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Procedure for Camera Characterization

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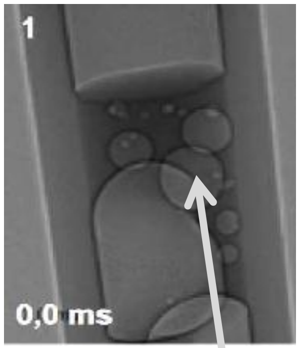
Outline

- Noisy and efficiency in the silicon pixel detectors “basic concept”
- Pixel characterization & protocol → by Beam light setup

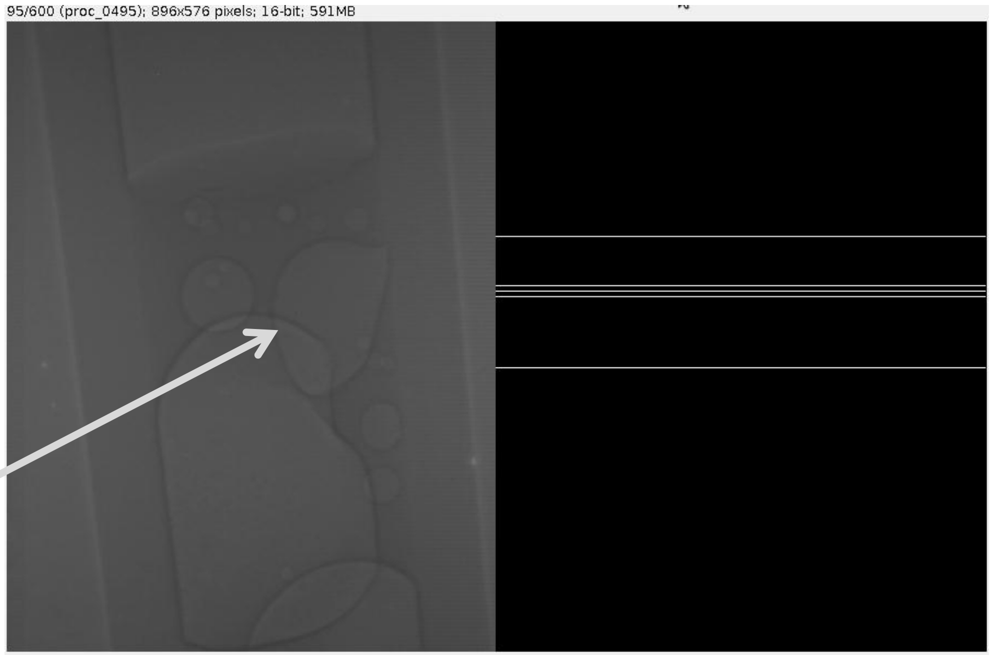
Sub-sampling strategy for rows 'fast reject'

Fast reject algorithm has been verified in the UFO environment using real data sample.

Reference image



Next fast event

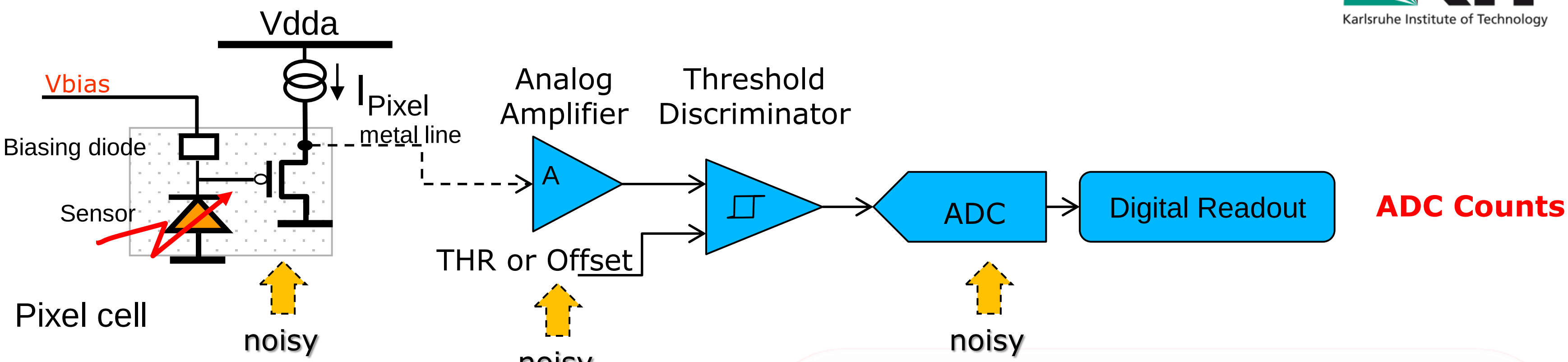


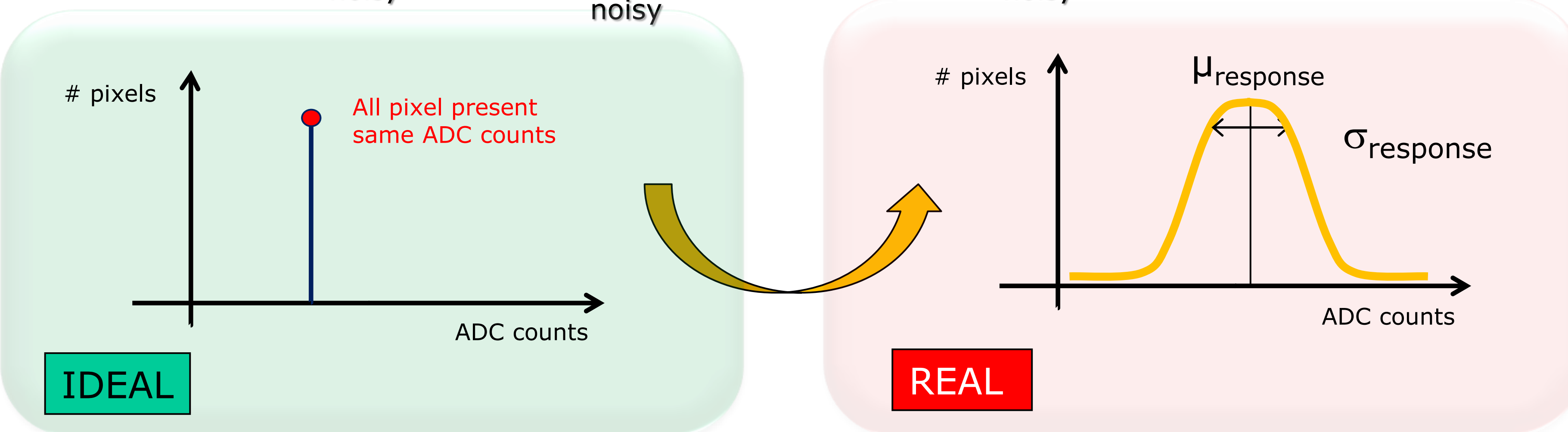
Region with changing

Fast trigger rows signals

- This simulation proof that the row trigger strategies → works
- Allows to reach a speed frame readout (kHz range)

Idea and Real detector response





For a uniform light explosion, the mean value ($\mu_{response}$) → is correlated at the mean value of the energy released in the sensor matrix. The STD value ($\sigma_{response}$) → take into account the non-uniform response between pixels.

Characterize silicon pixel detector → to have a clear idea how optimize the ($\mu_{response}$, $\sigma_{response}$) in the different operating point.

Noise contributions in UFO Camera

Several noise sources are present in UFO camera, each component should be proper characterized by different test setup.

The main noise source are located:

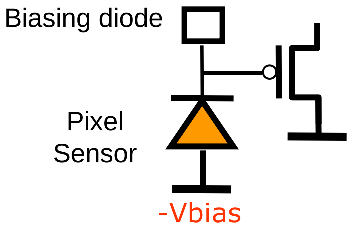
- **Detector and FEE (Front-End Electronic) →**
  - **Fano factor** $\overline{Q} = q * E / w$ $\sigma_Q = q * \sqrt{F * E / w}$ (w=3.6eV)
  - **Shot, thermal (white noisy) + Flicker (red noisy)**

New activity

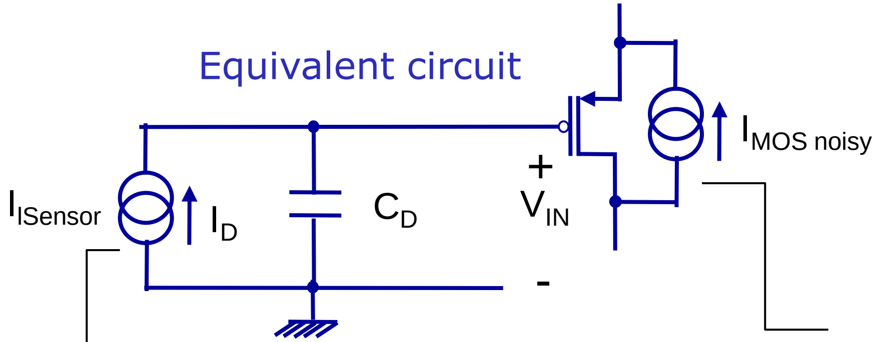
External environment condition→
  - **temperature, power supply noisy, etc.**

- **Beam distribution and instability →**
  - **Detector under non-uniform illumination → will be compensated using different strategies, etc.**

Noisy in the Active Silicon Pixel Detectors



Pixel cell



$$\langle i^2{}_{sD} \rangle = 2qI_D$$

Sensor: "dark" or "leakage current" noisy → shot noisy (white noisy)

$$\langle e^2{}_n \rangle = \left(\frac{K_f}{WLC_{ox}^2 f^\alpha} + \frac{4kT\gamma m}{g_m}\right) df$$

MOS: Ficker and Thermal noisy → (Red + white) noise

The sensor noisy

Fano factor → negligible

Leakage current I_D: Temperature, quality of the lattice structure (impurity concentration)

Exposure Time → Leakage current is integrated in the detector capacitance

$$\Delta V_C = \frac{1}{C_D} \int_0^{T_{EXP}} I_D \, dt$$

Noisy from FEE

Flicker → Technology process steps, the geometrical parameters, etc.

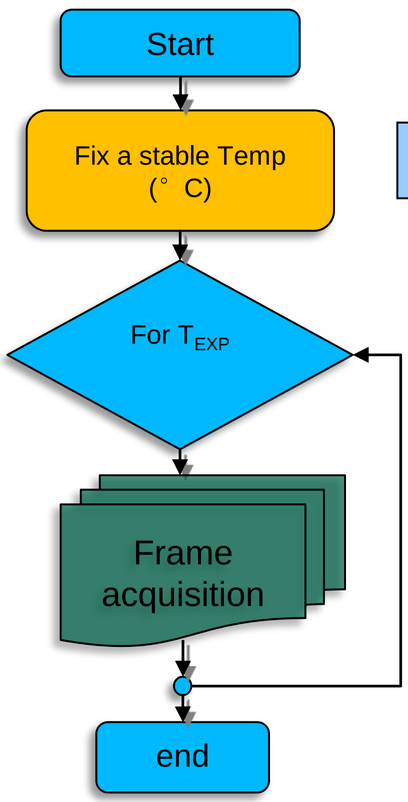
Thermal → From the MOS working point (weak or strong inversion), current source used to polarize the MOS.

ADC quantization noisy in LSB

Noisy estimation (METHOD-1)

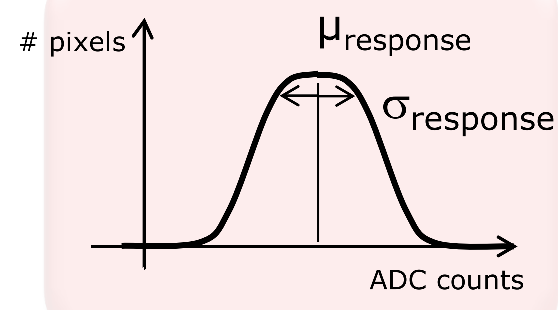
Initial: Detector in dark environment

Measure algorithm



Data analysis

Noisy distribution



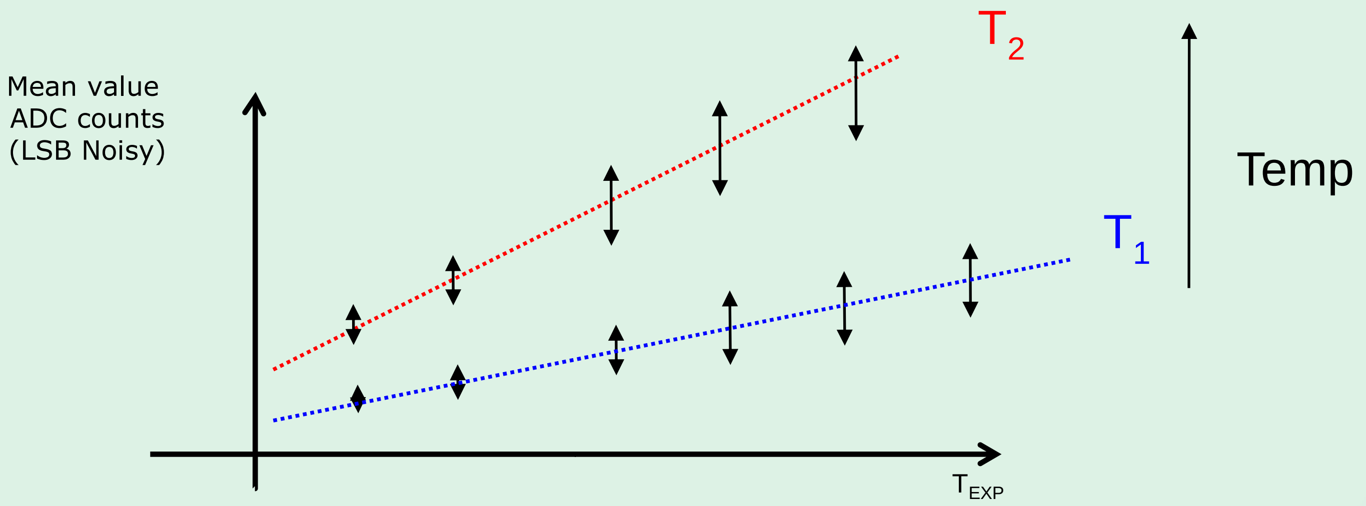
Goal:

→ Shape of the distribution (Gaussian, etc..)
→ Mean value → represent the noisy estimation in LSB
→ Sigma → correlated at the mismatch between pixels

Noisy estimation (METHOD-1) (ii)

Noisy vs Detector temperature and exposure time

Noisy distribution in different operating point

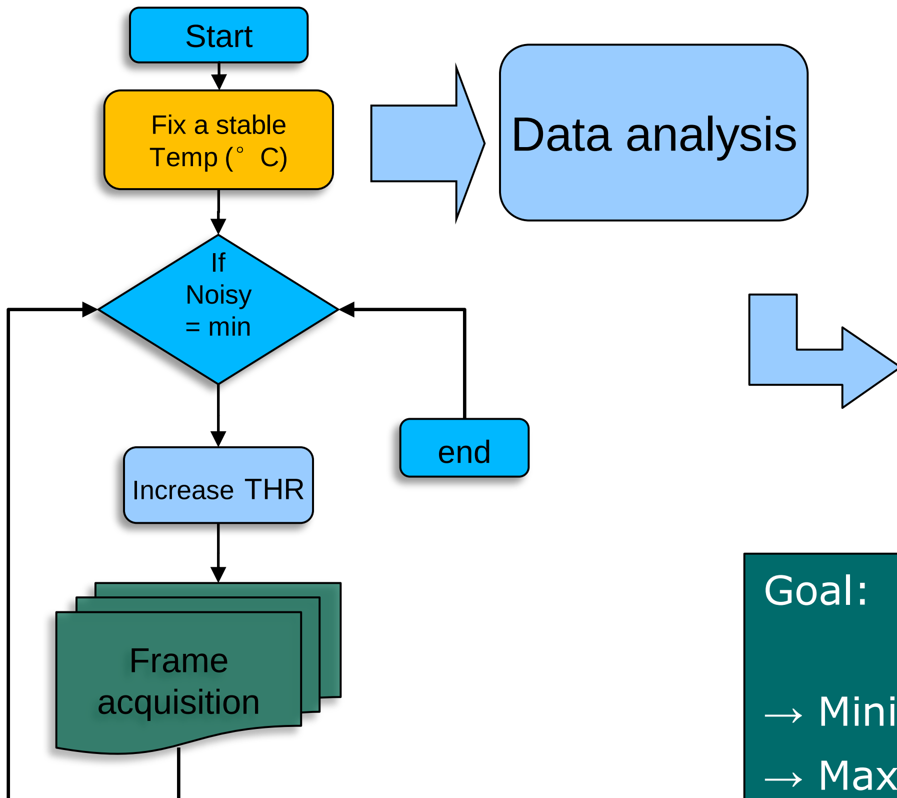


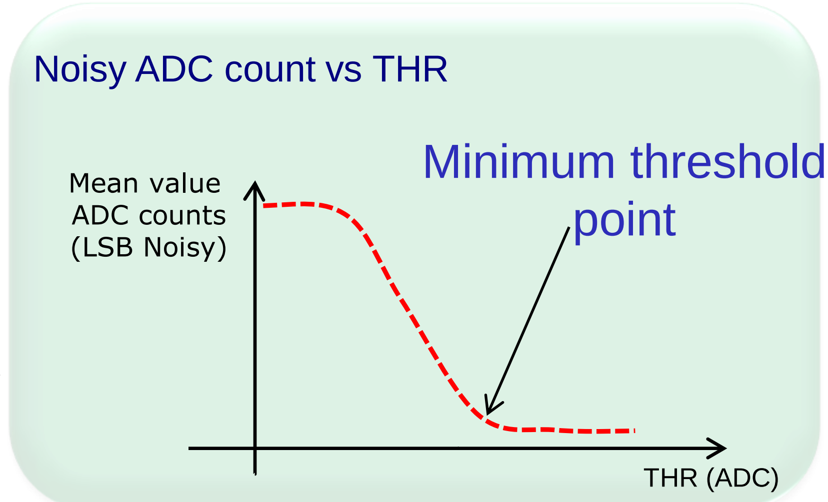
- Understand the maximum temperature to keep the noisy level under reasonable condition
- The effects of a long exp. time must be well evaluated

Minimum threshold estimation (MET. - 2)

Initial: Fix the Temp. and exposure time found in MET.-1. Detector → dark

Measure algorithm





Goal:

→ Minimize the mean and STD noisy values

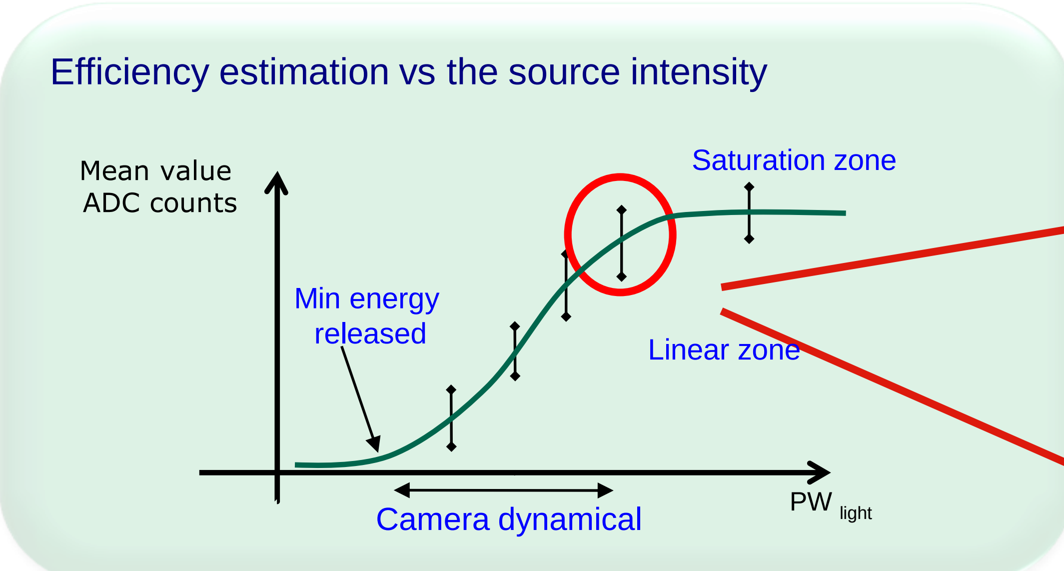
→ Maximize the S/N ratio

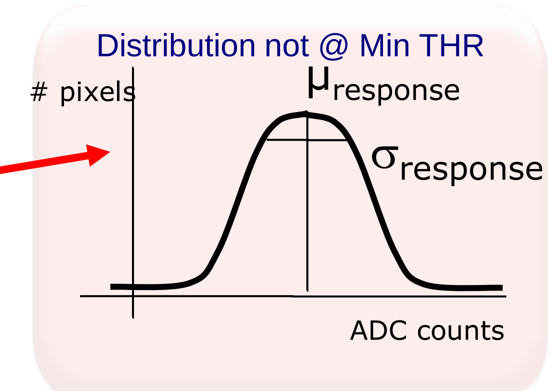
N.B. all camera available have a threshold discriminator but not in all model is accessible

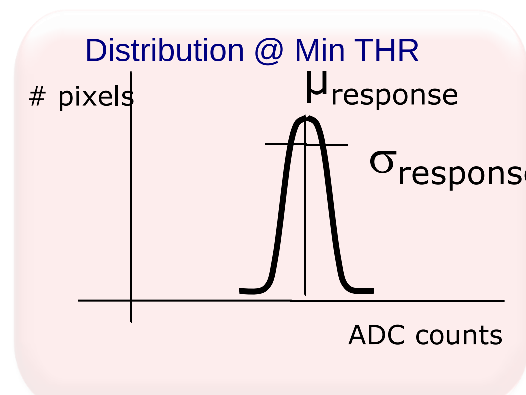
Detector efficiency estimation (METHOD-3)

Initial: Detector @ minimum threshold operating point → max S/N ratio
- Wavelength @ middle band (540 – 580 nm)

Algorithm: one or more frames @ progressive luminosity intensity (from min to max)→ for each intensity value (mean and STD) must be evaluated







Results:

→ Min energy released → camera sensitivity
→ Linear zone → gain of FEE
→ Saturation zone → Dynamical range
→ The Gaussian shape → non/uniformity between columns
→ S/N ratio estimation μ_{eff} / μ_{noisy} @ Min THR point

Efficiency vs FEE settings (METHOD-4) (ii)

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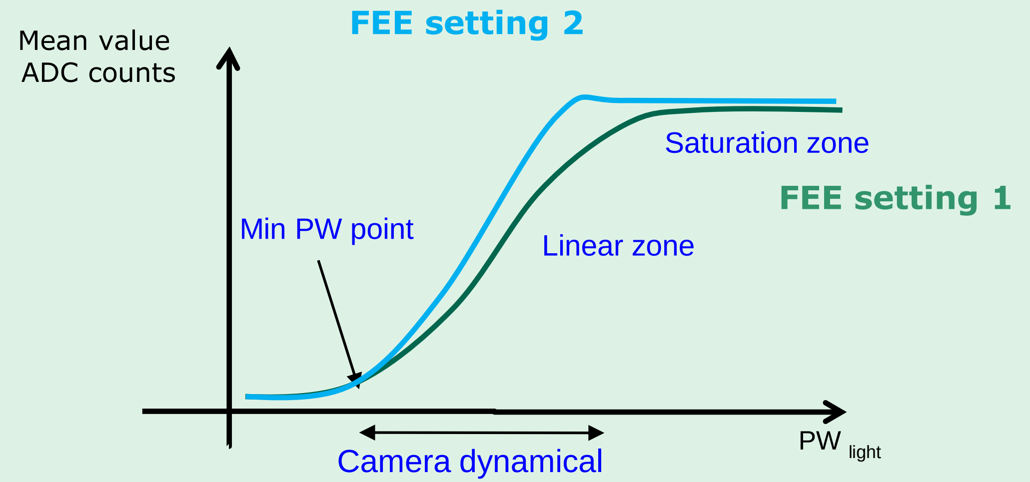
Initial: Detector @ minimum threshold operating point → max S/N ratio

– Wavelength @ middle band (540 – 580 nm)

Efficiency estimation vs FEE parameters (Gain, V_ramp1/2 ..)



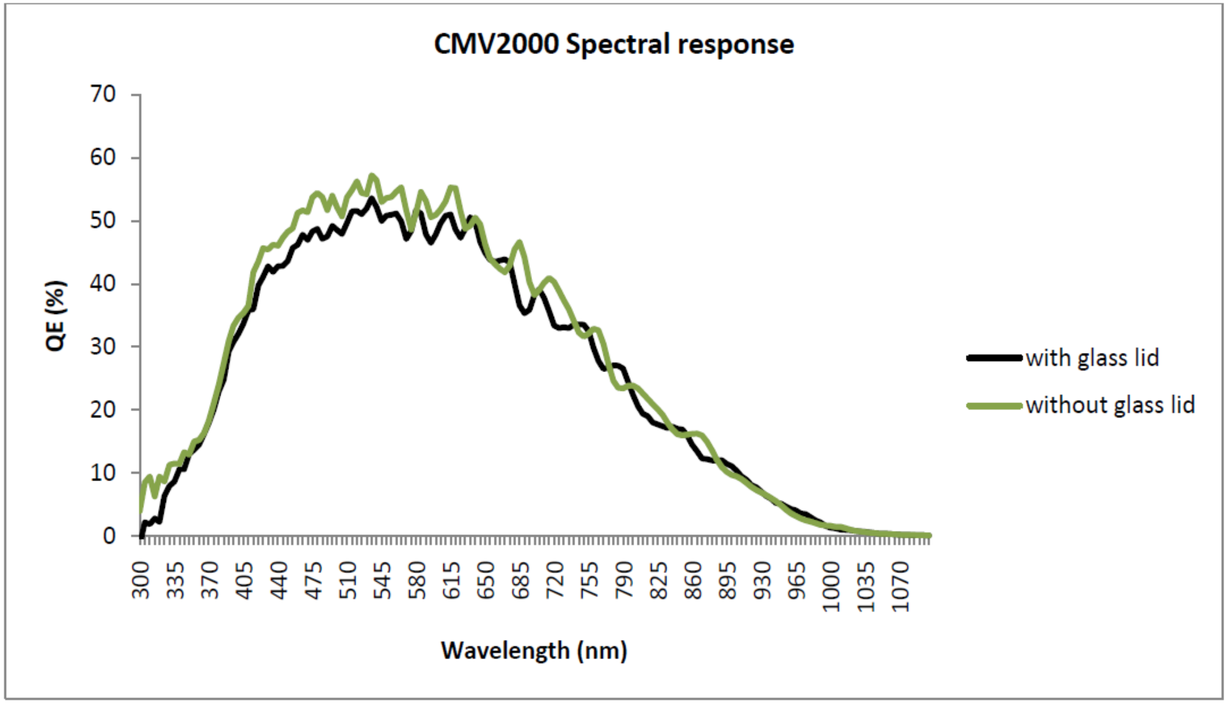
Results:

Estimation of the S/N and pixel distibution for different analog settings

Spectral response (METHOD -4)

Initial: Detector @ minimum threshold operating point → max S/N ratio

- PW light @ 50% of mean ADC counts.



GOAL: → spectral response for monochrome Pixel matrix

GOAL: → spectral response vs camera FEE settings

Conclusion & what's next

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A protocol for camera characterization is under definition, basic method are defined:

METHOD 1 → noisy behaviour and distribution

METHOD 2 → Min THR estimation

METHOD 3 → Efficiency & S/N in ADC (counts) estimation

METHOD 4 → spectral response

Second step consists in additional Methods using radioactive source (FE55) for conversion ADC count to ENC (equivalent noise charge)

Laser test setup for fast reject → test and performance