Camera Performances Spacification and Evaluation

RIPTIDE meeting 20/03/2024

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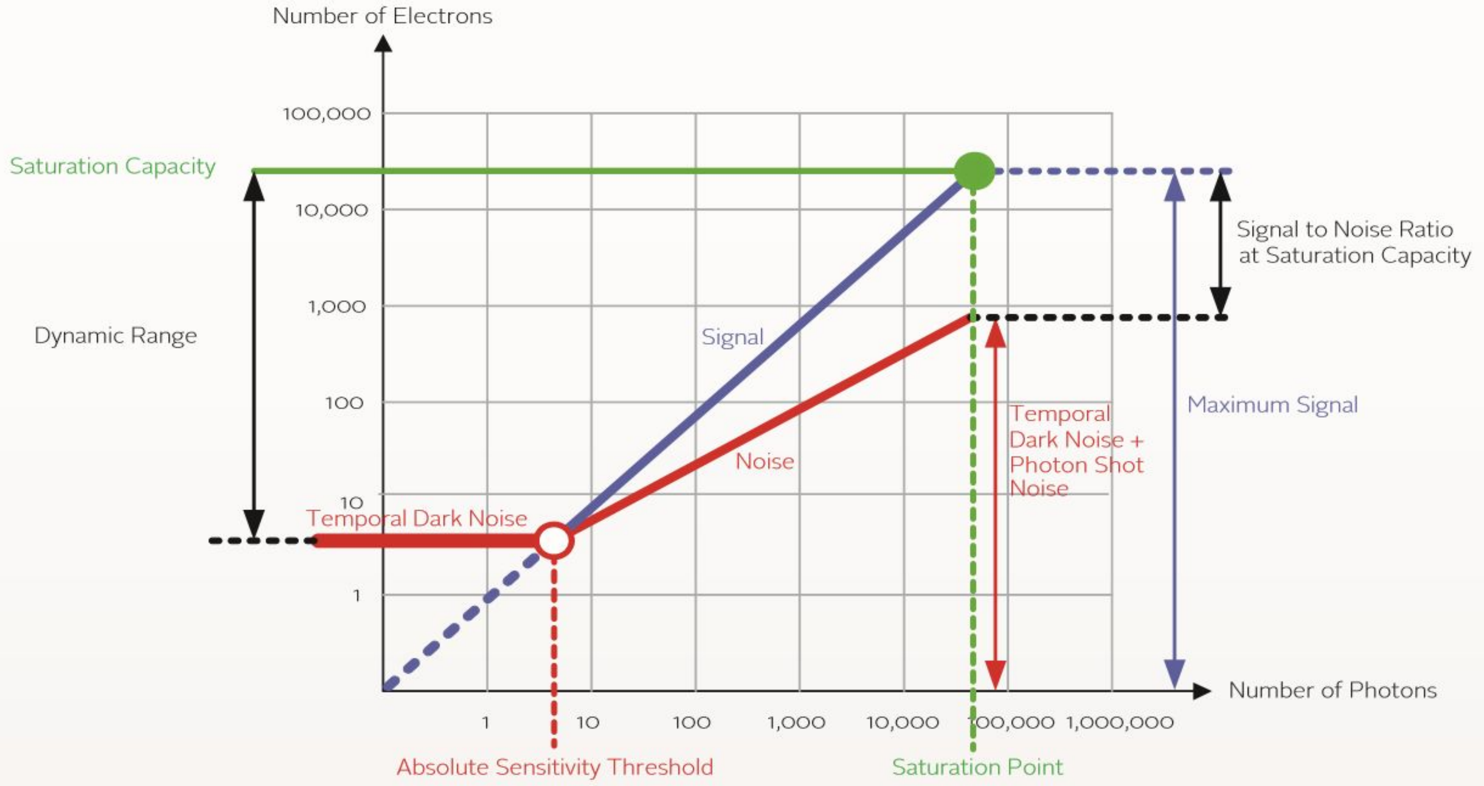
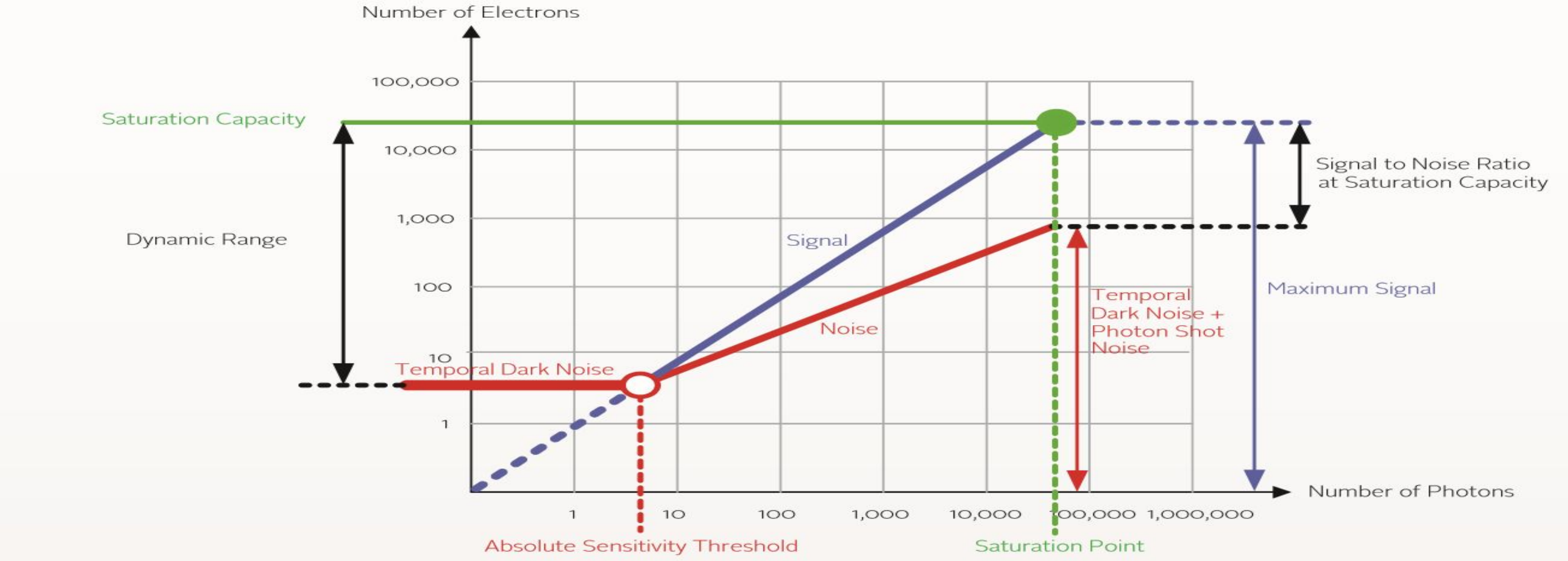
Description of Characteristic EMVA 1288 Values

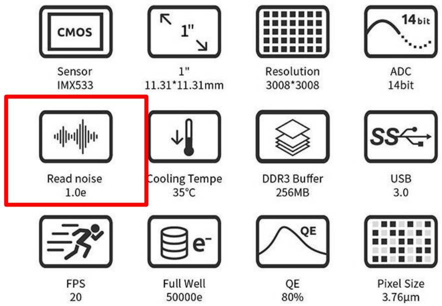


Description of Characteristic EMVA 1288 Values



- **Absolute Sensitivity Threshold**: The smallest detectable amount of light. Expressed in number of electrons. The point where signal equals temporal dark noise. This is important to understanding low light performance!
- **Photon Shot Noise:** Signal noise equal to the square root of the incoming photons. Due to the randomly distributed particle nature of light.
- **Temporal Dark Noise:** Noise when no light is hitting the sensor, also known as read noise. Due to electric dark current, quantization noise, and other noise sources depending on the specific construction of the sensor and the camera electronics.
- **Saturation Capacity:** The maximum number of electrons each pixel can hold before reaching non-linear response.
- **Dynamic Range**: Ratio of maximum signal (saturation capacity) to the minimum signal (temporal dark noise)
- **Signal to Noise at Saturation:** Ratio of the maximum signal (saturation capacity) to noise (photon shot noise). At saturation, temporal dark noise is insignificant compared to photon shot noise and can be ignored.

IMX533 Sony Sensor



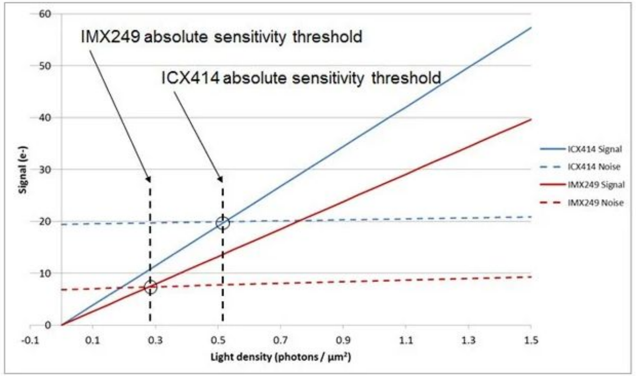
LUX19HS (Alexima) Global Shutter CMOS

System Gain*	68 e-/DN
Temporal dark noise*	32 e-
Signal-to-Noise Ratio*	42 dB
Absolute sensitivity threshold*	38 e-
Saturation Capacity*	43700 ph
Dynamic Range*	52 dB

EMVA1288 measurements (v3.1 typ. preliminary)

Dynamic range	TBD dB
Saturation capacity	15 000 e⁻
Temporal dark noise	10 e⁻
System gain	15 e⁻/DN
Signal-to-Noise Ratio	50 dB

IMX533 Sony Sensor



IMX249 will reach absolute sensitivity threshold at a lower light density and thus will perform better in lower light applications.

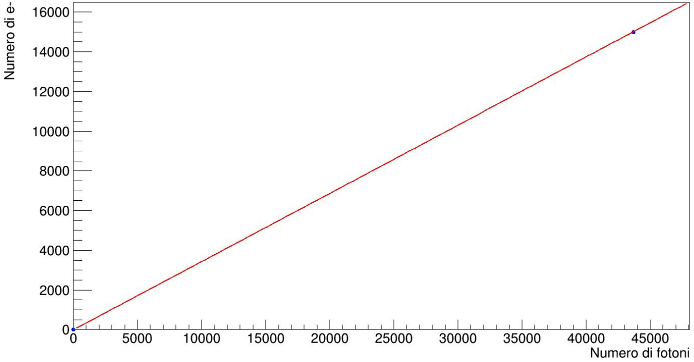
https://www.baslerweb.com/en/learning/cmos-sensor-selection/

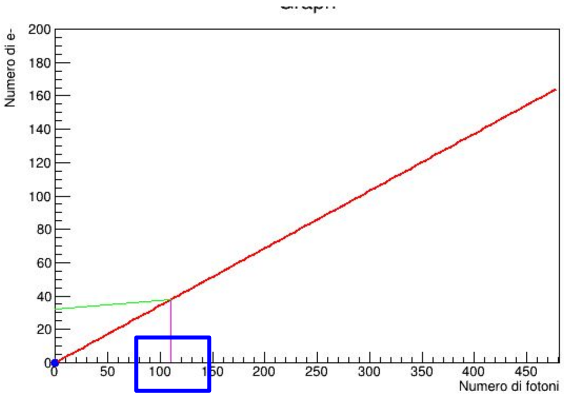
Sensitivity threshold

The effects of this can be seen by comparing the absolute sensitivity threshold, which is defined in the EMVA1288 standard. This indicates how much light, i.e. photons, the sensors need on average to generate a signal that stands out sufficiently from the noise. This value is 10 for first-generation Pregius sensors, while second-generation Pregius models achieve a value of 3 and STARVIS sensors achieve a value of 4.

	STARVIS	Pregius 1st gen	Pregius 2nd gen
Absolute sensitivity threshold	4	10	3

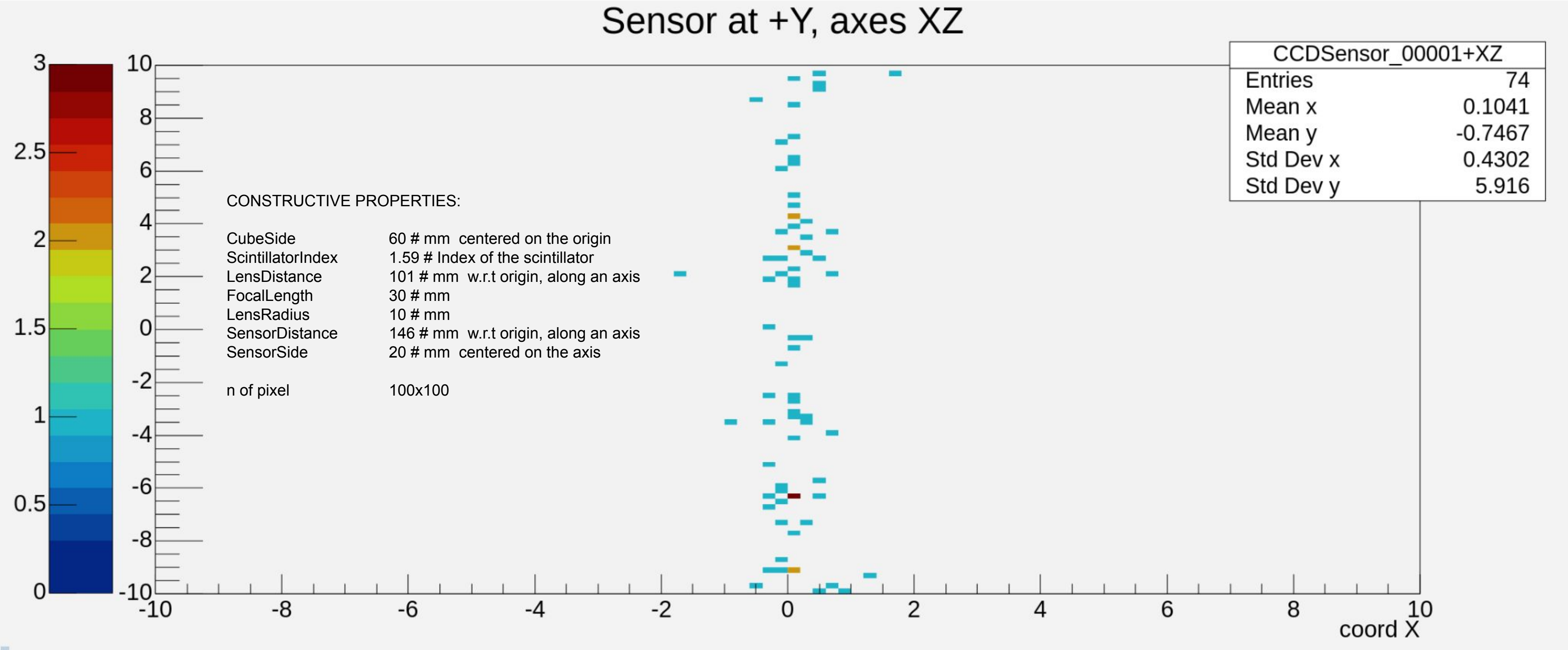
LUX19HS (Alexima) Global Shutter CMOS





Impossible to see muons...

mu+
source position: [0,0,30] cm
particle direction: [0,0,-1]
energy: 4 GeV



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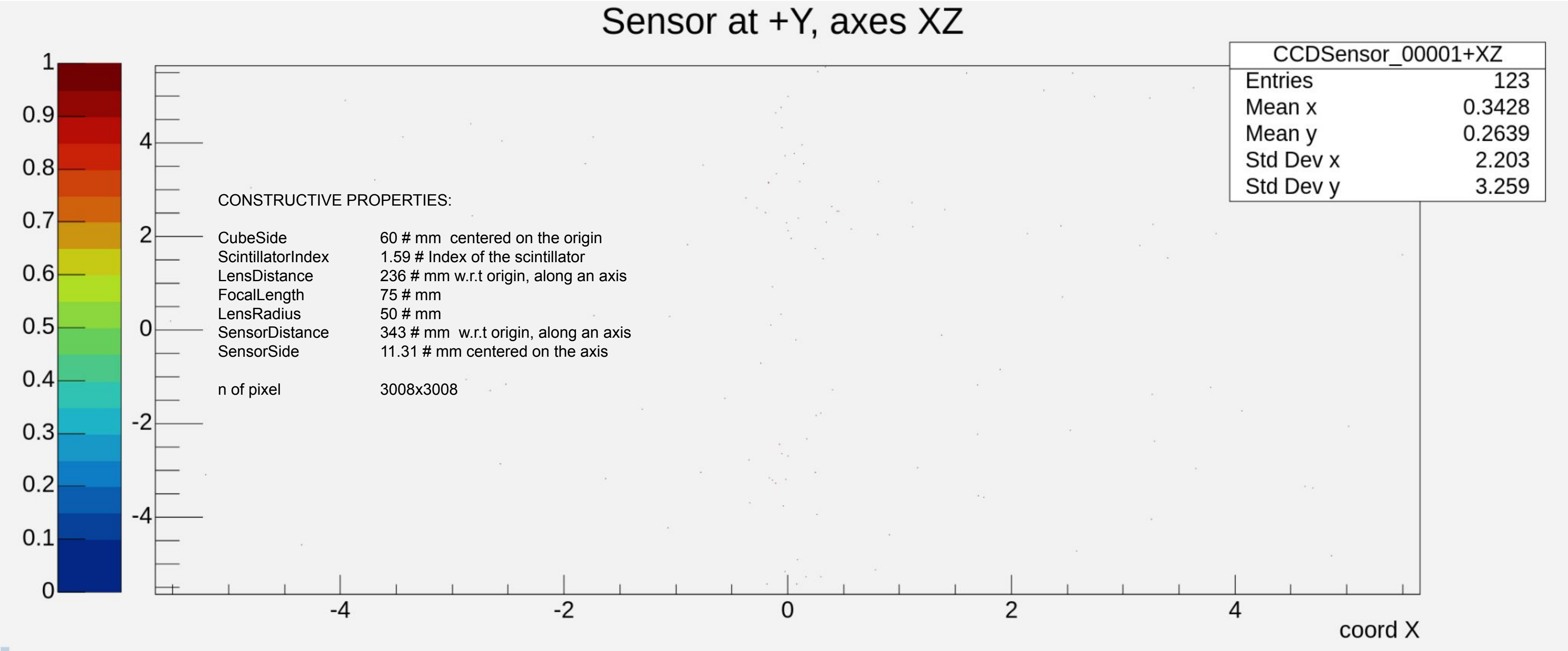
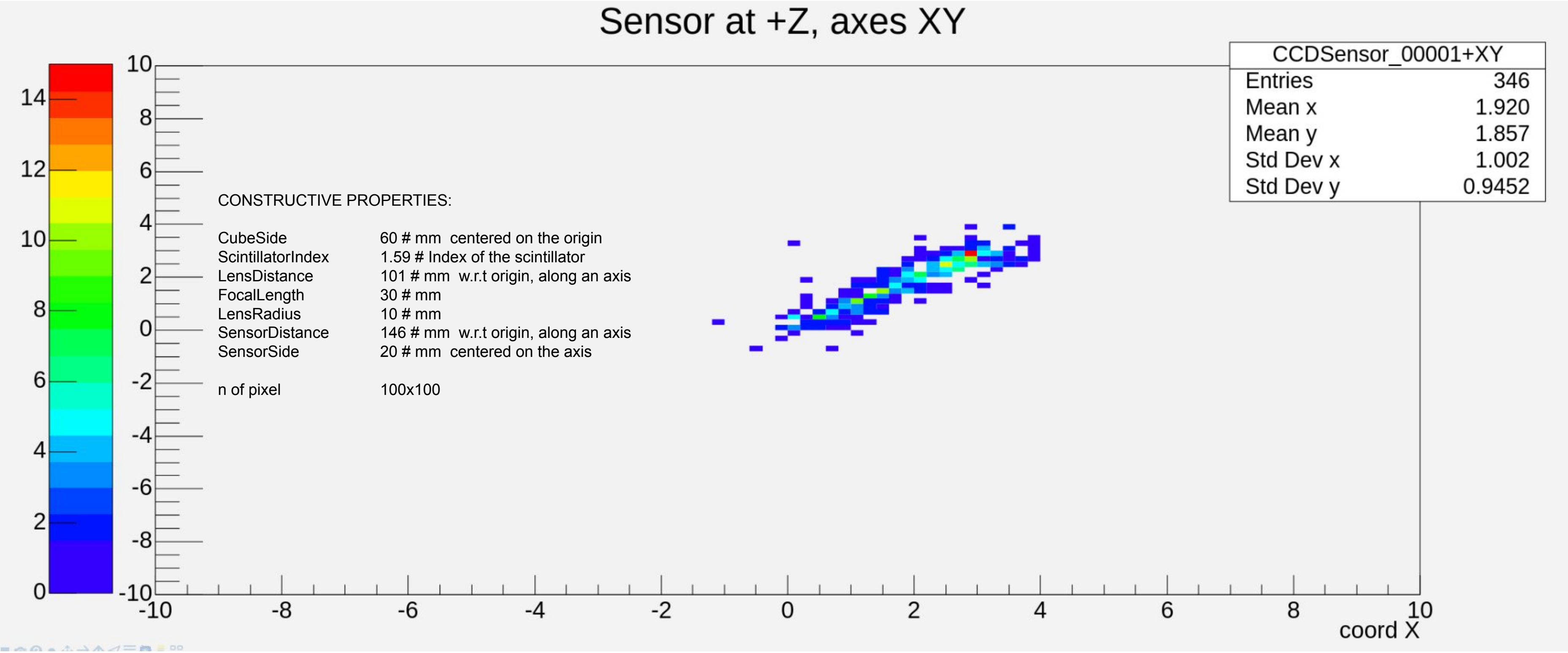


... and Protons ?

proton
source position: [0,0,0] cm
particle direction: [-1,-1,0]
energy: 30MeV



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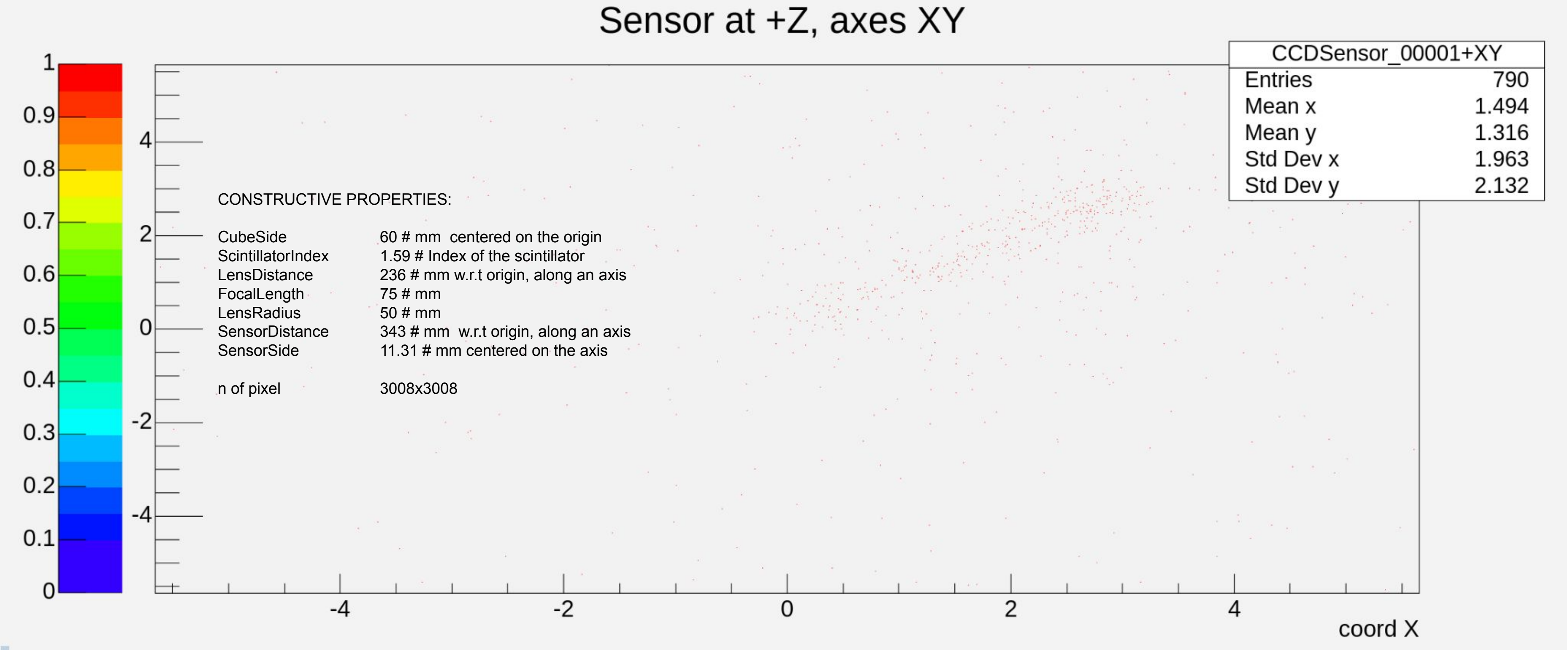

Possible Solutions

Image Intensifier (10^4-10^6 gain)

Better performing sensors...

0.27 electrons rms (@Ultra quiet scan)

Specifying machine vision terminology

Exposure time: the time span for which a sensor is exposed to the light so as to record a picture.

Quantum efficiency: how many photons are traducted into electrons

System Gain: represent the number of gray levels that each photoelectron is converted to. [e-/GL]

EM-Gain: an additional mechanism to multiply the number of photoelectrons generated from incident photons.

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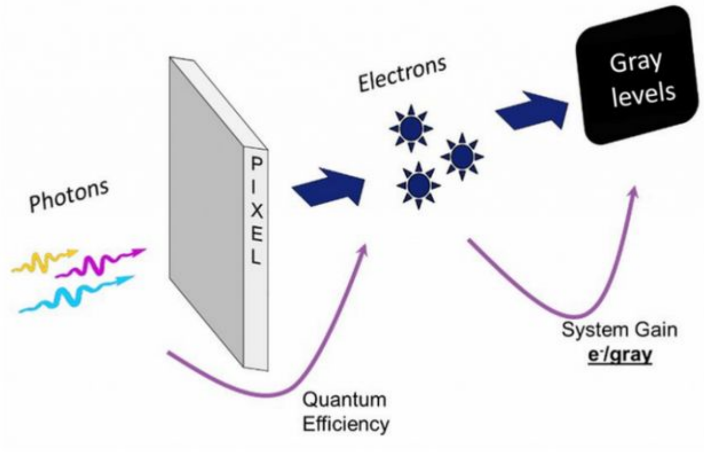

Figure 1: Diagrammatic representation of how photons are converted to gray levels on a scientific camera.

https://www.photometrics.com/learn/white-papers/photons-electron-and-gray-levels

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Readout Noise: includes pixel noise, circuit noise, and ADC quantization noise.

Dark current: noise caused by thermally generated electrons

Bias: offset

Signal in grey level: output of the camera pixel per pixel (due to AD conversion)

Signal in electrons: signal should be quantified in photoelectrons as these are real world values for intensity measurement that allow for consistent signal representation across all cameras.

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$$\text{Read Noise} + \text{Dark current} = \frac{\text{Standard deviation}_{\text{Diff image}} * \text{Gain}}{\sqrt{2}}$$

at exposure time ≠ 0

Bias: offset

Signal in grey level: output of the

$$\text{Signal in Electrons} = (\text{Signal in Grey Levels} - \text{Bias}) * \text{Gain}$$

Signal in electrons: signal should be quantified in photoelectrons as these are real world values for intensity measurement that allow for consistent signal representation across all cameras.

https://www.photometrics.com/learn/camera-test-protocol

Camera Test Protocol

step by step processes to evaluate the camera performances.

TELEDYNE PHOTOMETRICS
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Technical Note: Camera Test Protocol

Scientific CMOS, EMCCD and CCD Cameras

Camera Test Protocol

Introduction

The detector is one of the most important components of any microscope system. Accurate detector readings are vital for collecting reliable biological data to process for publication.

To ensure your camera is performing as well as it should be, Photometrics designed a range of tests that can be performed on any microscope. The results of these tests will give you quantifiable information about the state of your current camera as well as providing a method to compare cameras, which may be valuable if you're in the process of making a decision for a new purchase.

This document will first take you through how to convert measured signal into the actual number of detected electrons and then use these electron numbers to perform the tests. The tests in this document make use of ImageJ and Micro-Manager software as both are powerful and available free of charge.

Table of Contests

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