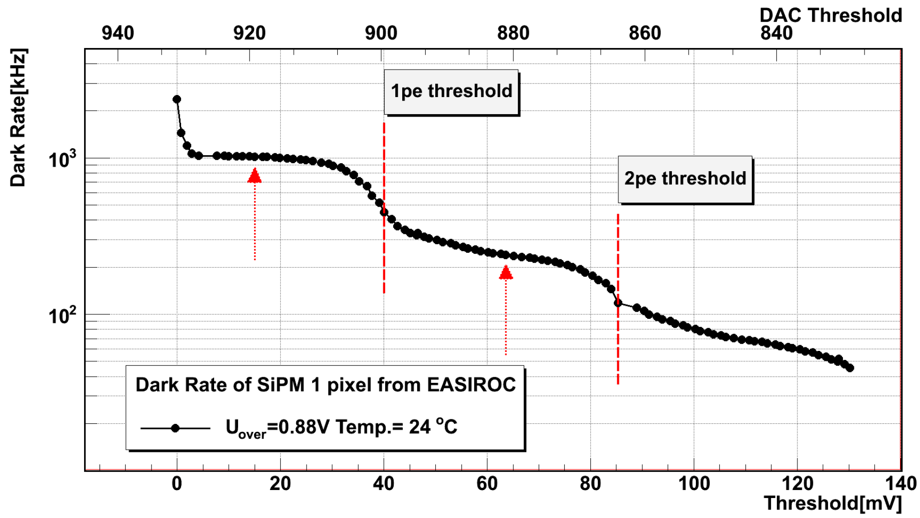

Figure 3. Thermal noise rate of a 1 pixel SiPM Hamamatsu S11828-3344m operated at an over-voltage of 0.88V as a function of the discriminator threshold. The red arrows indicate the threshold from where the cross level was computed (see text). The dashed red lines mark the threshold level relative to 1pe and 2pe.

4.2 Method 2: Cross talk from pulse height distribution

The dark count SiPM pulse height distribution was obtained using the High Gain electronics chain setting the shaping time to 50ns and collecting a number of events of $\sim 10^5$. These measurements include also the effects of the afterpulses that are not observed in the method 1 because of the shorter integration time. The results are shown in Figure 4, where the peak relative to the pedestal (0pe), 1pe , and 2pe are significantly resolved. We first evaluated the afterpulses contribution in the spectral interval between 1pe and 2pe. We fitted with a Gaussian the 1pe peak and found that it is well modeled with a sigma $\sim$4.4 ADC (Analog to Digital Converter) unit. To fit the event distribution relative to 2pe we fixed the sigma at the value 6.2 ADC($\sqrt{2} \cdot 4.4$), leaving free the other two parameters. The complete fitting model, continuous red line, is presented in figure 4. The afterpulse contribution $P_{afterpulse}$ in the 50ns shaping time window is obtained from the difference between the number of events detected in the spectral region bounded by the two red dashed lines and the integrated counts on the 2pe Gaussian fitted curve. We find that the afterpulse contribution is $P_{afterpulse} \cong 14\%$.

The distribution shows also the presence of an excess of counts in the higher ADC channel due to cross talk with multiple photo-electron($\geqslant 3$). Assuming that the contribution of the afterpulse is equal to the level measured between 1 and 2pe, we evaluated the total cross talk contribution from the following equation:

$$P_{crosstalk} = \frac{(1 - P_{afterpulse}) \times \sum_{k=910}^{1000} count_k}{\sum_{k=840}^{1000} count_k} \tag{4.1}$$

where $P_{crosstalk}$ is the cross talk probability, $count_k$ is the number of events for each ADC unit.

We find a cross talk value $\sim 22\%$.

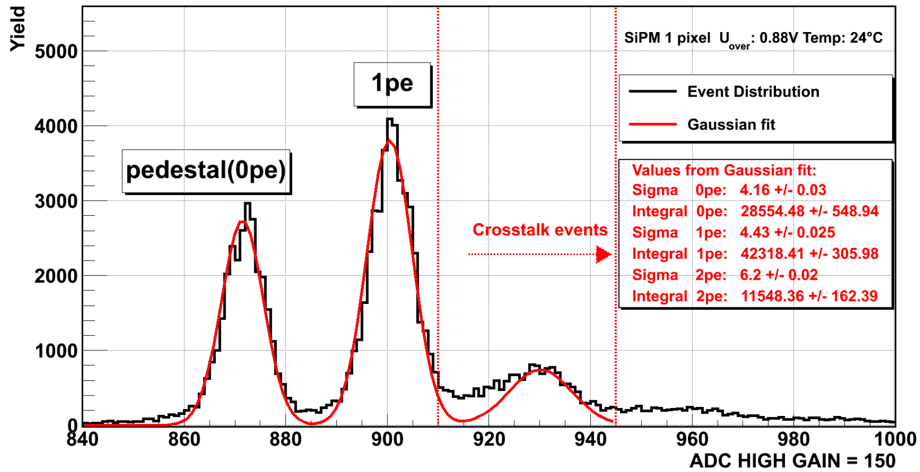

Figure 4. Sample charge histogram recorded for the uniformity scan measurement. The red line shows the fitting model.

5. Summary and Conclusion

In this paper we focused our attention in developing independent methods to evaluate the cross talk level. The measurements we presented were performed at room temperature without any temperature control among different SiPM pixel. The two methods considered for the investigation give comparable cross talk levels(22% – 24%).
The ASTRI SST-2M prototype will be tested on field in Italy: the installation is foreseen in 2014 at the INAF "M.G. Fracastoro"[11] observing station in Serra La Nave near Catania. The camera will operate at the controlled temperature of about 15°C and more extensive tests and measurements are in progress to evaluate the cross talk level in real operating condition. Cross talk is a characteristic feature of the SiPM technology adopted. The new generation of SiPMs show a cross talk level of a few percent.

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