The EUSO-BALLOON instrument and evaluating the performance of PDM

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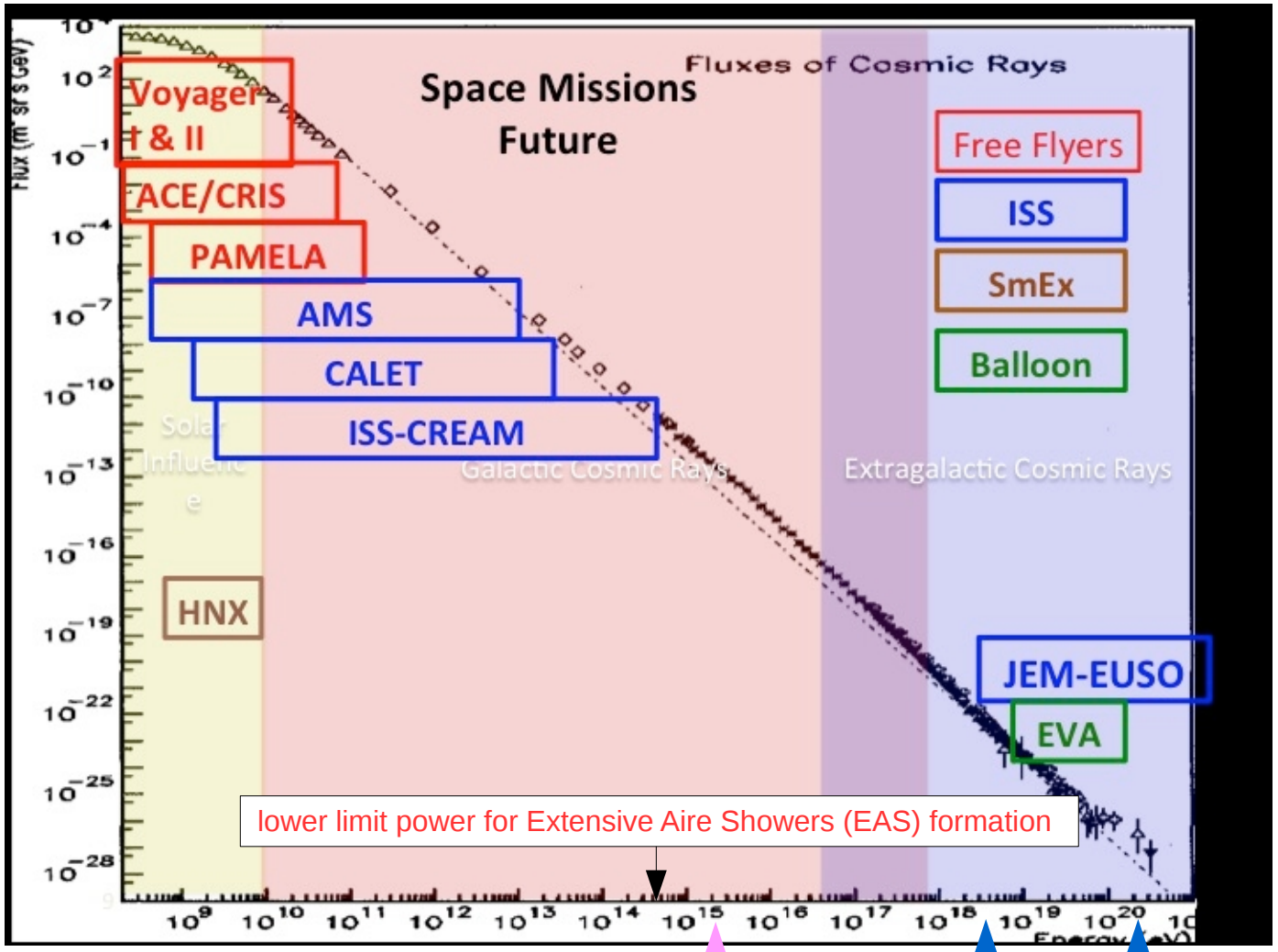
PHENIICS Day

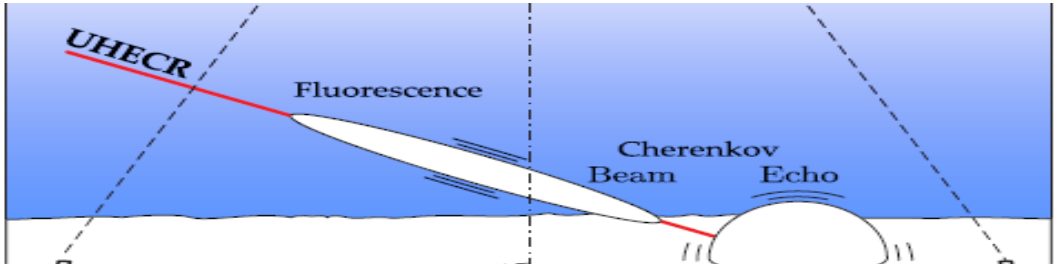
Introduction

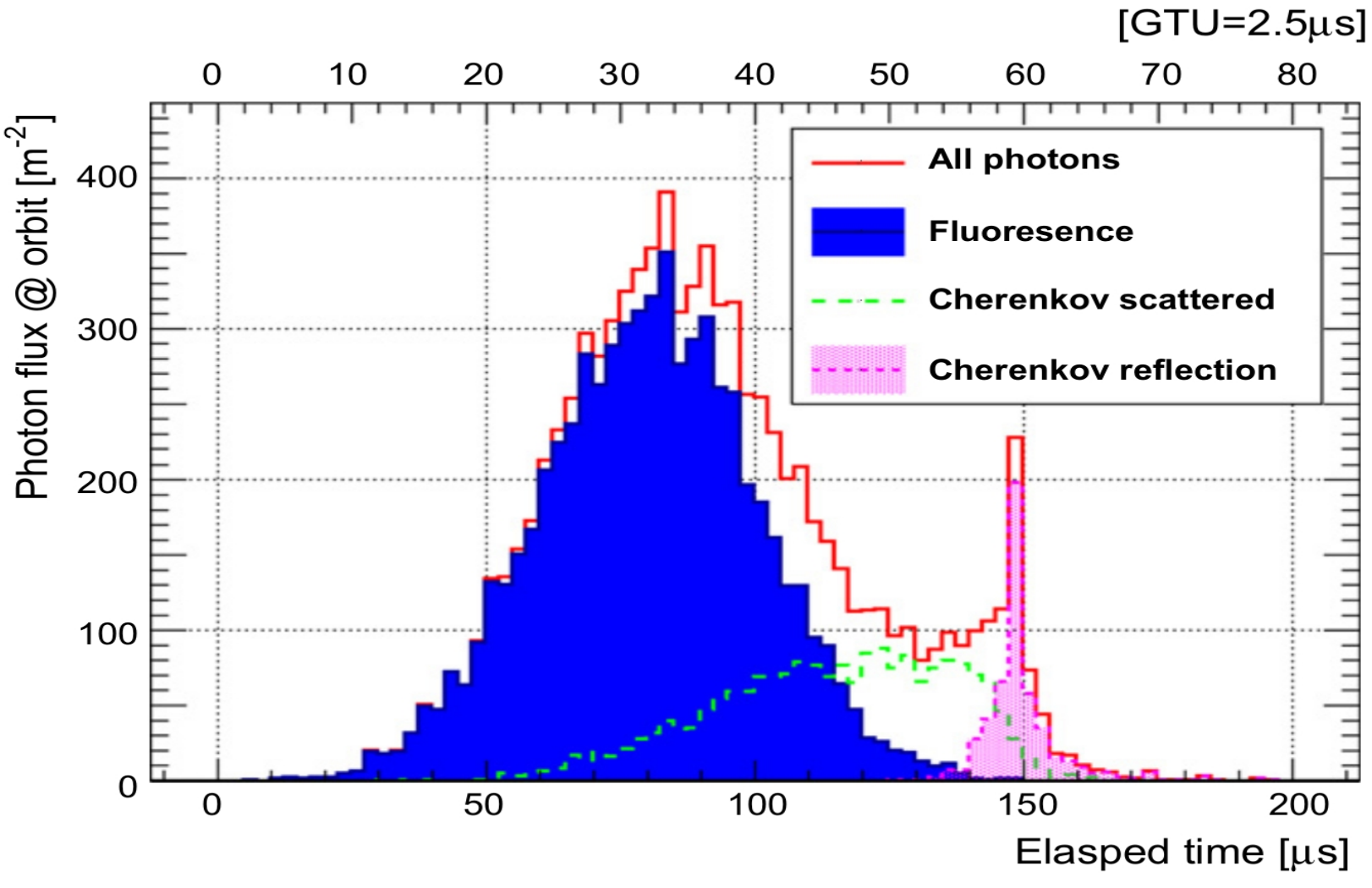
- The TA-EUSO, SPB-EUSO, K-EUSO, mini-EUSO are a serie of telescopes of the family of JEM-EUSO telescope which have the goal to study UHECR.
- This work involve the integration of PDM camera and the flight mission of EUSO-Balloon in Timmins Canada 2014. This is the first phantfinder of JEM-EUSO with the detection chaine whole.
- The second part of this work was the post calibration and evaluation of performance of the electronic systeme.
- The third part was to develop a method for recover information of pixels with poor performance.

Space Missions for Cosmic Rays

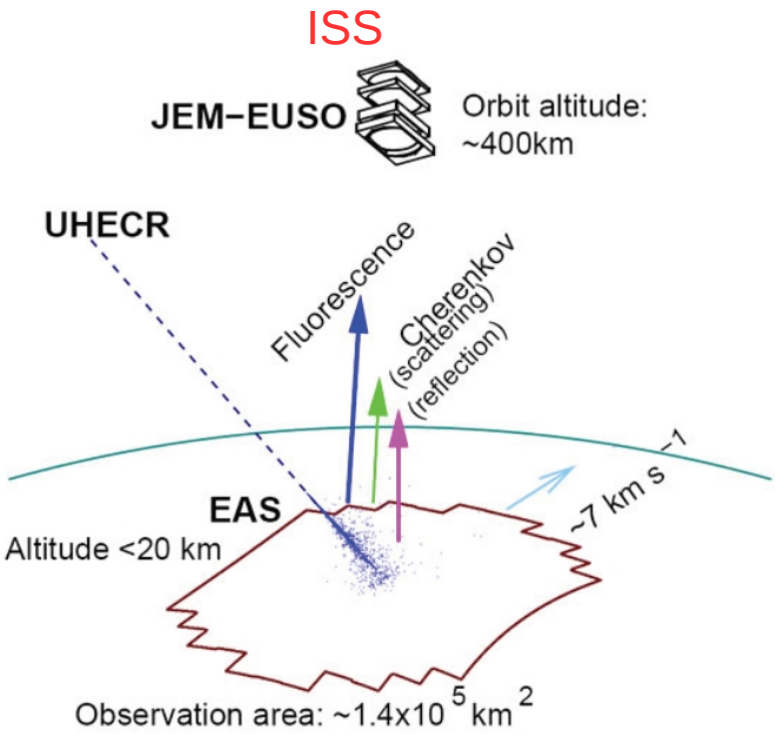


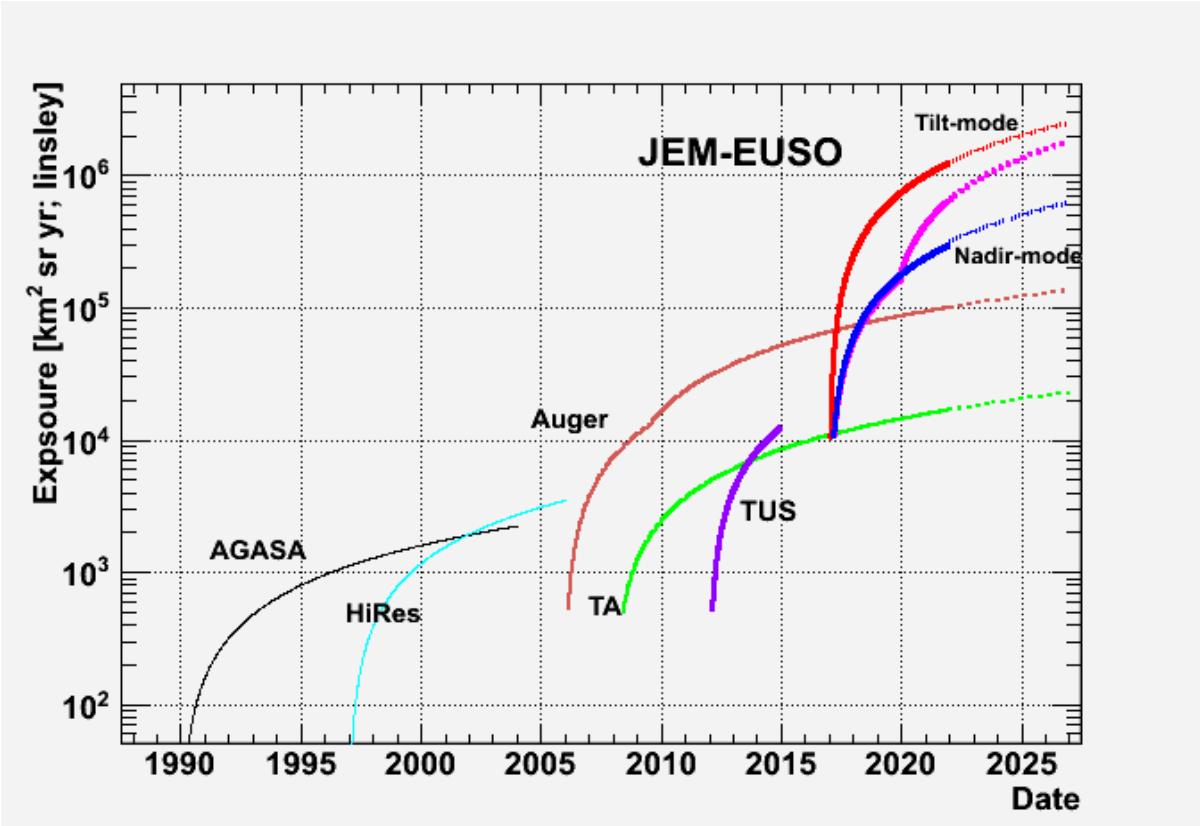
Signature of the EAS (extensive air showers)





Project JEM-EUSO (Extreme Universe Space Observatory-Japanese Experiment Module of the International Space Station)

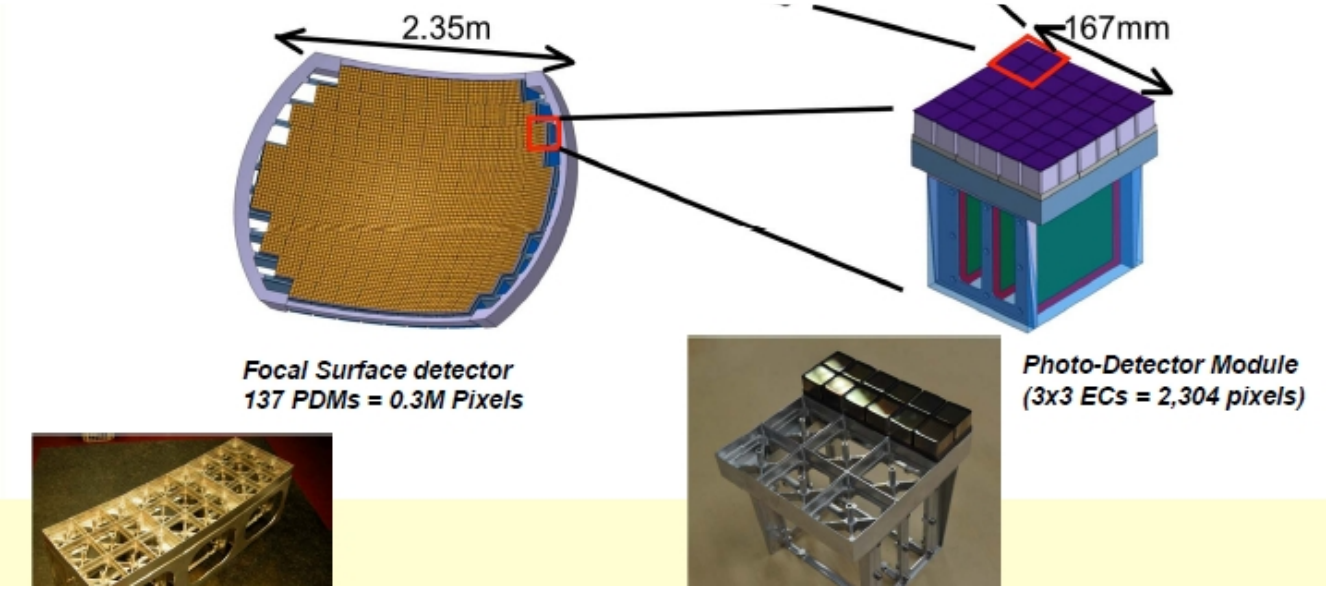




- Field of View (FoV) de 60° (0.75 km par pixel)
- Time resolution 2.5µs.
- Lens of Fresnel : 2,5m of diameter.
- The data acquisition rate~300kb/s

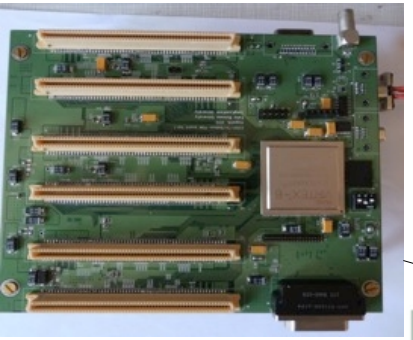
- Statistical detection of more than one order of magnitude greater than Auger.

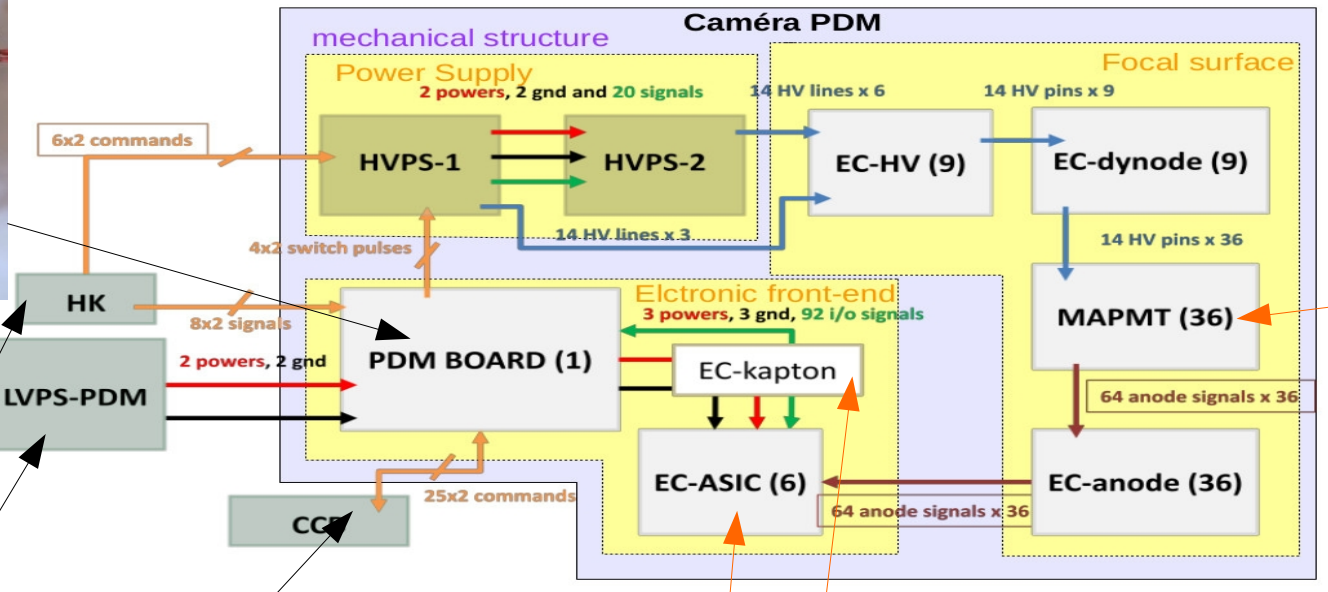
The Focal surface tu camera (PDM) of JEM-EUSO.



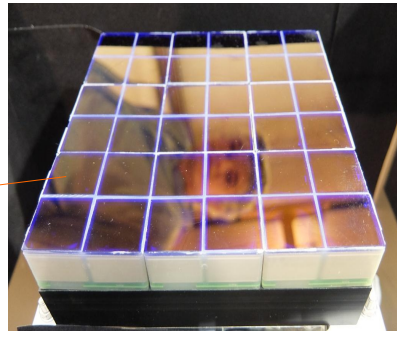
The camera (PDM) of EUSO-Ballon (Panthfinder of JEM-EUSO)

FPGA-board



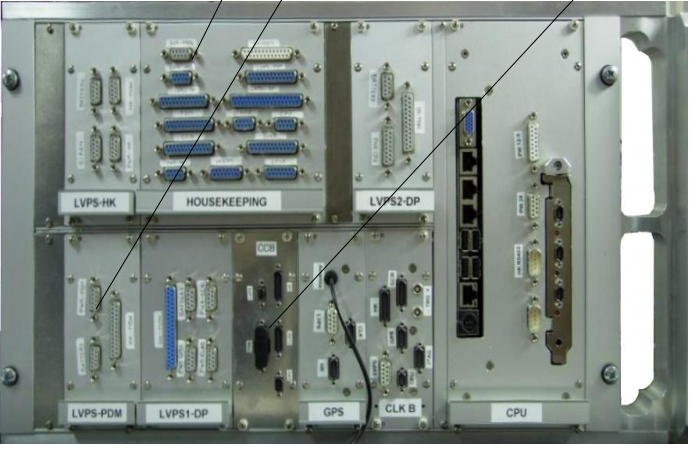


Detector : MAPMT
(multi Anode photomultiplier)

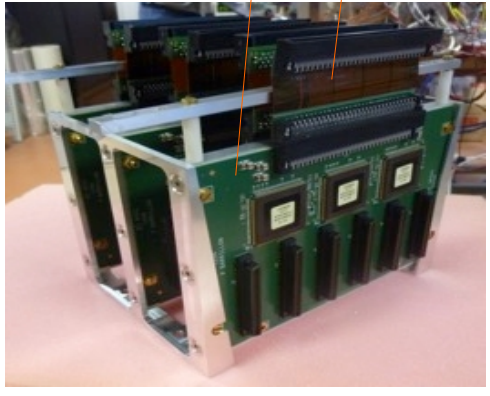


Time resolution= 5ns

Data Processor



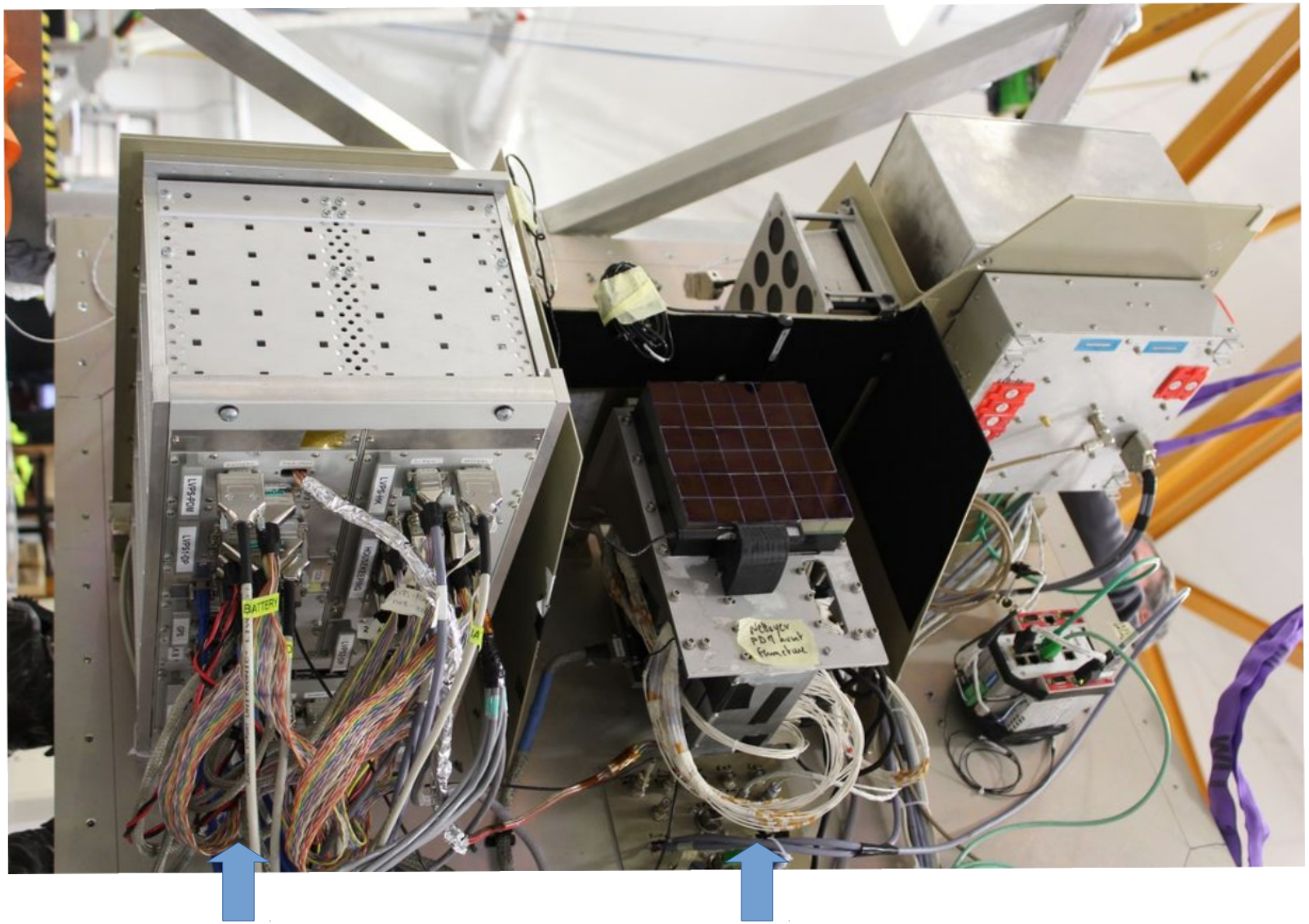
general scheme of PDM



ASICs boards

GTU=2.5µs

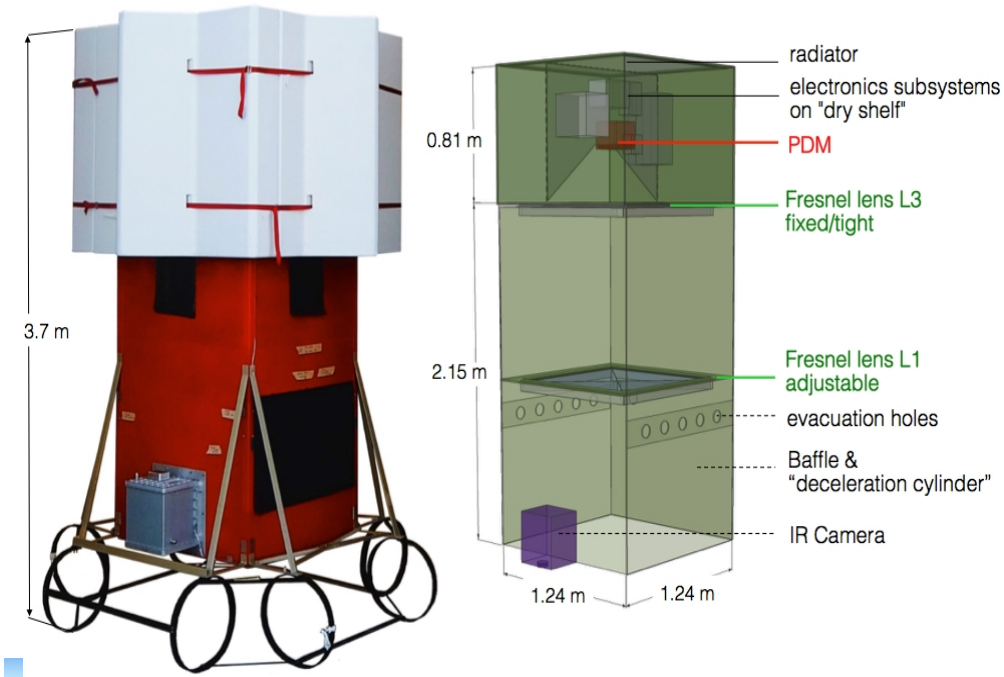
Complete assembly of the camera



Data Processor (DP)

Camera PDM
(Photon detection module)

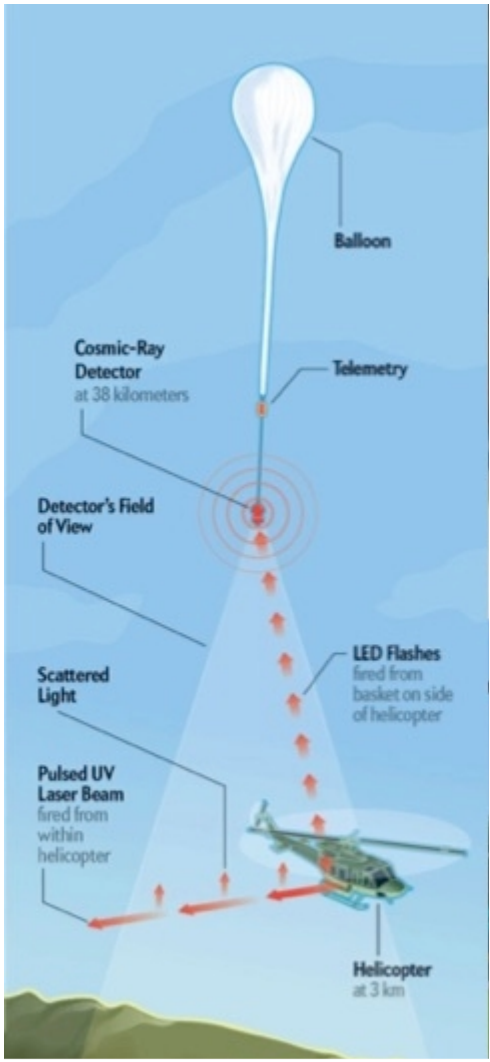
MISSION EUSO-Balloon

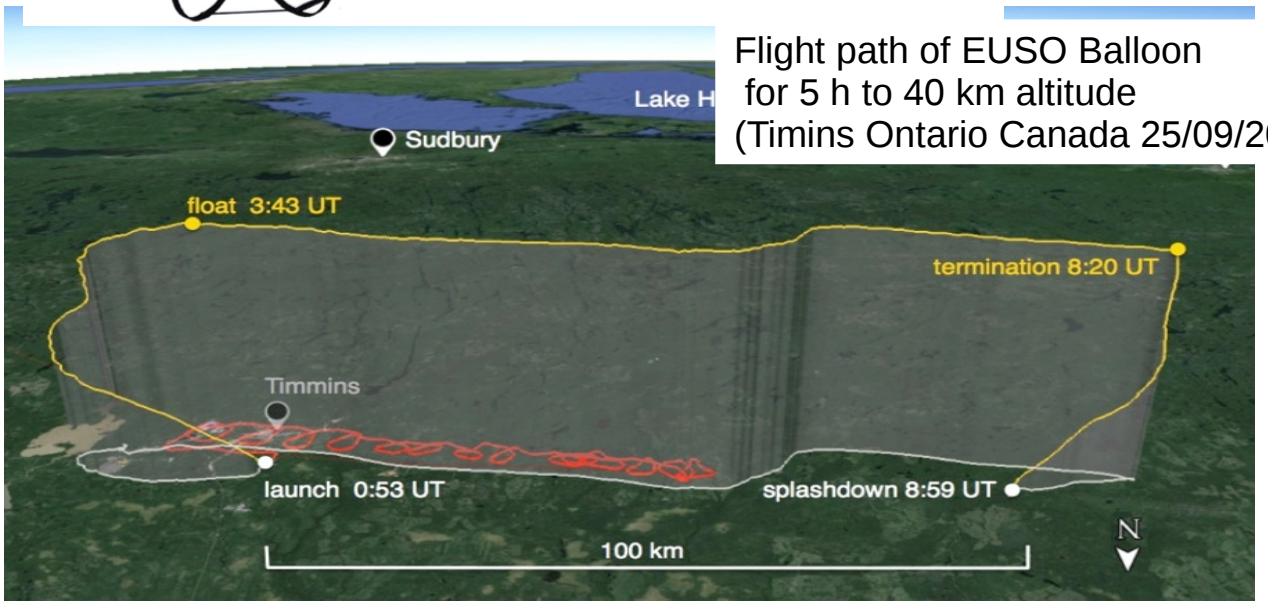


Objectives

- **Detection of background UV**
- **Detection of trace of beam laser which simulate a EAS**

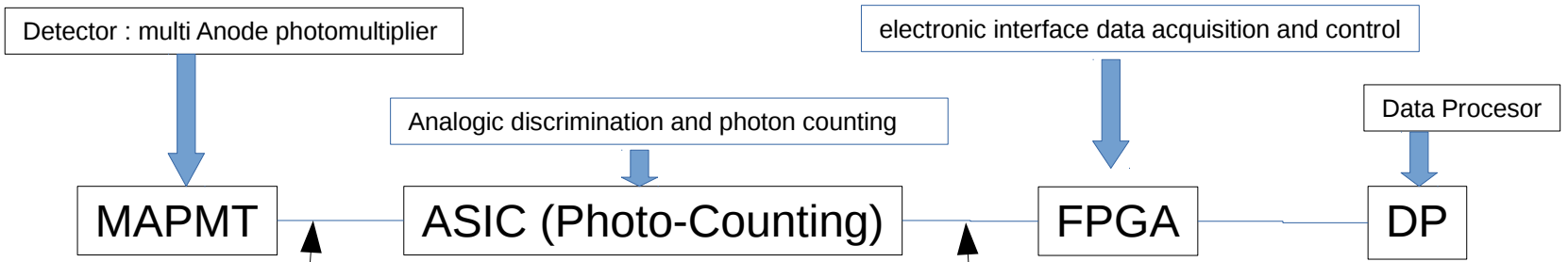
PDM sensitivity test



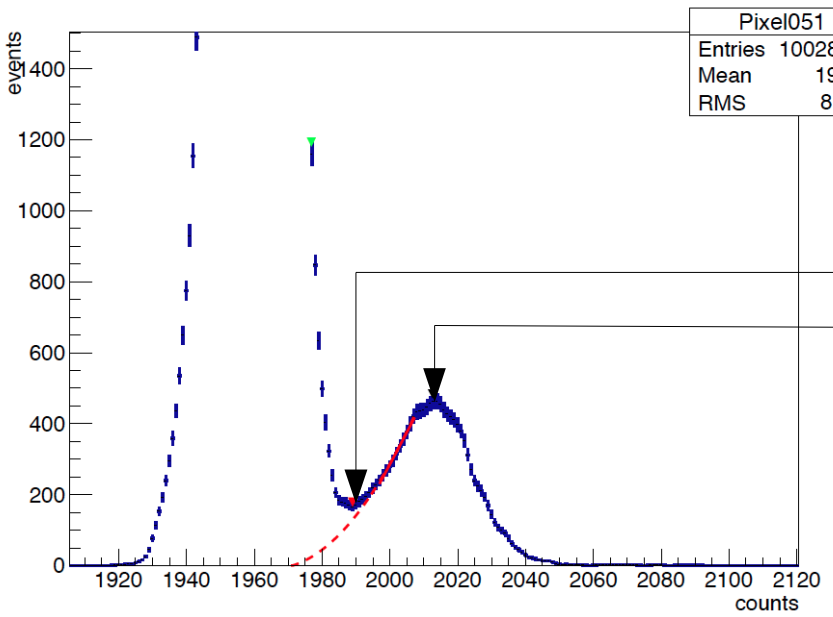


Flight path of EUSO Balloon
for 5 h to 40 km altitude
(Timins Ontario Canada 25/09/2014)

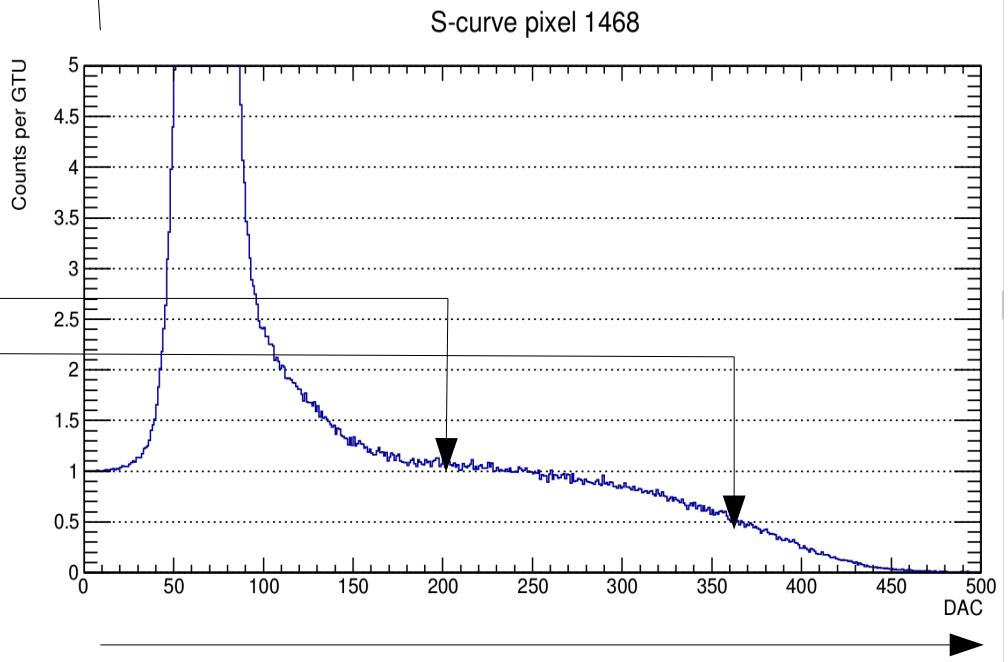
S-Curve ?



Spectrum charge

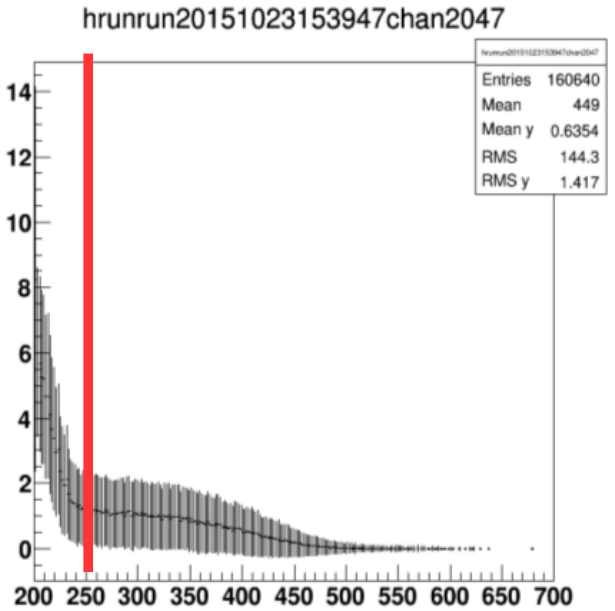


Q

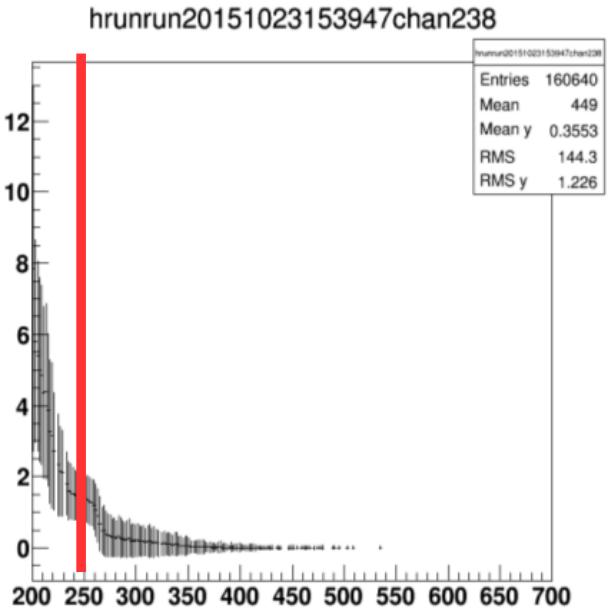


Discrmination Thershold (Vth)for analogic signal in the ASIC.

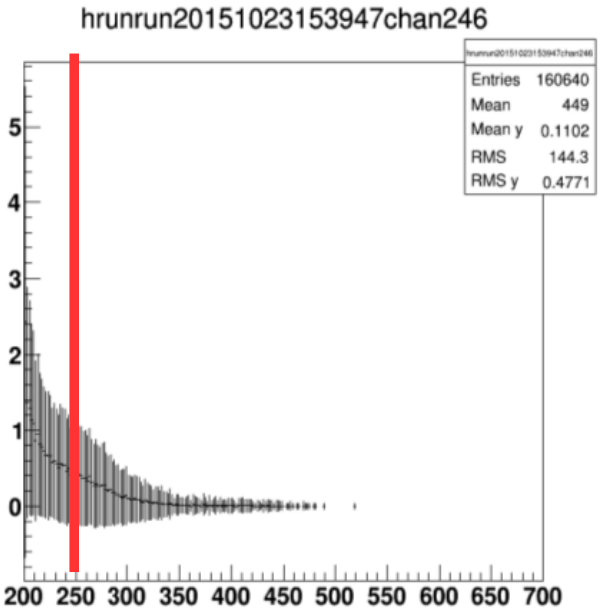
But there are bad pixels



(a) pixel type0



(b) pixel type1



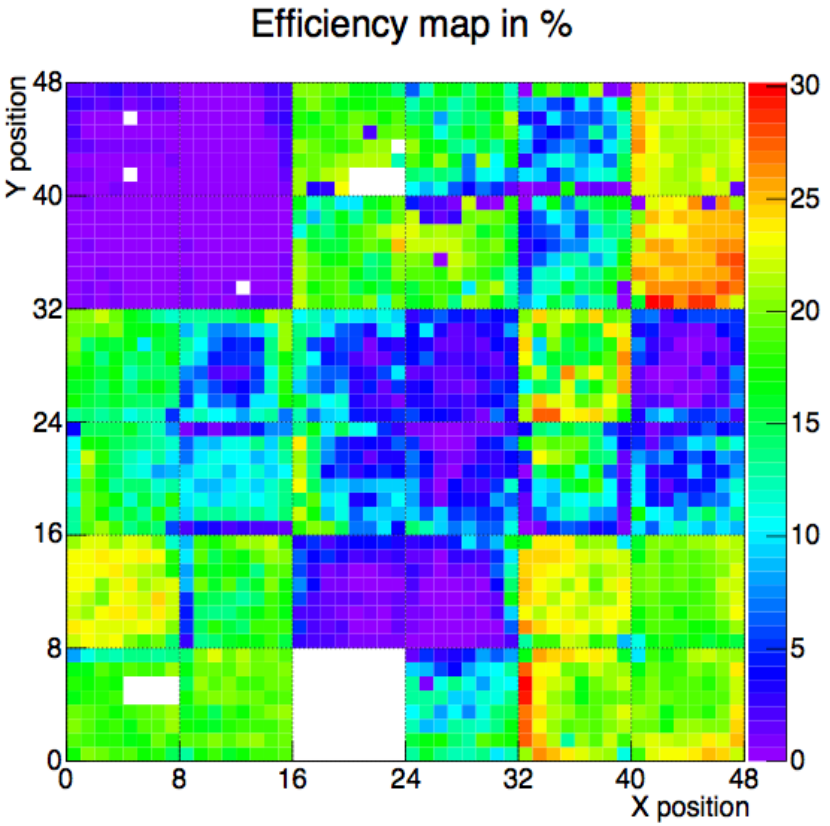
(c) pixel type2

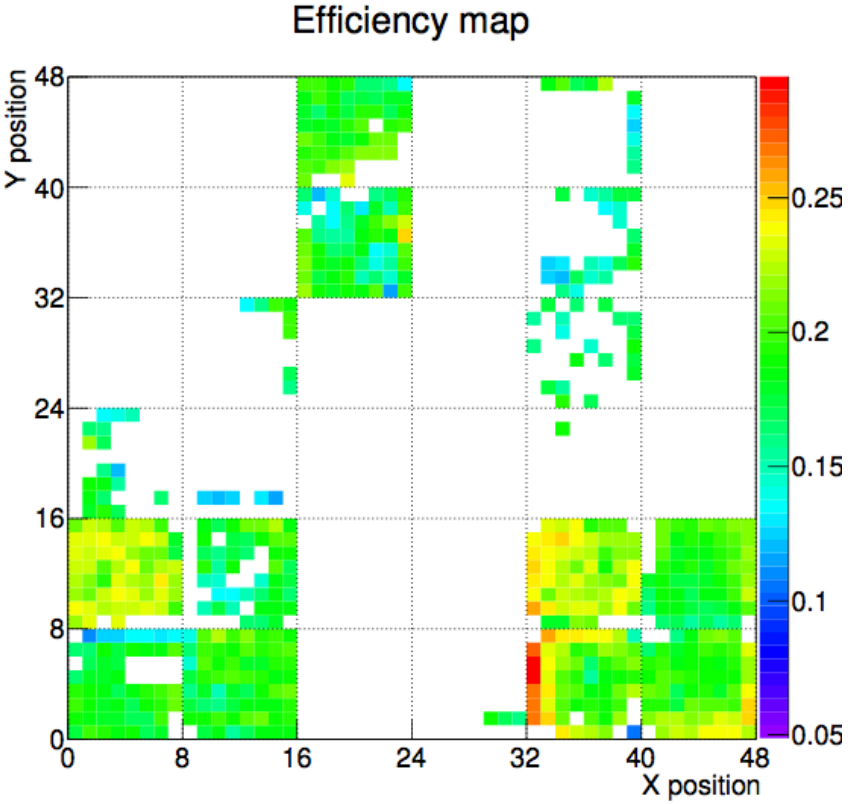
The red line indicates the threshold of discrimination of the analog signal

There are two problems: 1) a wide Piedestal (electronic noise) 2) a short SCurve

MAPMT deterioration is unavoidable with use. It means that sensitivity is reduced and this is evident with the backward of Scurve.

Result of absolute calibration





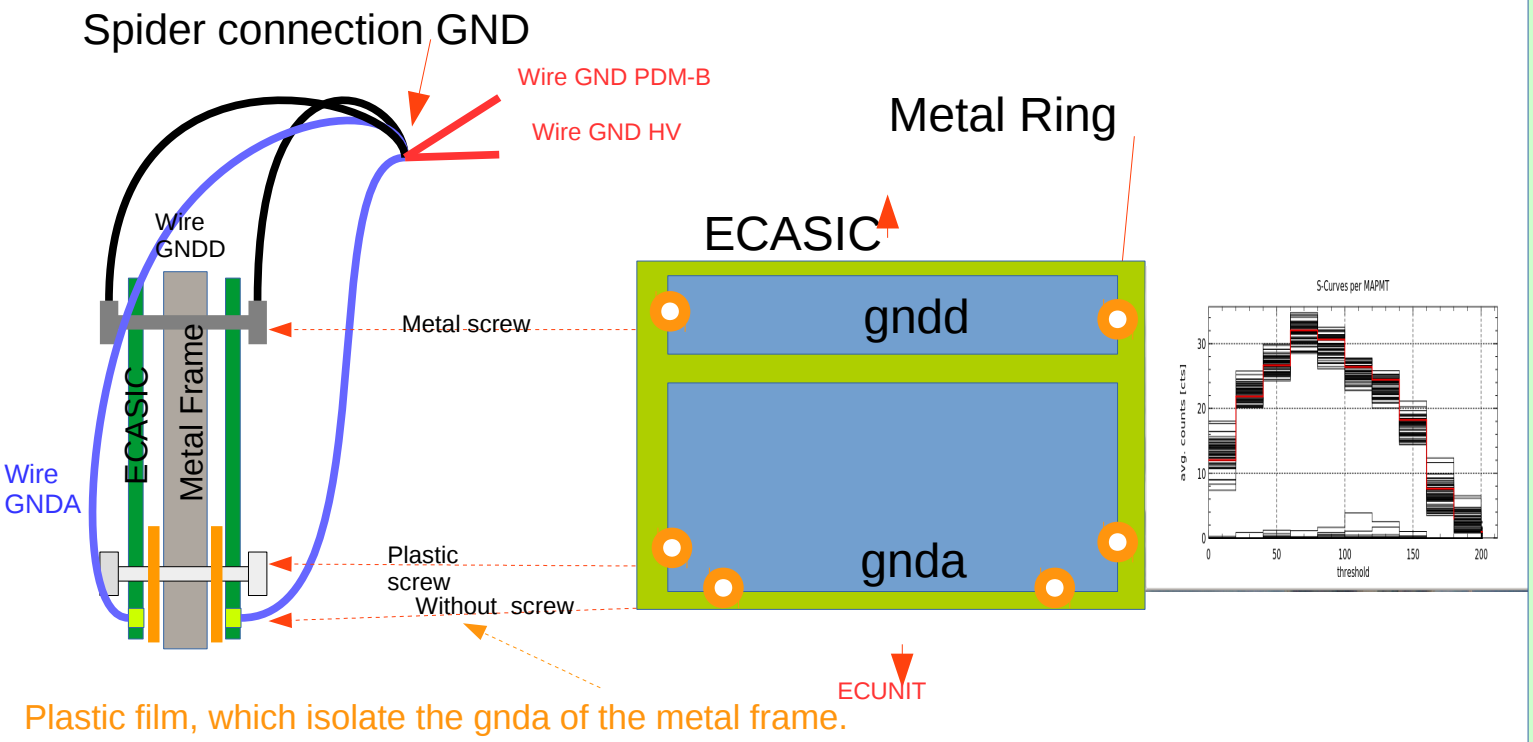
Result of calibration after flight at 950V

NOW !! Our goal is recover some information of the bad pixels.

- Selected pixels:
  - mean PDE of ~19%
  - sigma of ~3%
  - calibrated with an accuracy better than 4%

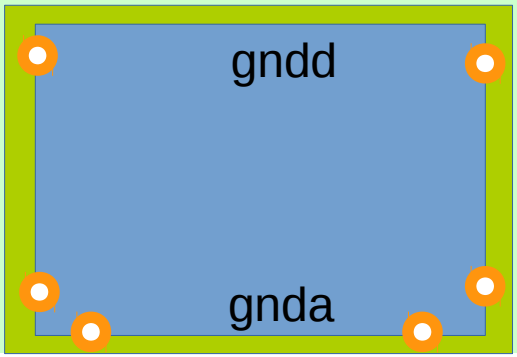
The grounding configuration and the electronic noise

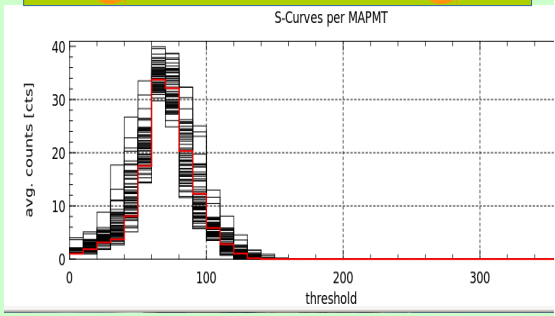
- During the flight the connection of grounding was used the spider wires as the picture.



The reason for having such a wide pedestal was due to the poor CONNECTION between gnda and gndd of ECASICs.

Improvement





Connecting with low impedance the gndd and gnda electronic noise is reduced.

Trigger Philosophie

UHECR are not the only targets of detection. Also we want to detect meteors, airglow, etc. which they have different intensity and development time.

This involves dramatic changes in detector sensitivity immediately. (Microseconds).

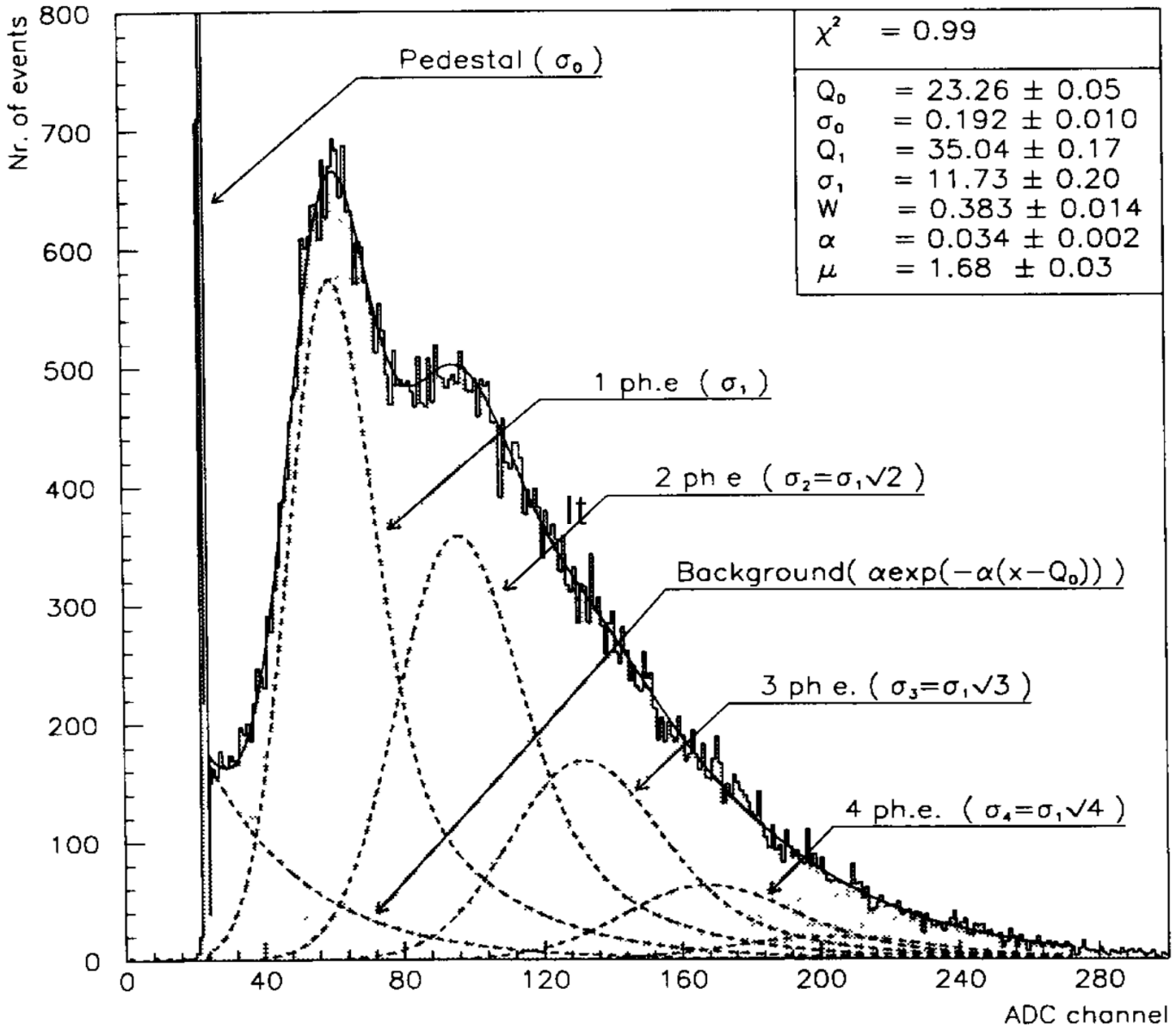
- L0 : signal over background UV. we can adjust the gain of photomultiplier and pre-amplification of analog-signal.
- L1 : Persistence trigger in fonction of correletion between the time and spatile (**events in neighboring pixels** for short times ~5ms)
- L2 : Persistence trigger in large periods (>50ms).

L1 an L2 have parameters which change the sensibility of the PDM.

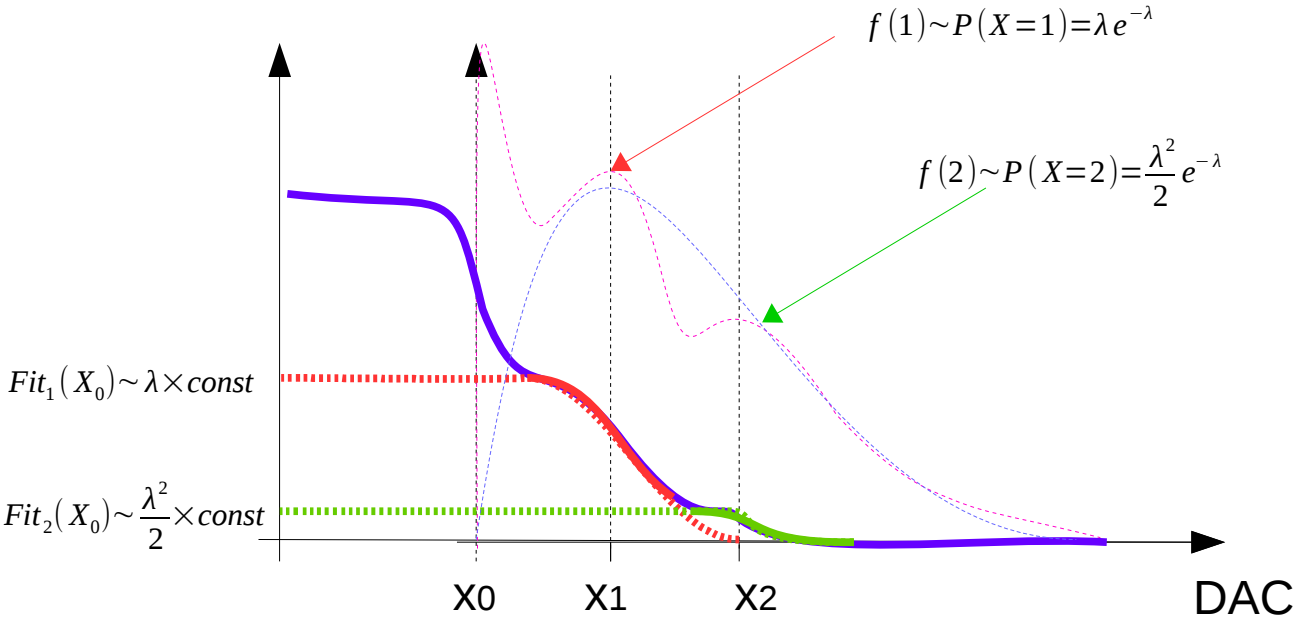
Homogenization of the sensitivity of the focal surface is needed.

Drawing on the contributions of 2PE per pulse

This is known than there are contributions of two or more photos in a impulse signal-out of PMTs.



Drawing on the contributions of 2PE per pulse



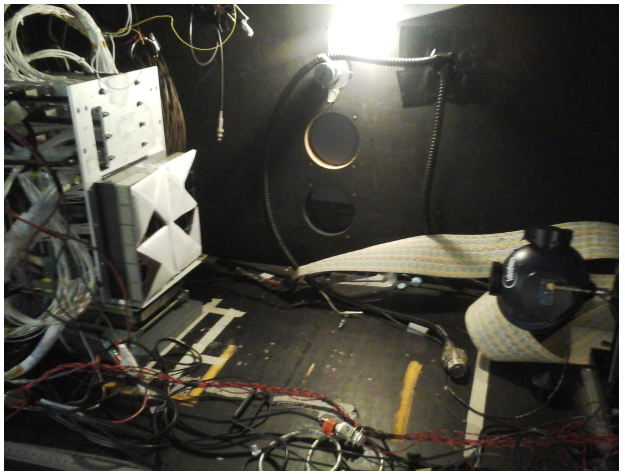
One could in-use this relationship to find the λ of each pixel.

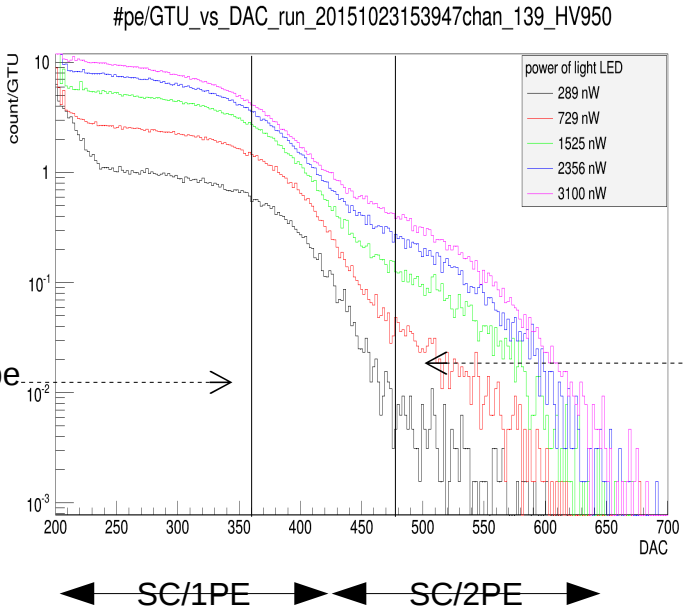
For pixels with weak gains, where it is impossible to see the SC for 1pe, if we know the lambda value, we could estimate counts by SC/1pe.

For this we will try use SC/2pe.

We must confirm this hypothesis with good pixels with enough data.

Post flight tests in black box with light to indentify the 2pe contribution with a complete PDM



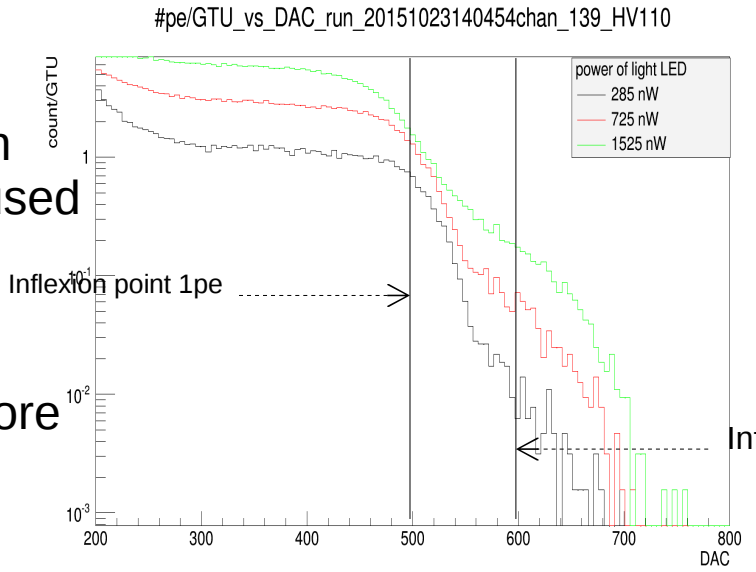


To 950V

We can observe the second 2 pe contribution.

These measurements allowed to have the relation between 1 pe and 2 pe contributions that will be used to recover the 1 pe position (see slide 5)

The efficiency increases when the PDM runs at 1100V. Which is why the contribution of 2PE is more evident in this case.



To 1100V

Proposed Fit function for the SCurve

$$\arg(x) = (x - a_1)/\pi a_2$$

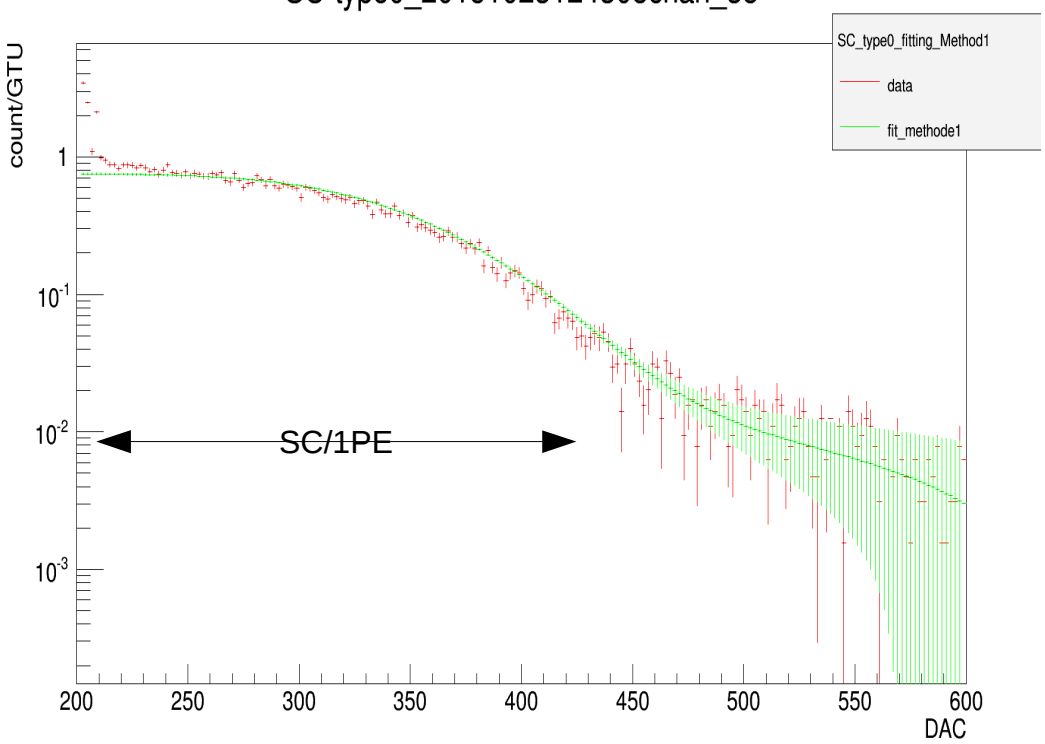
$$Fit_1(x) = a_0 \, Erf\, c(\arg))$$

$$Fit_2(x) = a_5 (a_3 x + a_4)$$

$$Fit(x) = Fit_1(x) + Fit_2(x)$$

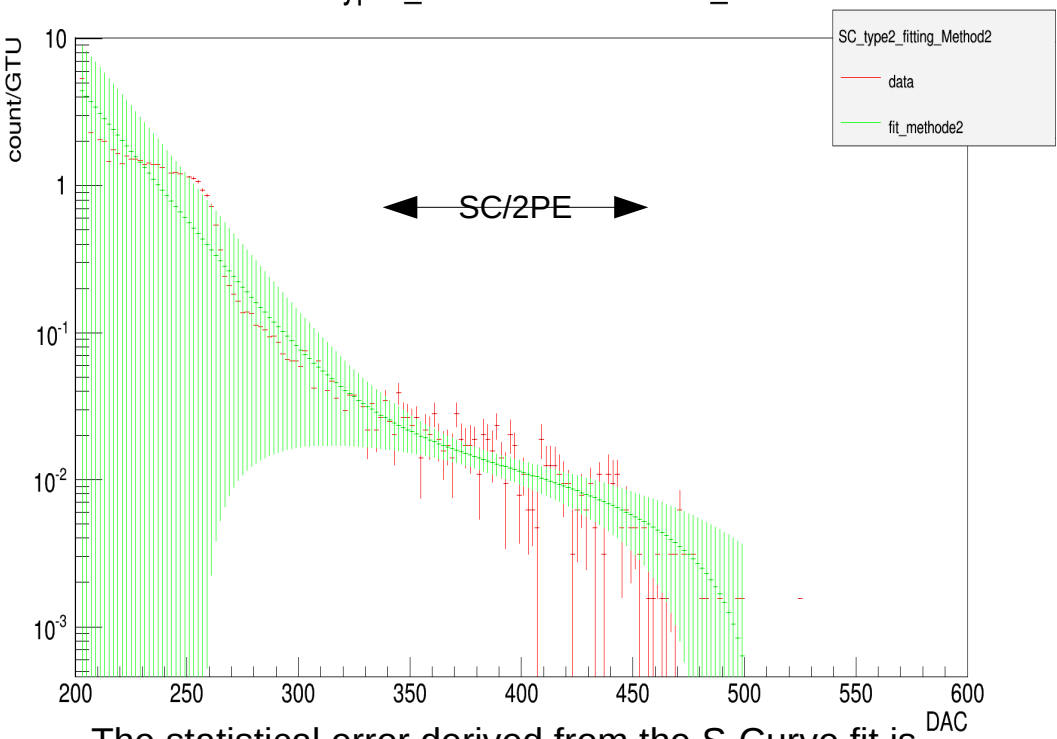
2 different functions are used : one for the 1pe region (Fit1) and another for the 2 pe region (Fit2).
A fit error is calculated and represented on the plots bellow.
A chi2 square method is being developped.

High gain

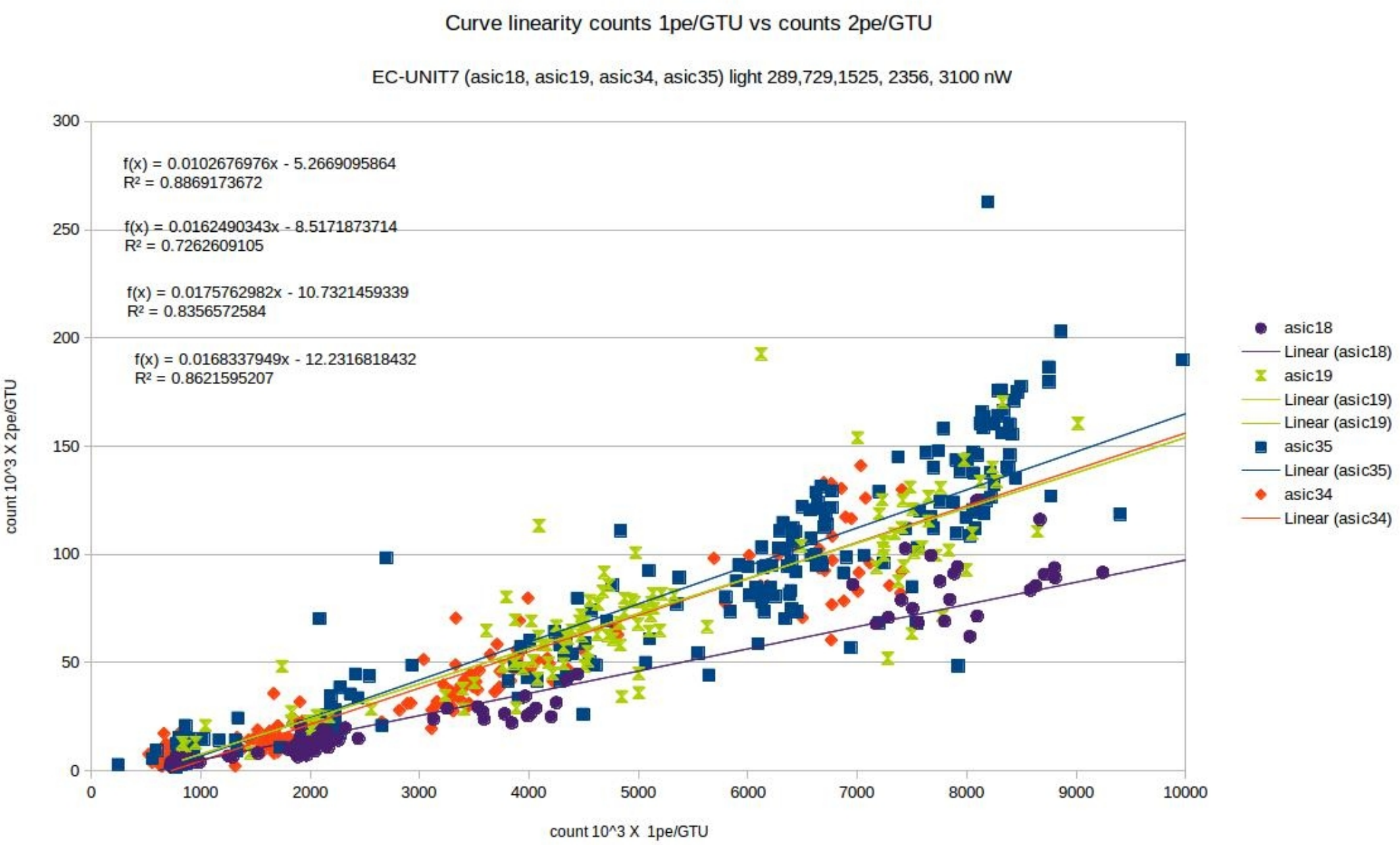


The statistical error derived from the S-Curve fit (green bar) is short in the SC/1pe

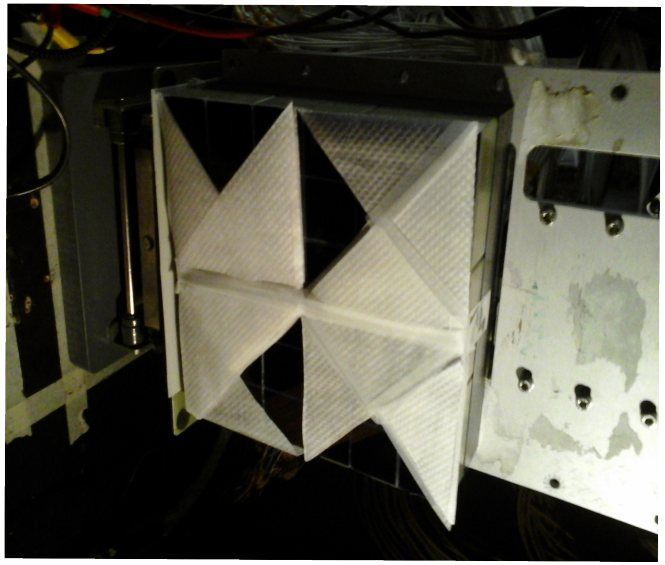
Low gain



The statistical error derived from the S-Curve fit is small in the flat part of SC/2pe. So the fit is enough for the analysis.


Curve linearity counts 1pe/GTU vs counts 2pe/GTU
EC-UNIT7 (asic18, asic19, asic34, asic35) light 289,729,1525, 2356, 3100 nW
f(x) = 0.0102676976x - 5.2669095864
R² = 0.8869173672
f(x) = 0.0162490343x - 8.5171873714
R² = 0.7262609105
f(x) = 0.0175762982x - 10.7321459339
R² = 0.8356572584
f(x) = 0.0168337949x - 12.2316818432
R² = 0.8621595207
count 10^3 X 2pe/GTU
count 10^3 X 1pe/GTU
0
50
100
150
200
250
300
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
asic18
Linear (asic18)
asic19
Linear (asic19)
Linear (asic19)
asic35
Linear (asic35)
asic34
Linear (asic34)

Testing the complete method to recover data



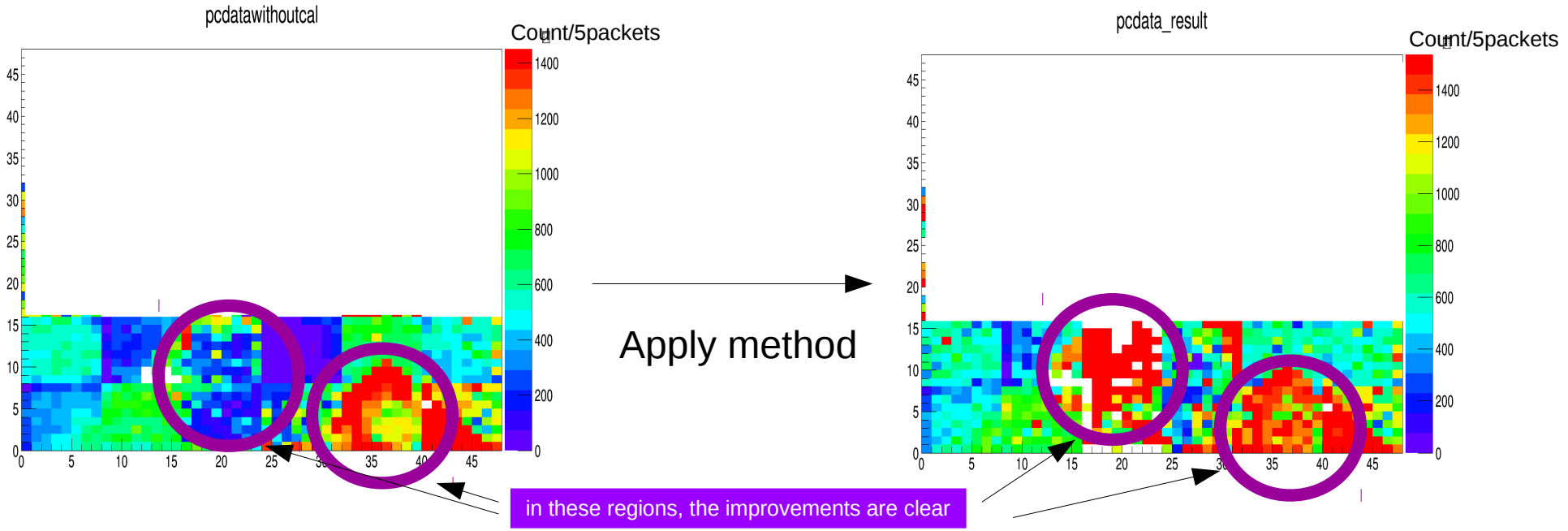
We installed a mask with different transparencies in order to observe the sensitivity in different regions on MAPMT.

We illuminated the PDM uniformly

We can see that there is an improvement in image resolution.

In the bottom-center ECUNIT, the red area corresponding to a triangular free area is recovered.

Homogeneity of the other triangular regions is improved



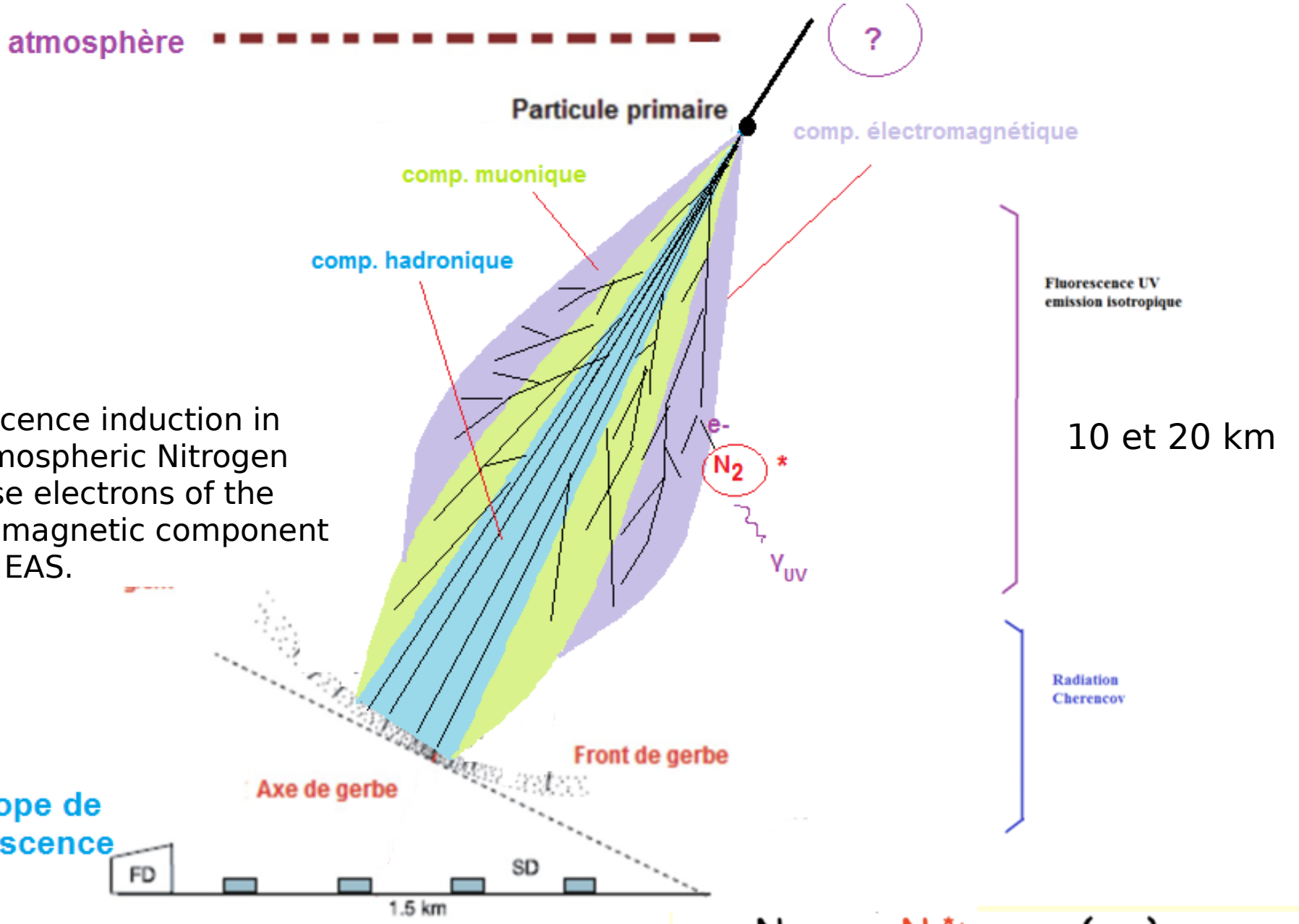
Conclusion

- The mission of EUSO Balloon achieved its main objective, achieving sensitivity to detect background UV and simulation of EAS with laser beam.

- One of the big problems was to reduce electronic noise by integrating all components. The sujestion to change the internal settings gnd in ASIC-boards was considered, now the new PDM for the next balloon takes this configuration.

- It is possible to use the signal of 2PE for pixels with low sensitivity. This allow homogenize FS and keep operating algorithms trigger.

EAS :extensive air showers



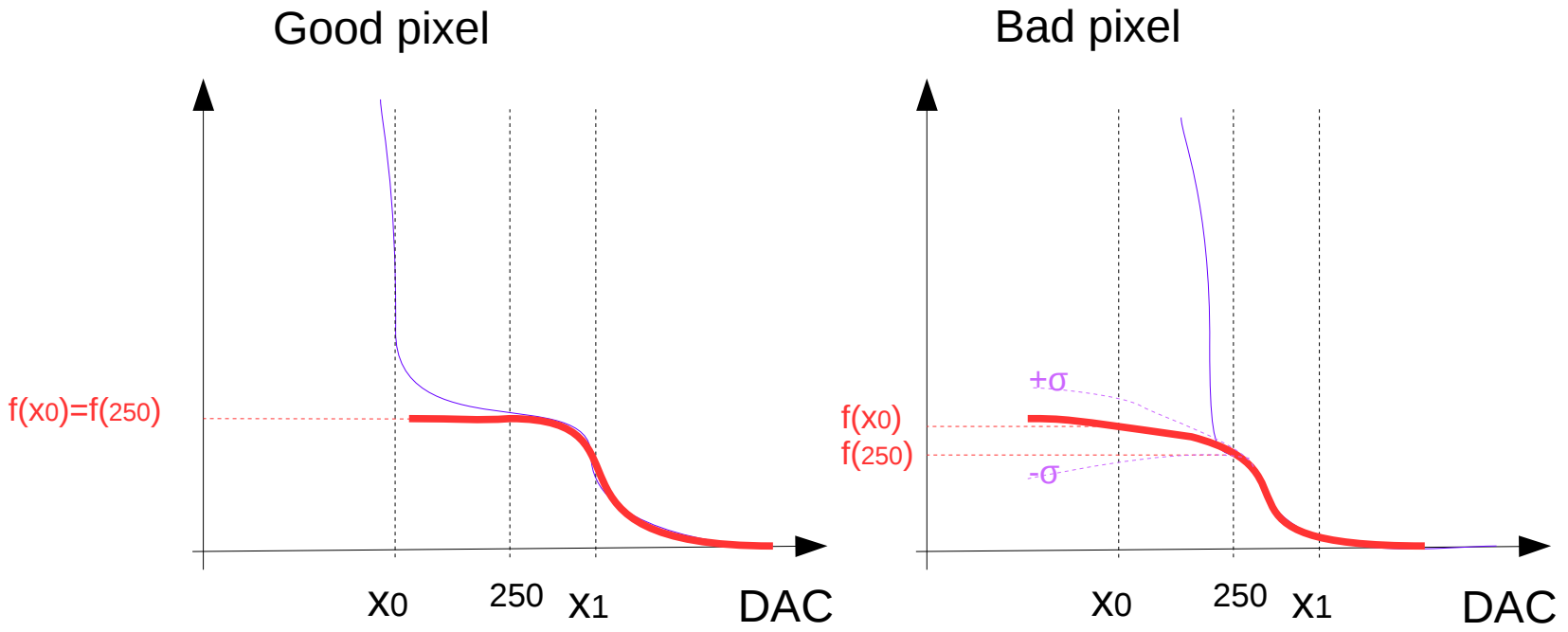
fluorescence induction in the atmospheric Nitrogen because electrons of the electromagnetic component of the EAS.

$$e^- + N_2 \rightarrow N_2^{*+} + e^- \quad (+e^-)$$

$$N_2^{*+} + e^- \rightarrow N_2^*$$

Electronic eficiency ε_e

-f is the fit-model function propose.
-The count estimate is f->f(x_0),this mean the function evaluate in the pieestal.
-θi are parameters of the fit function, its characterized each pixel.

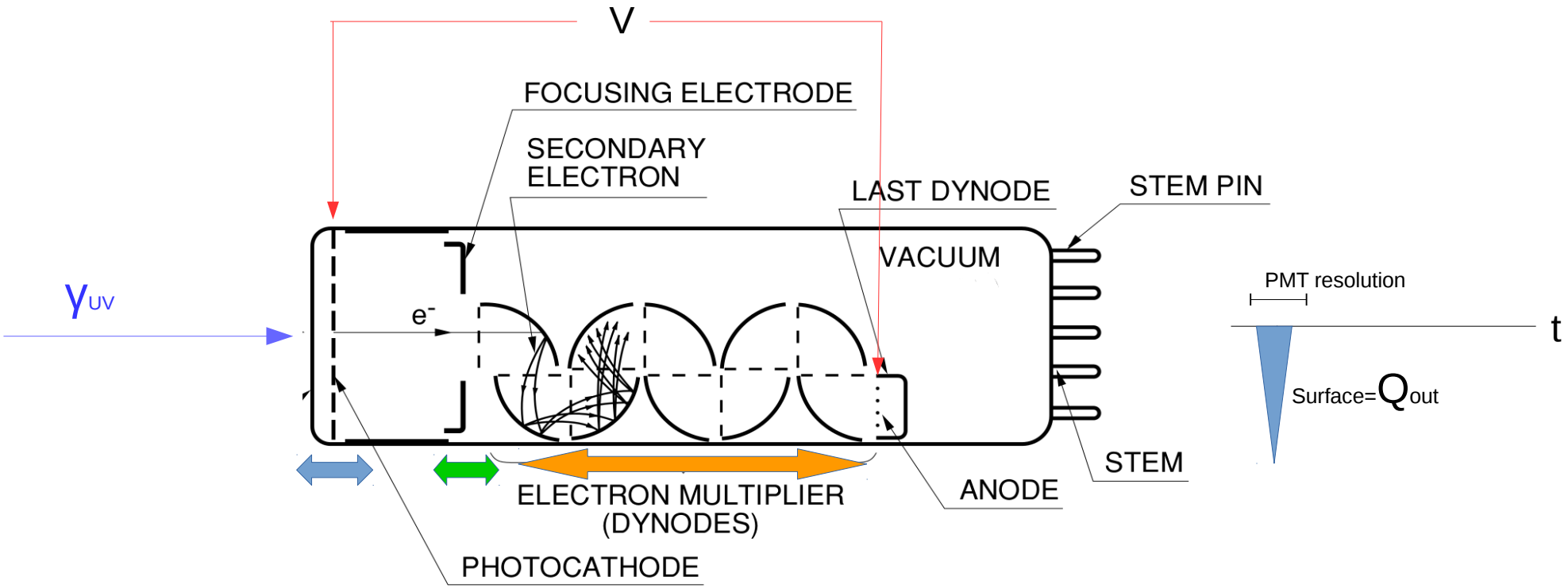


$$\varepsilon_e(x,x_0)=\frac{f(x,\theta_i)}{f(x_0,\theta_i)}$$

$$\varepsilon_e(250,x_0)=1 \qquad \varepsilon_e(250,x_0)<1$$

Determining ε_G , we can given an estimated value of counts/GTU of an error σ.
Later this would apply over the flight data.

detection of 1photon UV



$\varepsilon_{quant(\lambda)} = n_{pe\text{-}cath}/n_{\gamma_{UV}}$

$\varepsilon_{coll} = n_{pe\text{-}coll1°dyn}/n_{pe\text{-}cath}$

$\varepsilon_{Gain(V)}$=models diverses

$\mu = \mu(V)$ gain PMT

$\varepsilon_{abs} = \varepsilon_{quant(\lambda)} \times \varepsilon_{coll} \times \varepsilon_{Gain(V)}$

$n_{pe\_anode} = 1\gamma \times \varepsilon_{abs} \times \mu$

$(1.6\text{x}10\text{^-}19C) \times n_{pe} = Q_{out}$

Electronics workload ASIC