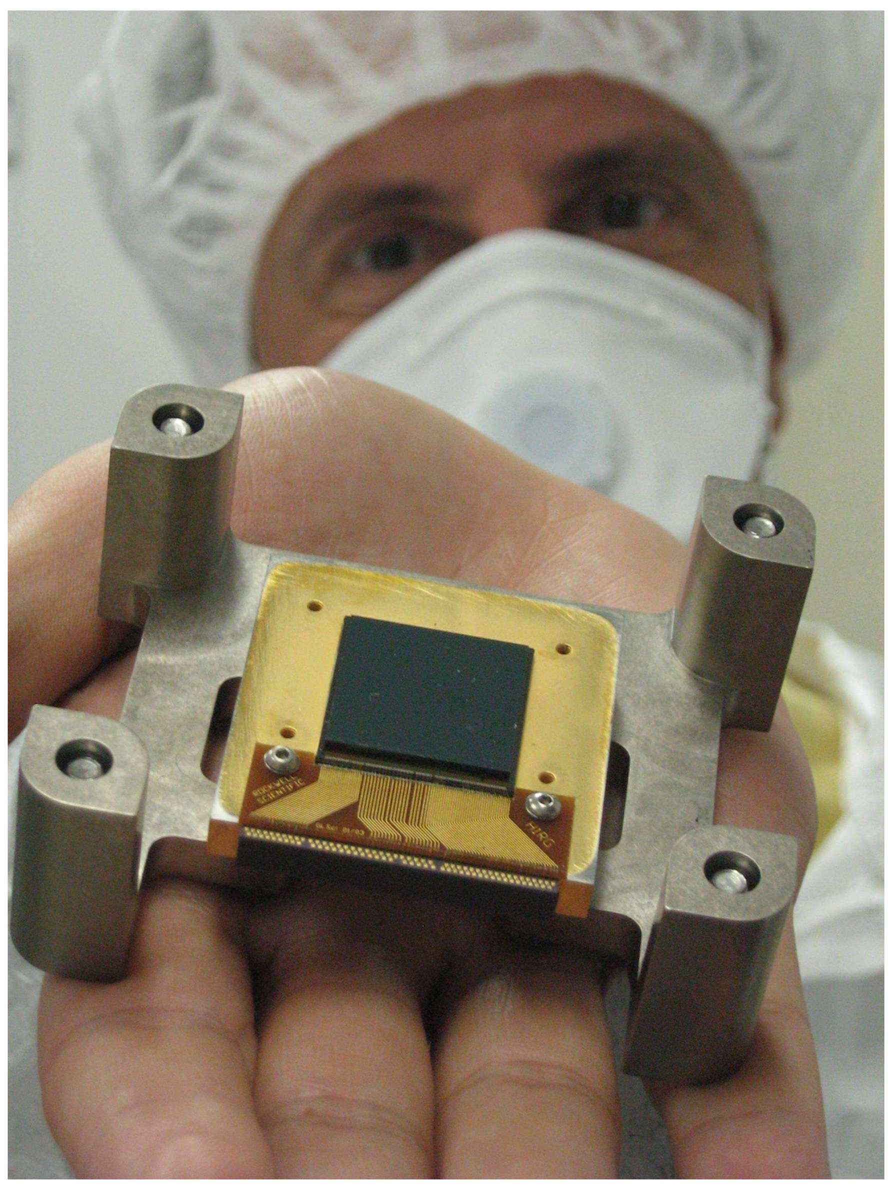

Measurement of the Non-linearity and Interpixel Capacitance of a H2RG Detector

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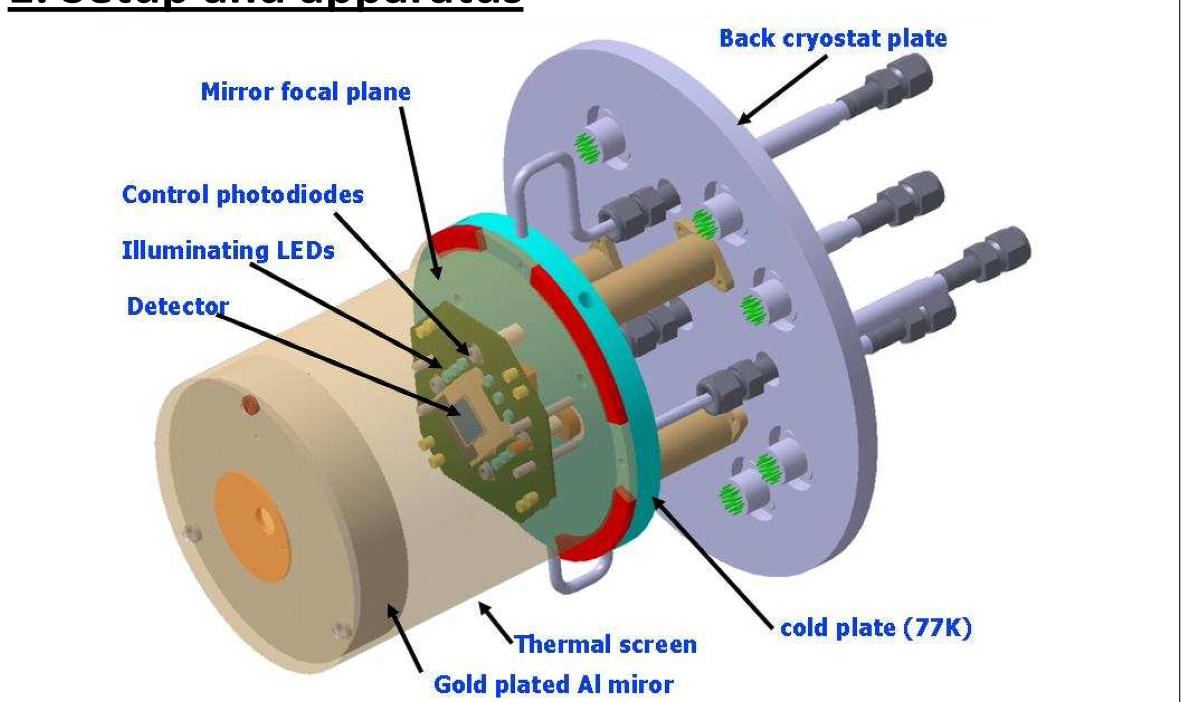
A temporal analysis of the noise of a H2RG detector is performed in view of the calibrationof a dedicated setup. The implication on the noise performance of the subtraction of the reference output is described, and we extend the correlation method to groups of several pixels to derive the ratio x of the interpixel capacitance to the pixel capacitance of a detector.

We find x = -0.0259 ±0.0017 (stat) ± 0.0020 (syst)

All measurements are consistent to a sub-percent accuracy.

1. Setup and apparatus



To implement the detector tests described here, a dedicated cryostat was built in-house.

Cryostat specifications :

- Temperature range 100K< T < 160K
- Temperature fluctuations < 0.1K at equilibrium

Cryostat instrumentation :

- Several LED's around the detector
- Gold coated mirror allowing flat fields illumination
- Photodiodes to control flux and flat

The acquisition system is based on the architecture, where each sensor is connected to an Ethernet Network. The main component is the mezzanine board, which includes a 32 bit RISC microprocessor with a linux operating system. The generic design of the Mezzanine board allows its use in many different applications.

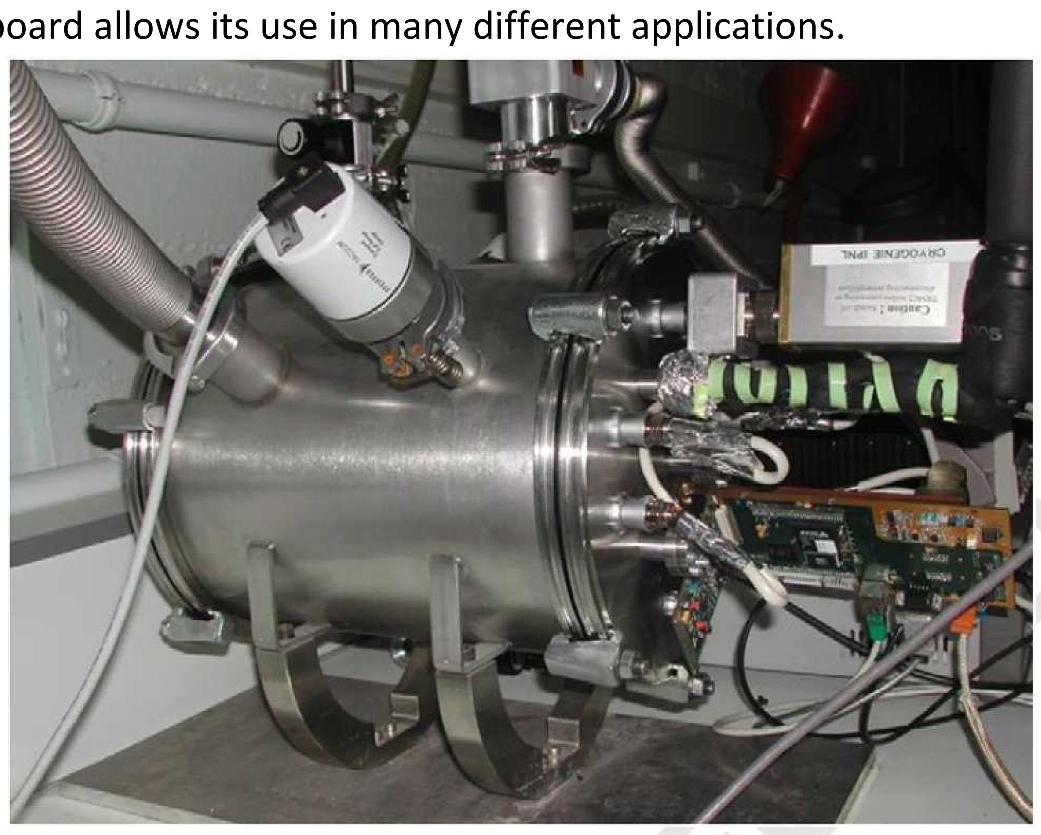
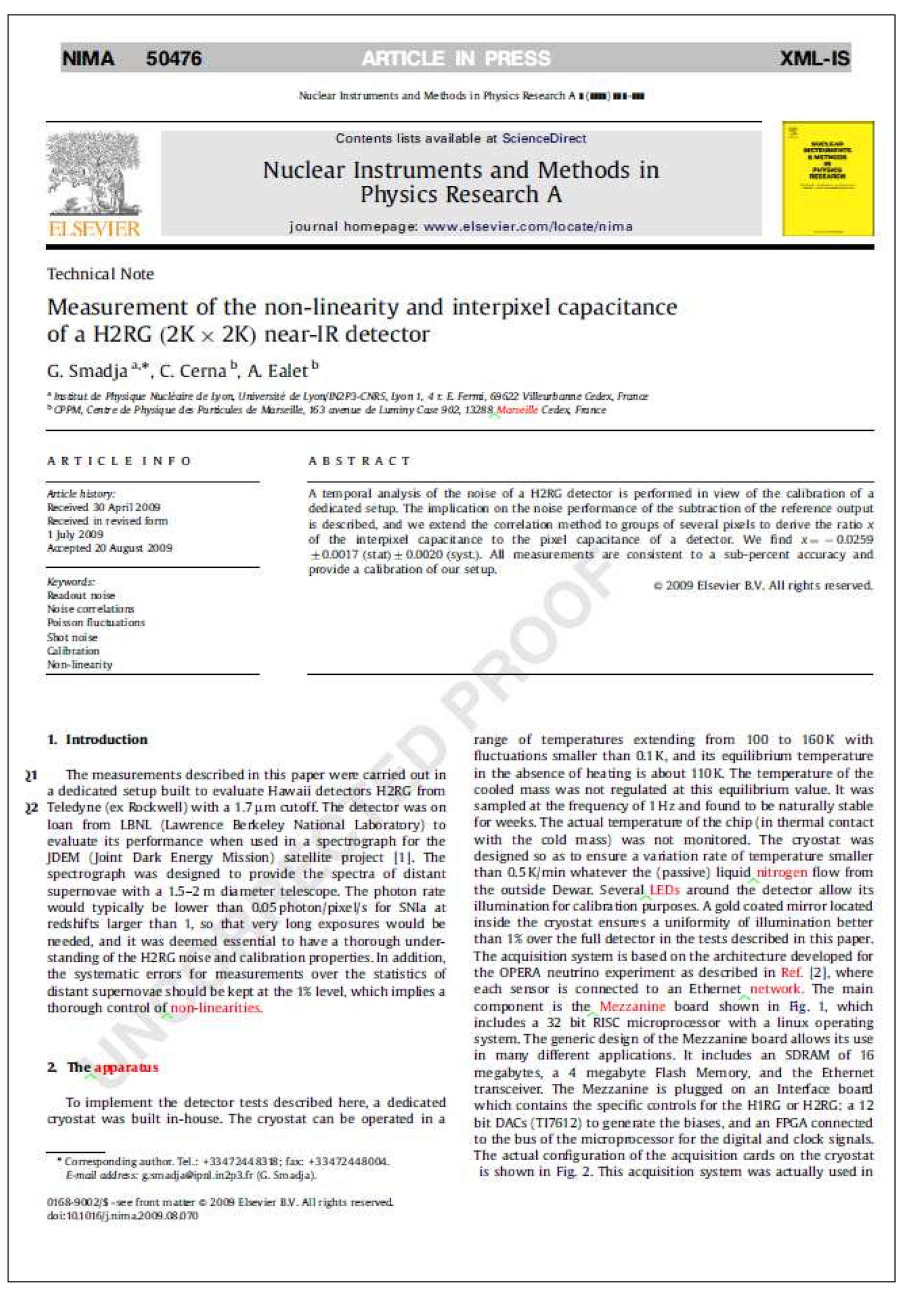


Fig. 2. Cryostat with the readout cards. The cryostat is cooled by liquid N2 from a 201 Dewar, providing an autonomy of 35 h. LEDs inside the cryostat allow a uniform illumination for calibration purposes.



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Technical Note

Measurement of the non-linearity and interpixel capacitance of a H2RG (2K × 2K) near-IR detector

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ABSTRACT

A temporal analysis of the noise of a H2RG detector is performed in view of the calibration of a dedicated setup. The implication on the noise performance of the subtraction of the reference output is described, and we extend the correlation method to groups of several pixels to derive the ratio x of the interpixel capacitance to the pixel capacitance of a detector. We find $x = -0.0259 \pm 0.0017$ (stat) ± 0.0020 (syst.). All measurements are consistent to a sub-percent accuracy and provide a calibration of our setup.

1. Introduction

Q1 The measurements described in this paper were carried out in a dedicated setup built to evaluate Hawaii detectors H2RG from Q2 Teledyne (ex Rockwell) with a 1.7 μm cutoff. The detector was on loan from LBNL (Lawrence Berkeley National Laboratory) to evaluate its performance when used in a spectrograph for the JDEM (Joint Dark Energy Mission) satellite project [1]. The spectrograph was designed to provide the spectra of distant supernovae with a 1.5–2 m diameter telescope. The photon rate would typically be lower than 0.05 photon/pixel/s for SNIa at redshifts larger than 1, so that very long exposures would be needed, and it was deemed essential to have a thorough understanding of the H2RG noise and calibration properties. In addition, the systematic errors for measurements over the statistics of distant supernovae should be kept at the 1% level, which implies a thorough control of non-linearities.

2. The apparatus

To implement the detector tests described here, a dedicated cryostat was built in-house. The cryostat can be operated in a range of temperatures extending from 100 to 160 K with fluctuations smaller than 0.1 K, and its equilibrium temperature in the absence of heating is about 110 K. The temperature of the cooled mass was not regulated at this equilibrium value. It was sampled at the frequency of 1 Hz and found to be naturally stable for weeks. The actual temperature of the chip (in thermal contact with the cold mass) was not monitored. The cryostat was designed so as to ensure a variation rate of temperature smaller than 0.5 K/min whatever the (passive) liquid nitrogen flow from the outside Dewar. Several LEDs around the detector allow its illumination for calibration purposes. A gold coated mirror located inside the cryostat ensures a uniformity of illumination better than 1% over the full detector in the tests described in this paper. The acquisition system is based on the architecture developed for the OPERA neutrino experiment as described in Ref. [2], where each sensor is connected to an Ethernet network. The main component is the Mezzanine board shown in Fig. 1, which includes a 32 bit RISC microprocessor with a linux operating system. The generic design of the Mezzanine board allows its use in many different applications. It includes an SDRAM of 16 megabytes, a 4 megabyte Flash Memory, and the Ethernet transceiver. The Mezzanine is plugged on an Interface board which contains the specific controls for the H1RG or H2RG: a 12 bit DACs (TI7612) to generate the biases, and an FPGA connected to the bus of the microprocessor for the digital and clock signals. The actual configuration of the acquisition cards on the cryostat is shown in Fig. 2. This acquisition system was actually used in

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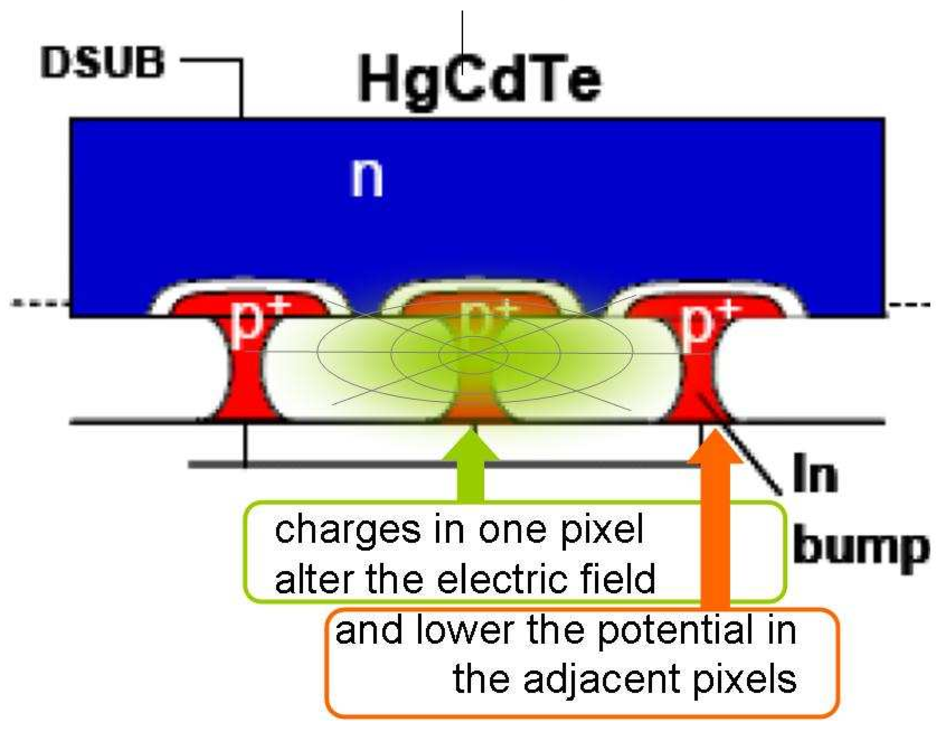
2. Calibration scheme

The method proposed here is a variant where the emphasis is on a redundant determination of the interpixel capacitance using groups of pixels, and a temporal analysis of the LED signal is performed, as would occur in an actual flux measurement. As the sensitivity of the result to common mode noise is an issue in correlation measurements, we compute the expected noise for groups of pixels, taking into account the presence of interpixel capacitance.

-> Influence Matrix between pixels



The charge in pixel i of a multipixel detector is also dependent on the voltage in pixel j, and the relation is given by the electrostatic influence matrix.

$$\Delta Q_i = C_{ij}\Delta V_j$$ So that : $$\delta V_j = (C)^{-1}_{ij}\,\delta Q_i$$

-> single pixel noise

Considering a pixel and its four neighbors, one can write C_{ij} as :

$$C_{ij} = C_0\begin{pmatrix} 1 & x & x & x & x \\ x & 1 & 0 & 0 & 0 \\ x & 0 & 1 & 0 & 0 \\ x & 0 & 0 & 1 & 0 \\ x & 0 & 0 & 0 & 1 \end{pmatrix}$$

Where C_0 is the pixel capacitance, and $x = C_{ij}/C_{ii} = C_{ij}/C_0$ is also called the interpixel capacitance.

Considering that x is small it is then possible to invert C_{ij} at the first order substituting x by $-x$

Under a uniform illumination, all fluences are equal. The shot noise in pixel i can be derived from the Poisson fluctuation in the pixels and be the writen as :

$$\langle(\delta_0)^2\rangle = \frac{kq}{C_0(1-4x)}\Delta A_0 = s_1\Delta A_0.$$

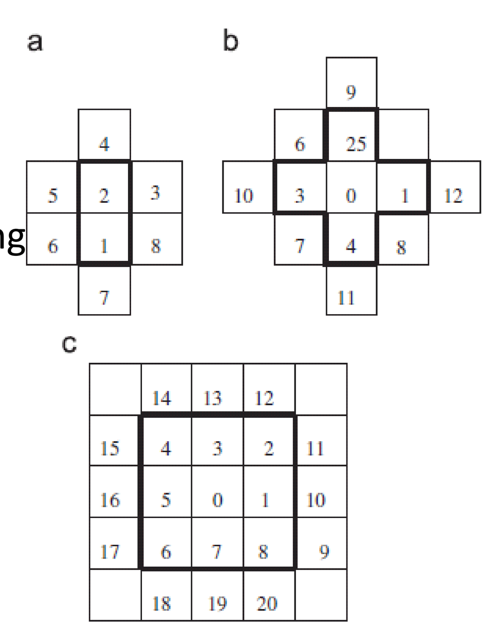
A noise reduction is obtained when the reference output (which monitors the variations of the bias level) is subtracted, and the sensitivity to common mode noise is reduced. The 'up the ramp' readouts were split between several 'bursts' of 'frame' acquisitions performed at the clock frequency (100 kHz) and separated by an adjustable time. The number of frames in each burst varied between 60 and 15, depending on the illumination.

The experimental results is shown on the *variance versus fluence* figure as the *single pixel* curve.

-> multi-pixel analysis

The previous formulae allow us to measure the ratio $x = C_{ij}/C_0$ by comparing the relation between noise and fluence for groups of pixels, as this changes the weight of the contribution of the neighbouring pixels.

The figure shows the contours of the pixels groups considered in this study.



The 2 pixels groups

A 8x8 capacitance matrix C should be considered and inverted exactly under the same assumptions as in the single pixel case (x small & first order only). The fluctuation for for pairs of pixels can then be found to be :

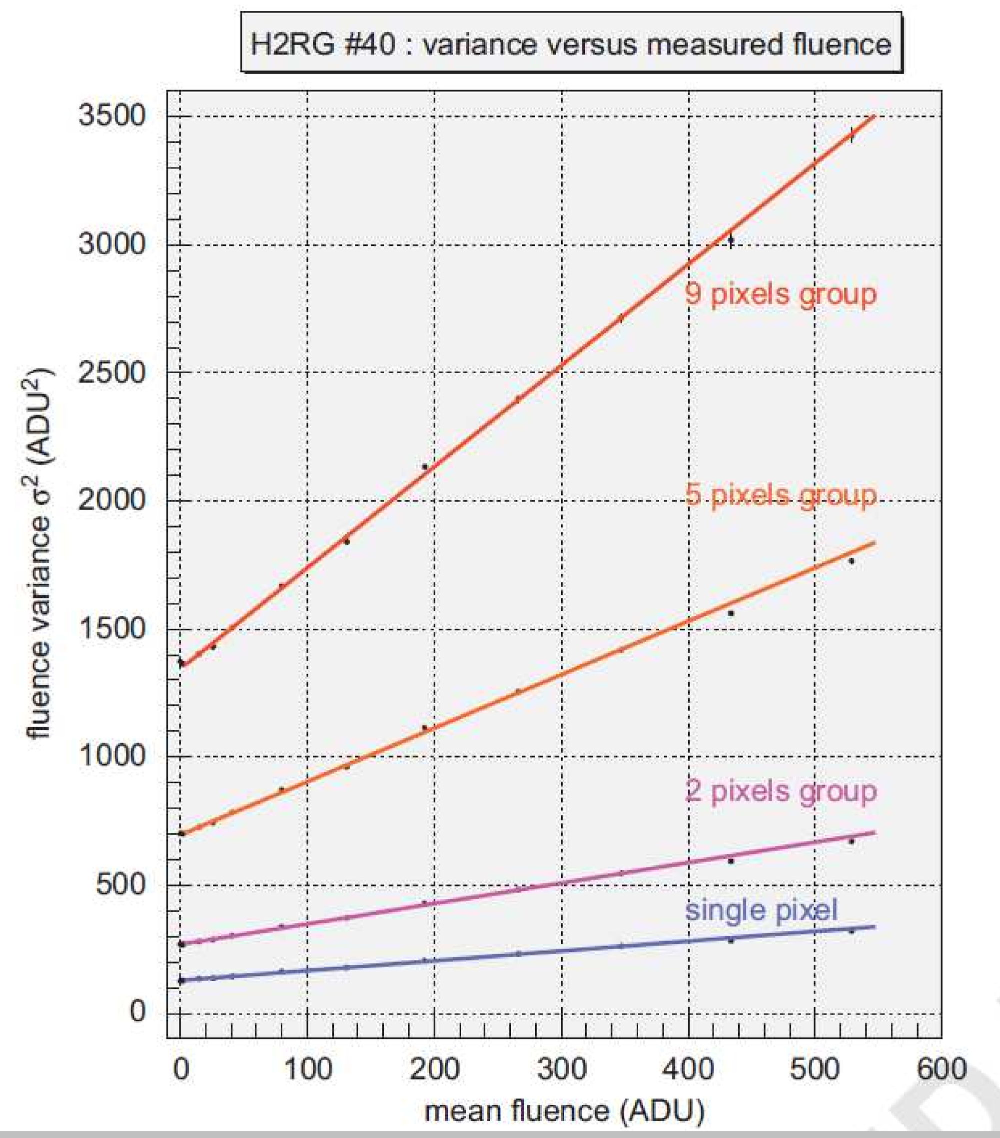
$$(\delta_2)^2 = 2\frac{kq}{C_0(1-4x)}(1-2x+4x^2)\Delta A_0.$$

5 and 9 pixels groups

In the same way we find for the 5 and 9 pixels groups :

$$(\delta_5)^2 = \left(\frac{kq}{C_0}\right)\frac{5-16x+40x^2}{1-4x}\Delta A_0. \qquad \delta_9^2 = \frac{kq}{C_0}\frac{9-48x+80x^2}{1-4x}\Delta A_0.$$

All the experimental measurements are reported on the figure below :



The three slopes ratio s9/s1, s5/s1 and s2/s1 give us a redundant evaluation of x :

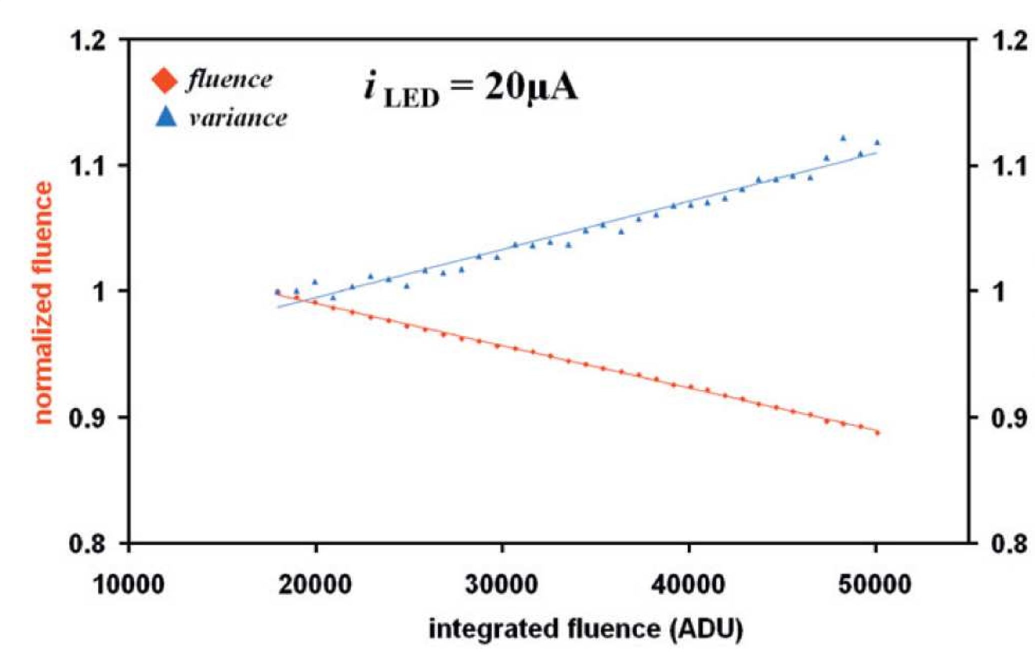
$$x = \frac{C_{int}}{C_0} = -0.0259 \pm 0.0017\ (\mathrm{stat}) \pm 0.0020\ (\mathrm{syst}).$$

The (single pixel) conversion factor can now be obtained as

$$f_1 = \frac{\Delta Q_0}{\Delta ADC_0} = \frac{1}{s_1(1-4x)^2} = 2.042(e/\mathrm{ADU})$$

3. Output FET non-linearities

We observes that the ADC level between 2 frames, proportional to dADC/dt, compared to the integrated ADC signal follow a proportional law. The fluence should be constant if the detector were linear. The slopes of the variance and of the fluence correspond to a similar and opposite relative variation.



A change of the tranconductance of the output fet could account for such a variation: the slope of the variance (from the larger thermal noise) would then be correlated to the apparent decrease of the fluence with the same ADC level, as observed.