Simulazione background e logica di trigger di JEM-EUSO per implementazione su FPGA

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JEM-EUSO (Extreme Universe Space Observatory onboard Japanese Experiment Module of ISS)

Observation of high energy cosmics rays from space

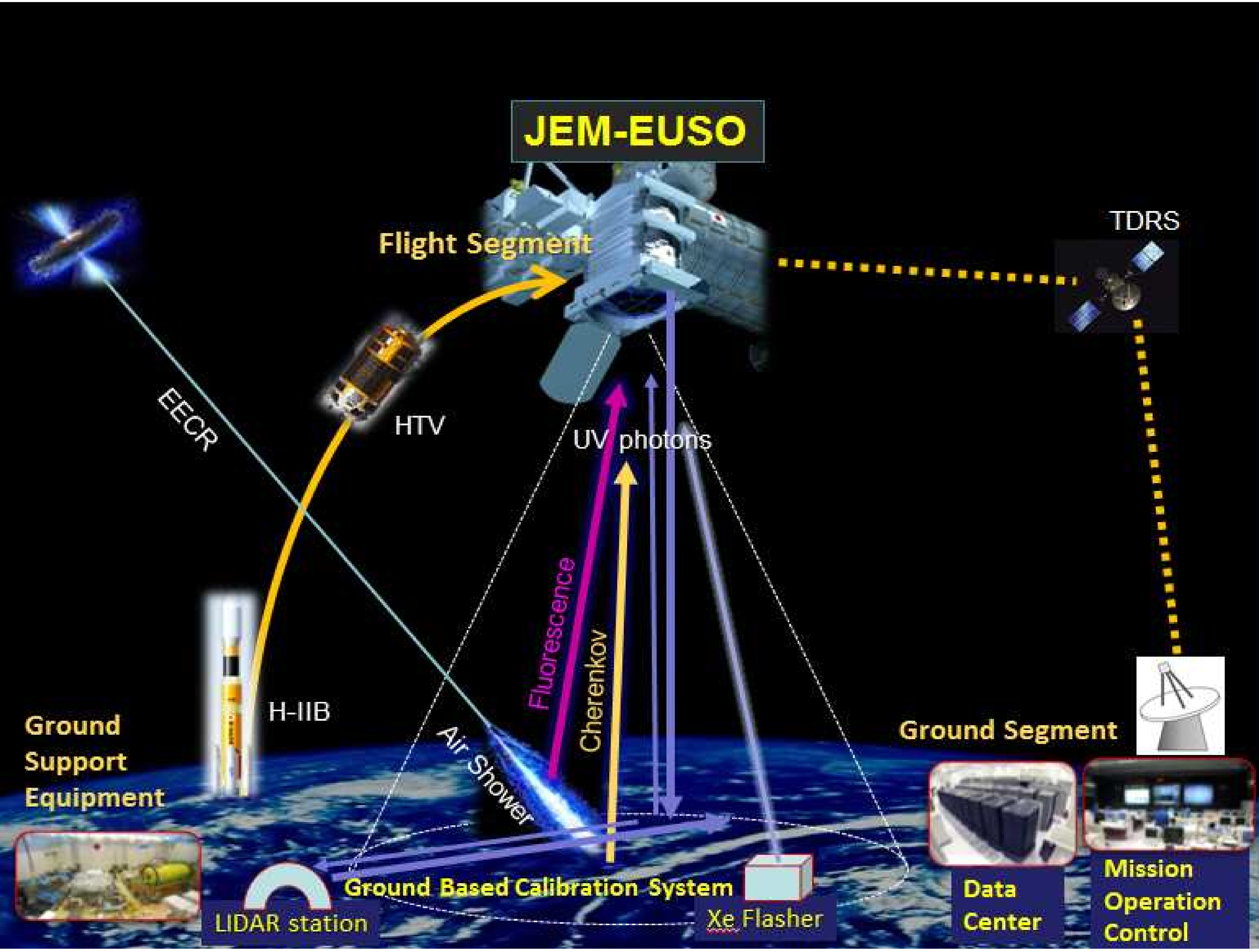
Science Objectives

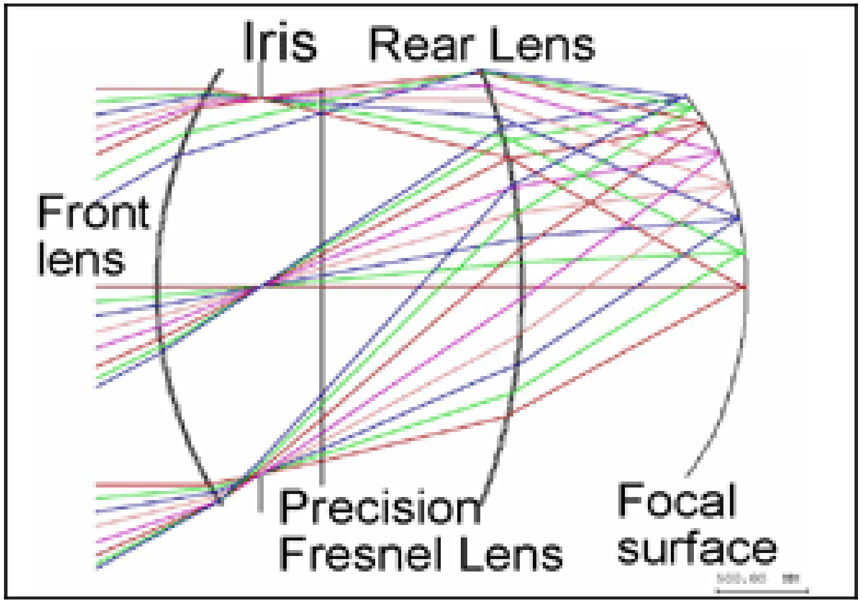
- **Main Objectives**:

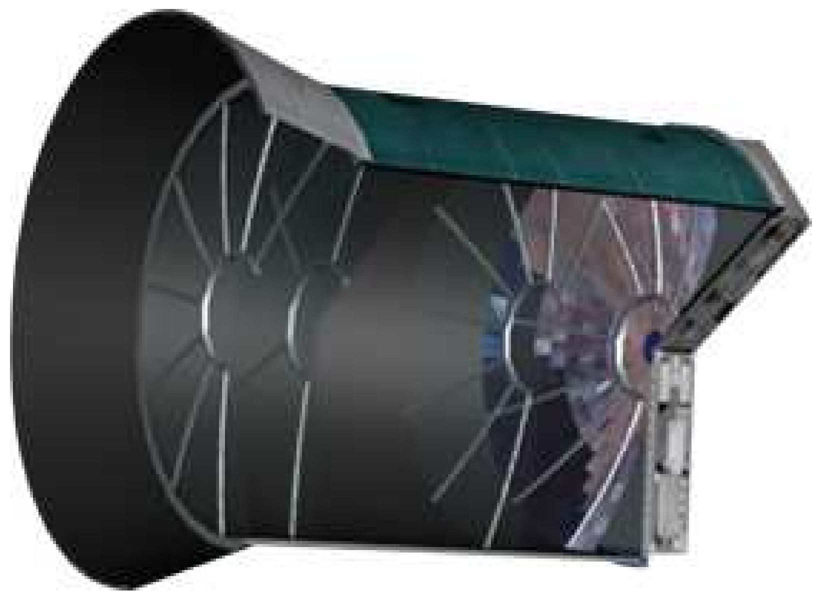
  Astronomy and astrophysics through particle channel with extreme energies > 5×10^{19} eV

  - Identification of individual **sources** by arrival direction
  - Measurement of the **energy spectrum** of individual sources
  - Understanding of the acceleration processes and source dynamic

- **Exploratory objectives**:
  - Detection of extreme energy **neutrinos**
  - Measurement of extreme energy **gamma rays**
  - Study the intensity and topology of Galactic and extragalactic magnetic fields
  - Global observation of **atmospheric** phenomena: nightglows, lightning and plasma discharges. meteors

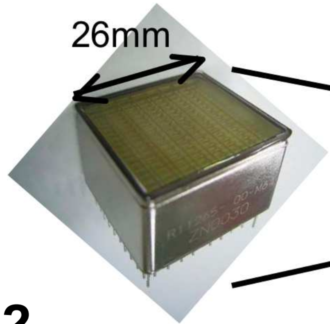

JEM-EUSO
Flight Segment
TDRS
EECR
HTV
UV photons
Fluorescence
Cherenkov
H-IIB
Air Shower
Ground Support Equipment
Ground Segment
Ground Based Calibration System
LIDAR station
Xe Flasher
Data Center
Mission Operation Control

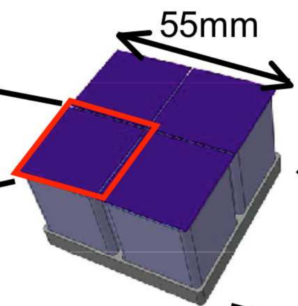




A double Fresnel lens module with 2.5m external diameters is the baseline optics for the JEM-EUSO Telescope, which observes the 300nm - 430nm optical bandwidth. Fresnel lenses (made of radiation hard light-weight plastic material) can provide a large-aperture, wide Field of View (FoV) system with reduced mass and low absorption. Its telescope has a full angle FoV of 60° and a 5 arcmin (=0.075°) angular resolution. This resolutio n corresponds approximately to (0.50 - 0.60) km on earth, depending on the ISS altitude

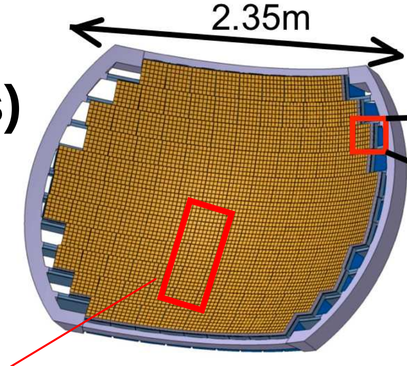
Main Components: Focal Surface Detector

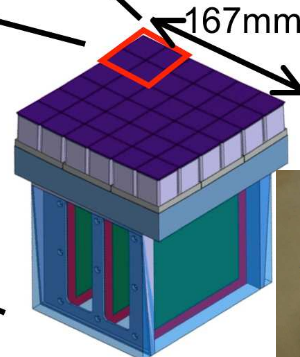


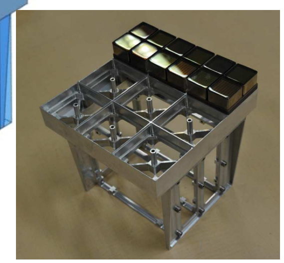


Elementary Cell (EC)
(2x2 PMTs = 256 pixels)

4932
MAPMTs
(8x8 pixels)







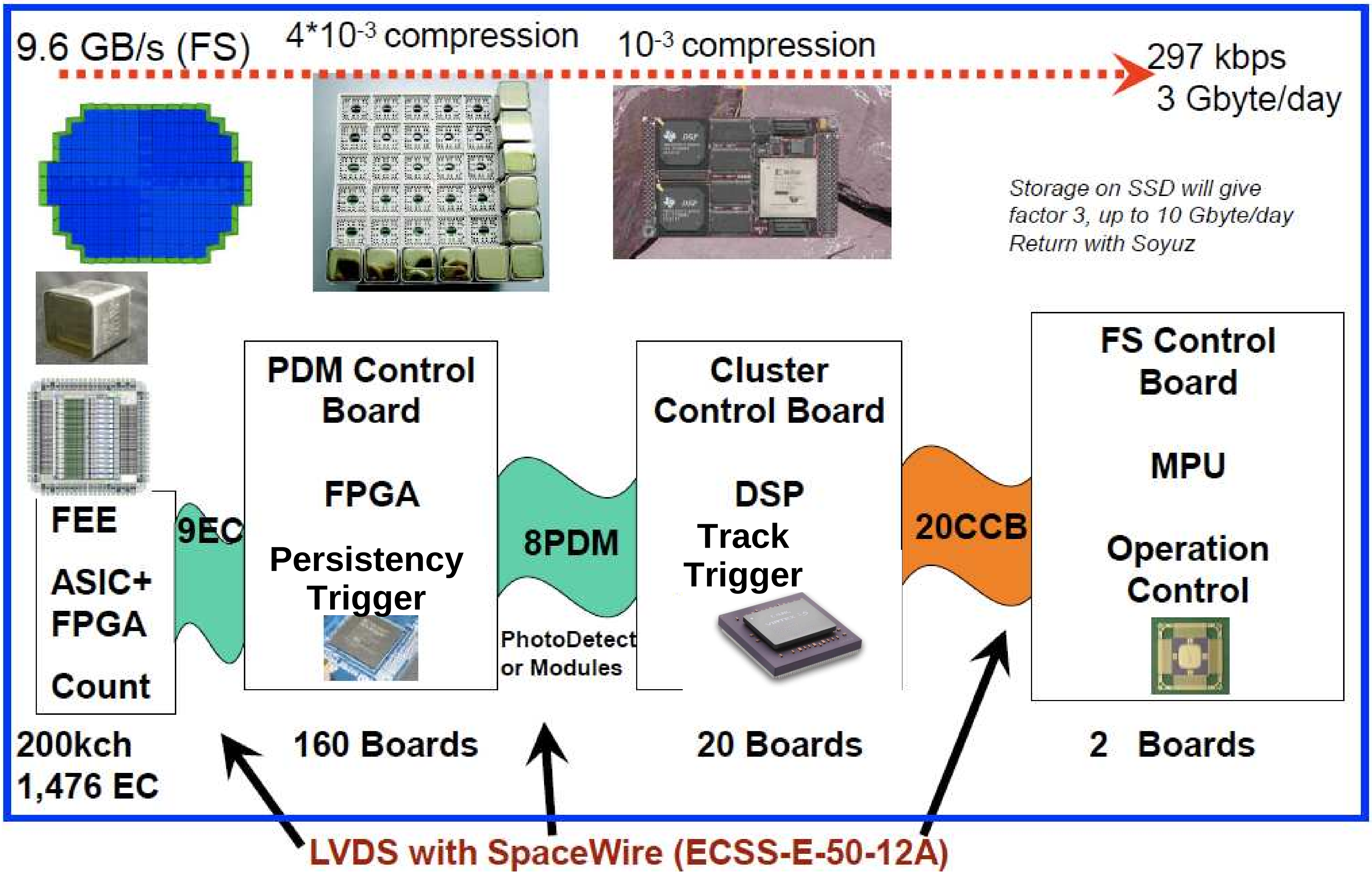
Focal Surface detector
137 PDMs
= 0.3M Pixels

Photo-Detector Module (PDM)
(3x3 ECs = 36 PMTS
2,304 pixels)

1 High Voltage / PDM

Wavelength range : (300-430) nm

JEM-EUSO DAQ – Data reduction block scheme



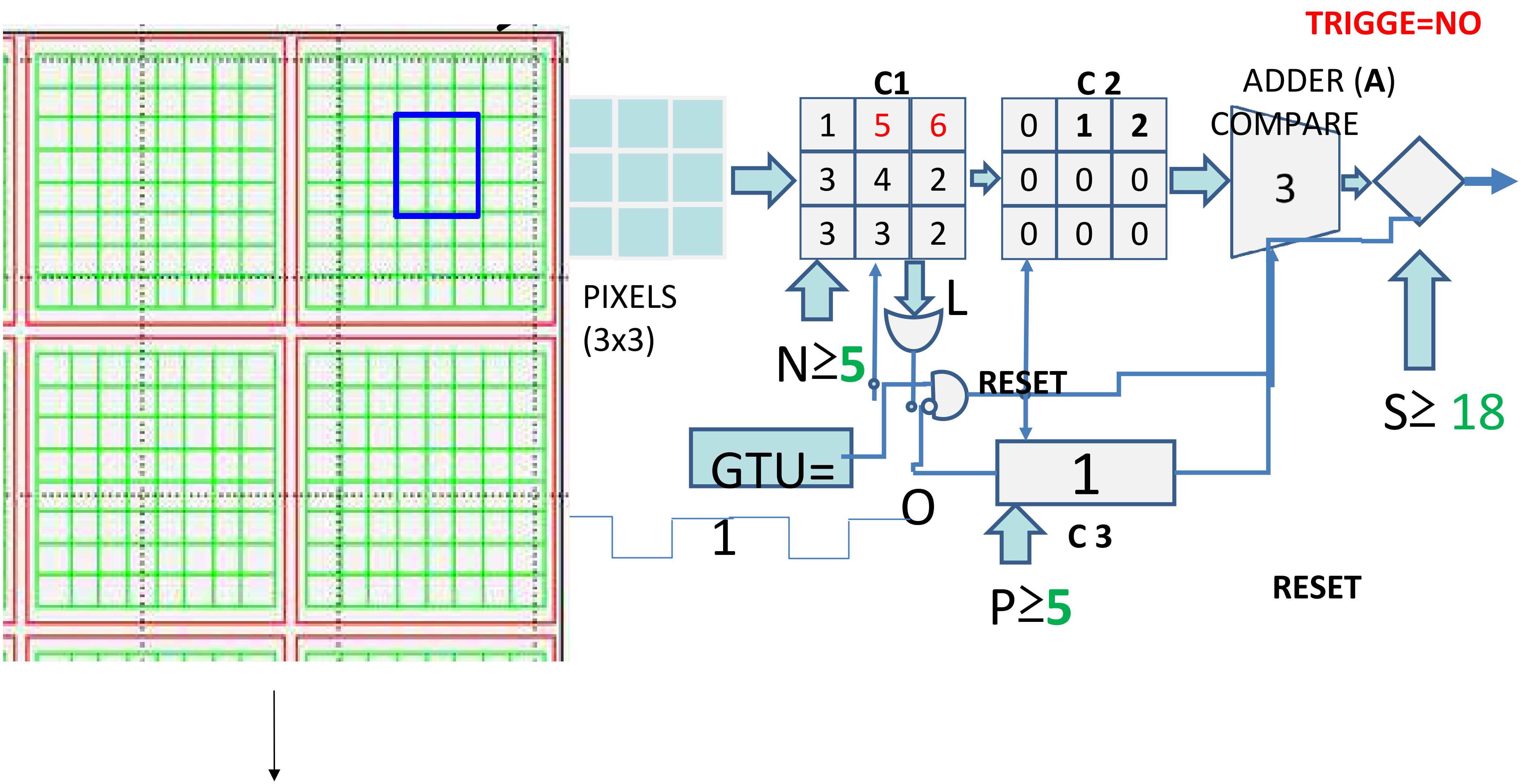
We work on the first-level trigger indicating signal' s increase compared with background's standard condition

- Standard Background Value (on the oceans in absence of moon light):

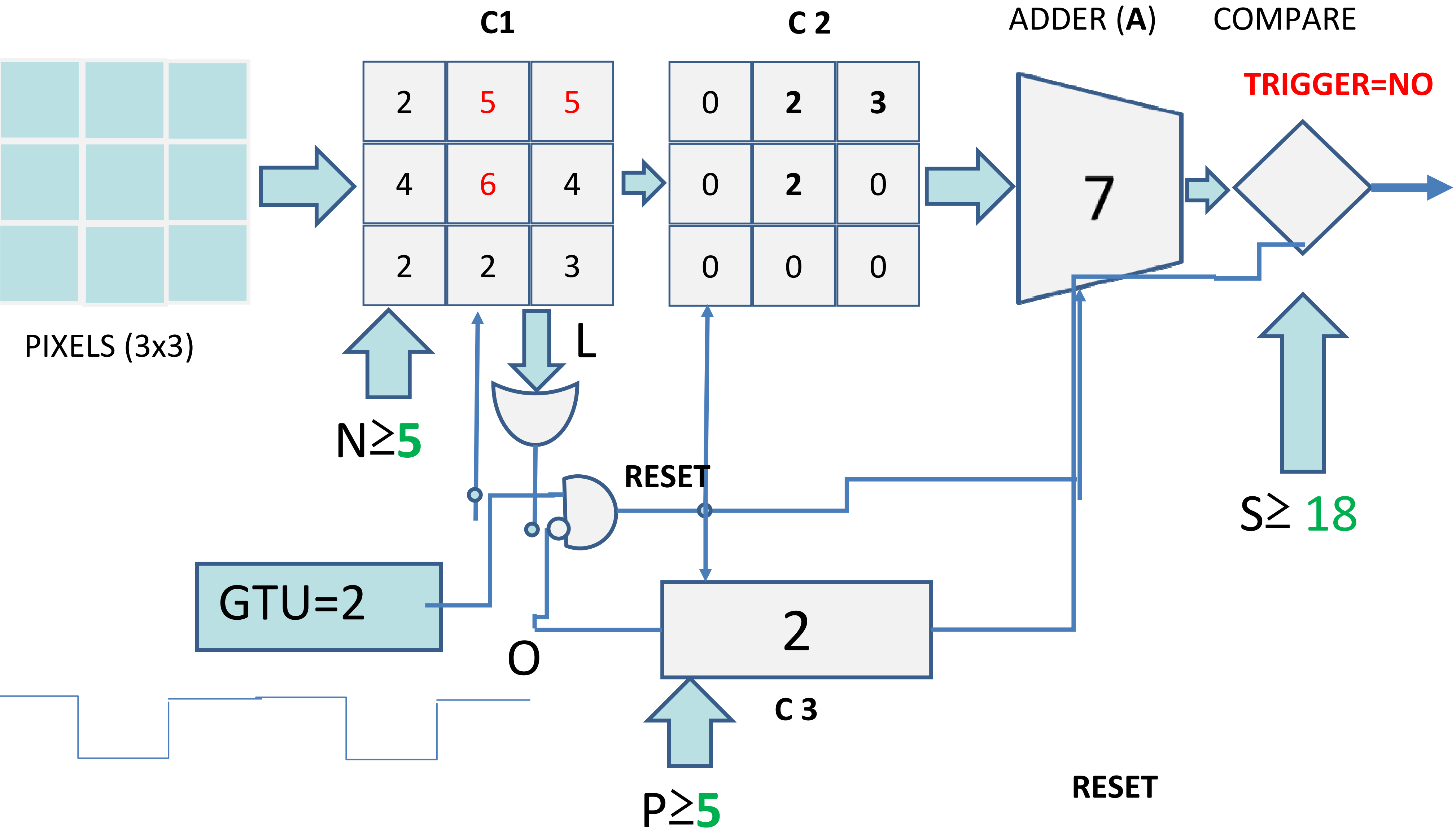
500 ph/(m²·ns·sr)=1.4 phe/pix/GTU

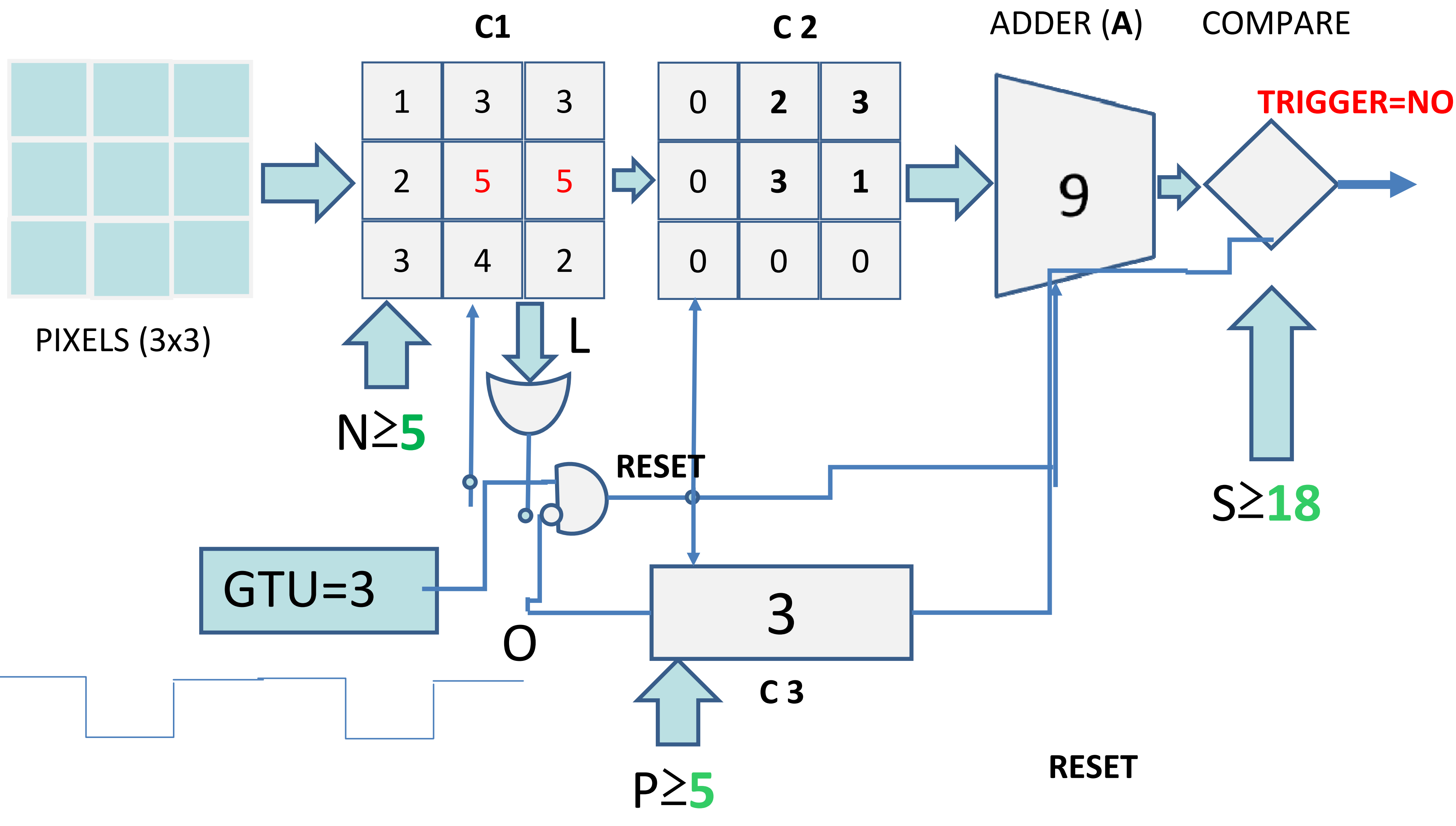
(GTU = 2.5 μs)

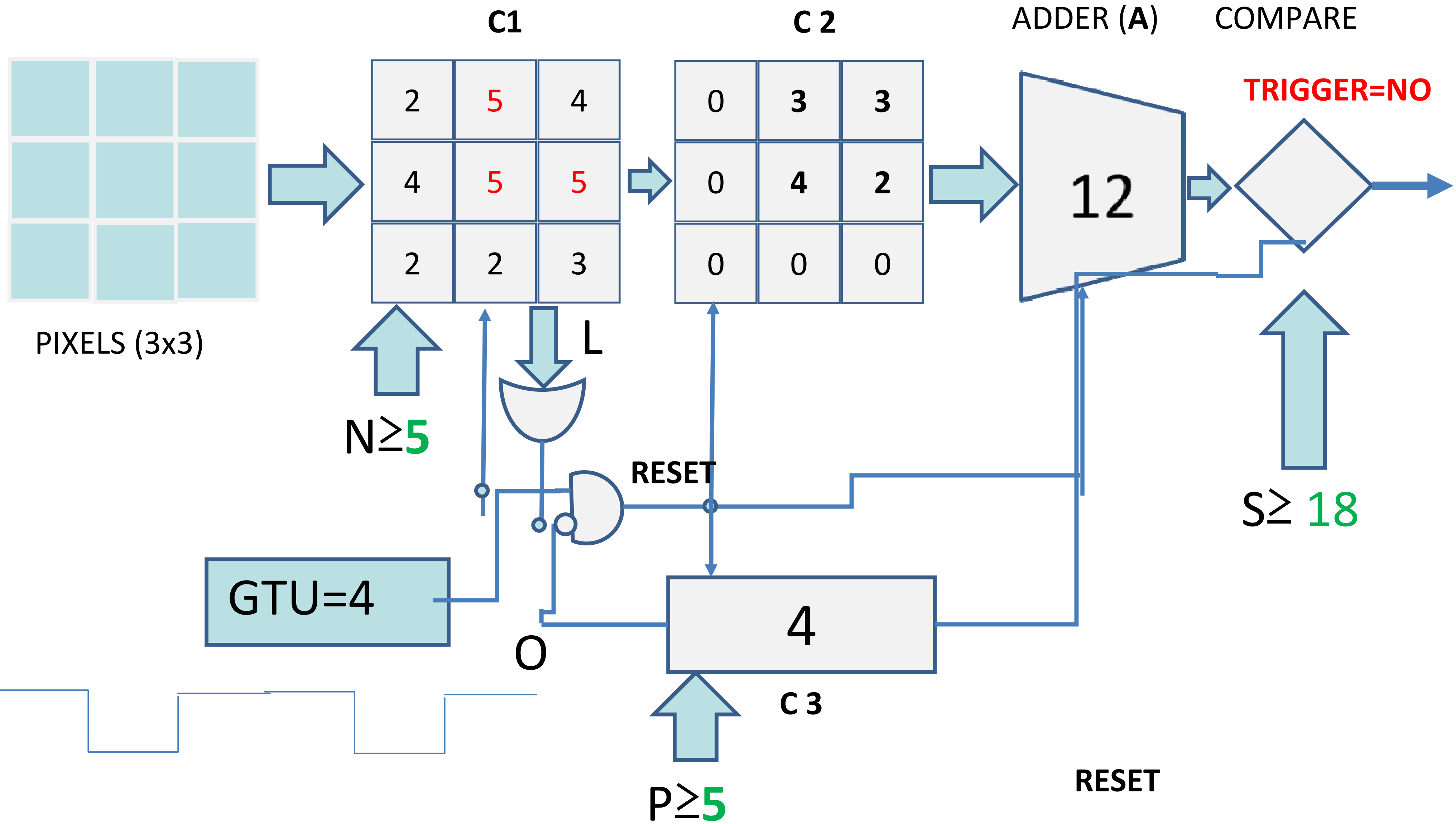
EXAMPLE:TRIGGER

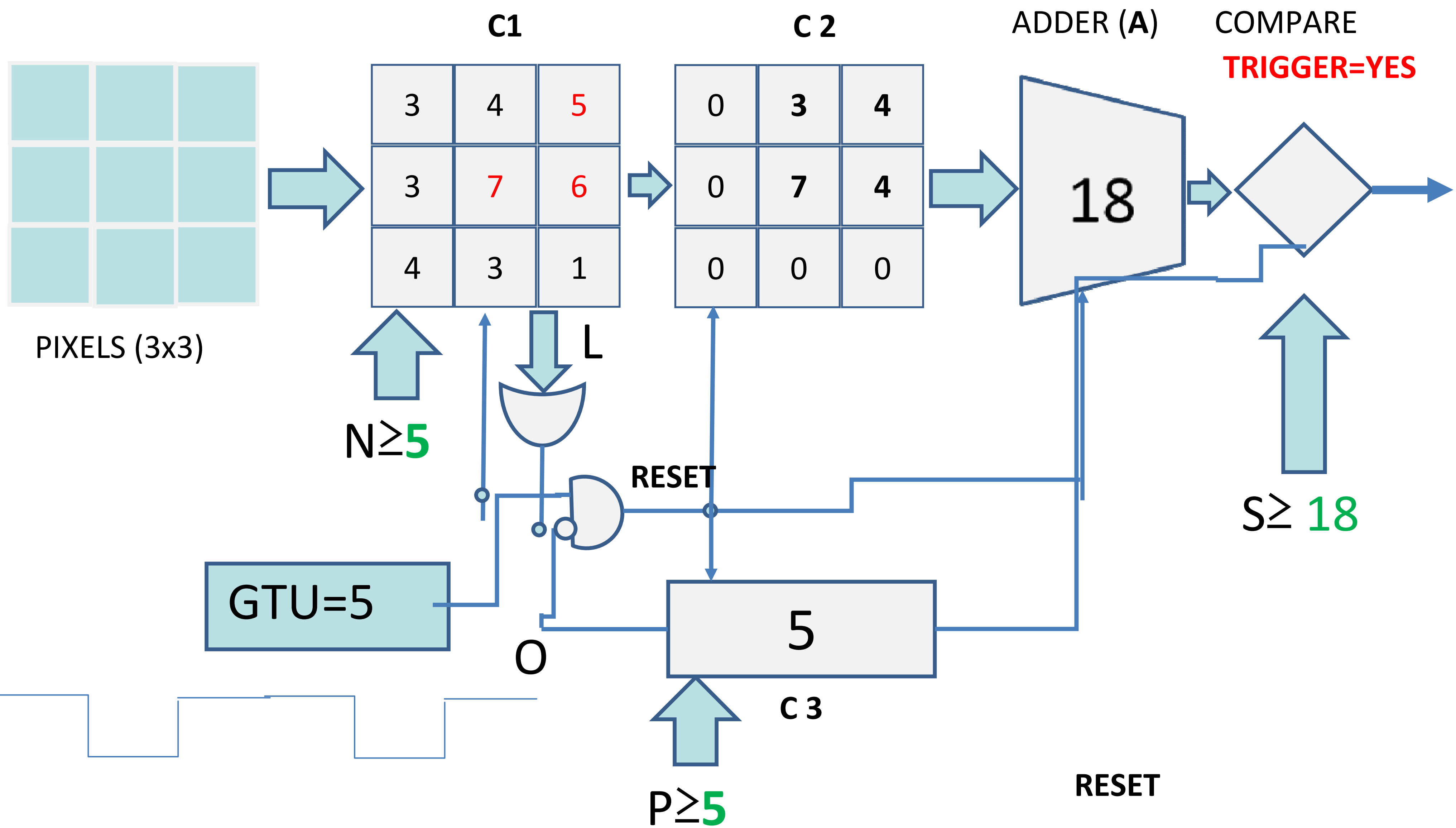


Elementary Cell (256 pixels)

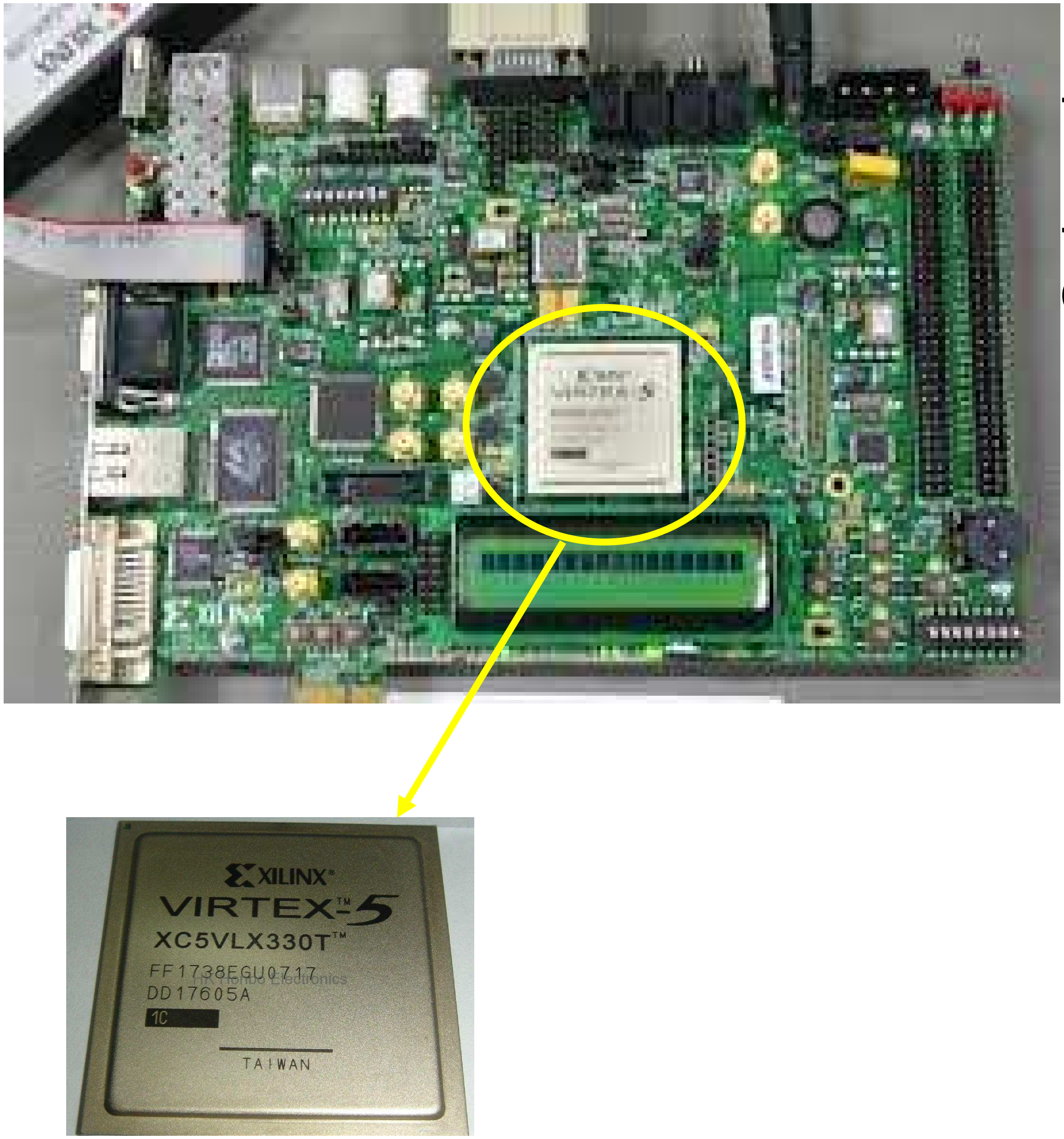

C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
2
5
5
4
6
4
2
2
3
0
2
3
0
2
0
0
0
0
7
PIXELS (3x3)
L
N≥5
RESET
S≥ 18
GTU=2
O
2
C 3
P≥5
RESET


C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
1
3
3
2
5
5
3
4
2
0
2
3
0
3
1
0
0
0
9
PIXELS (3x3)
L
N≥5
RESET
S≥18
GTU=3
3
O
C 3
P≥5
RESET


C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
2
5
4
4
5
5
2
2
3
0
3
3
0
4
2
0
0
0
12
PIXELS (3x3)
L
N≥5
RESET
S≥ 18
GTU=4
4
O
C 3
P≥5
RESET



C1
C 2
ADDER (A)
COMPARE
TRIGGER=YES
3 4 5
3 7 6
4 3 1
0 3 4
0 7 4
0 0 0
18
PIXELS (3x3)
L
N≥5
RESET
S≥ 18
GTU=5
5
O
C 3
P≥5
RESET



- algorithm tested on FPGA

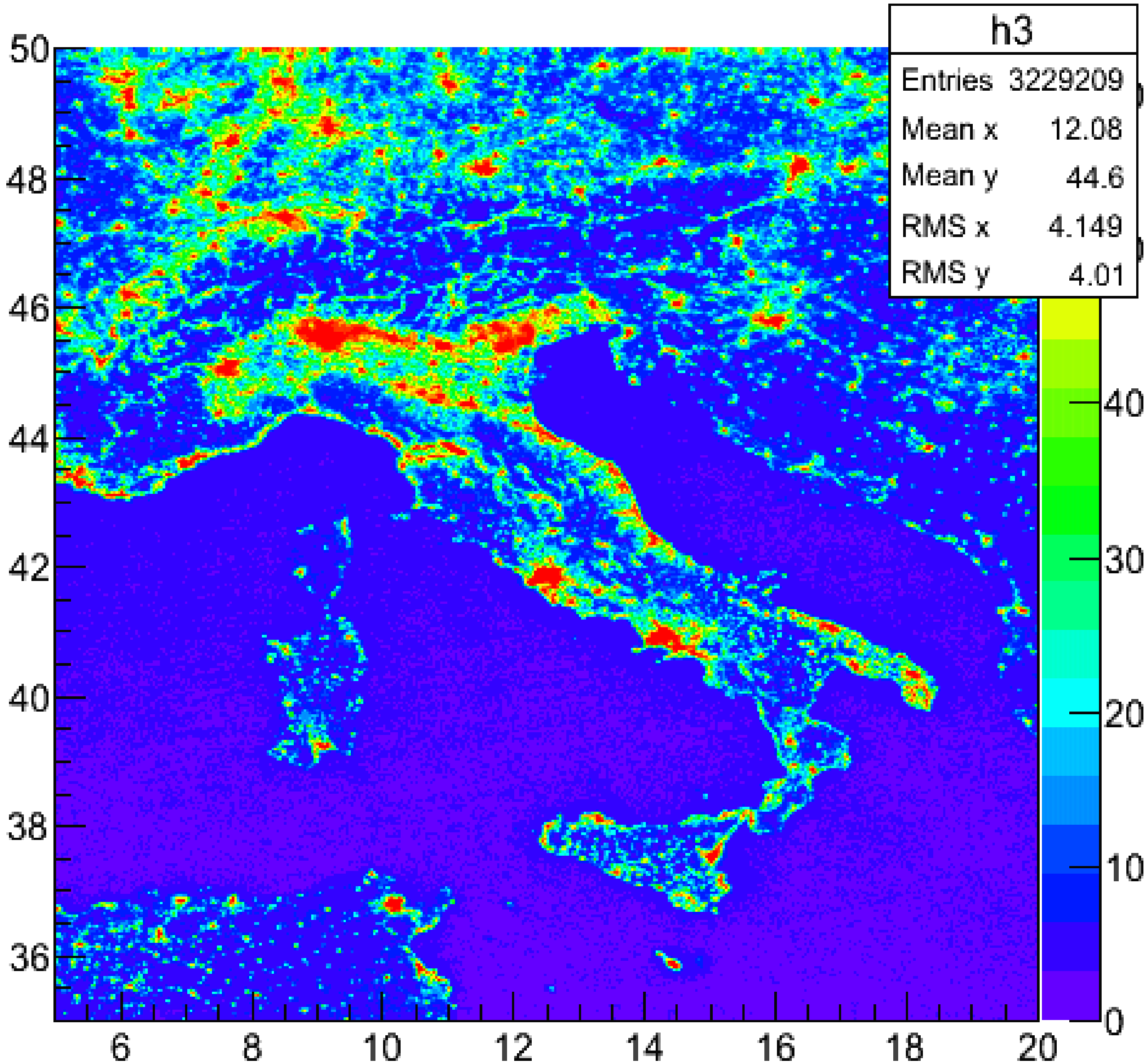
- rate of trigger for standard conditions background is ~ Hz

- Thresholds values set considering the average of each pixels counts on temporal range ~ ms

- How to set up the threshold value when the UV background changes. This appens for examplein corrispondence of a city.

- Try to understand how the UV backgrounds could changes

Background's simulation of cities with map created using data from DMSP(Defense Meteorological Satellites Program)



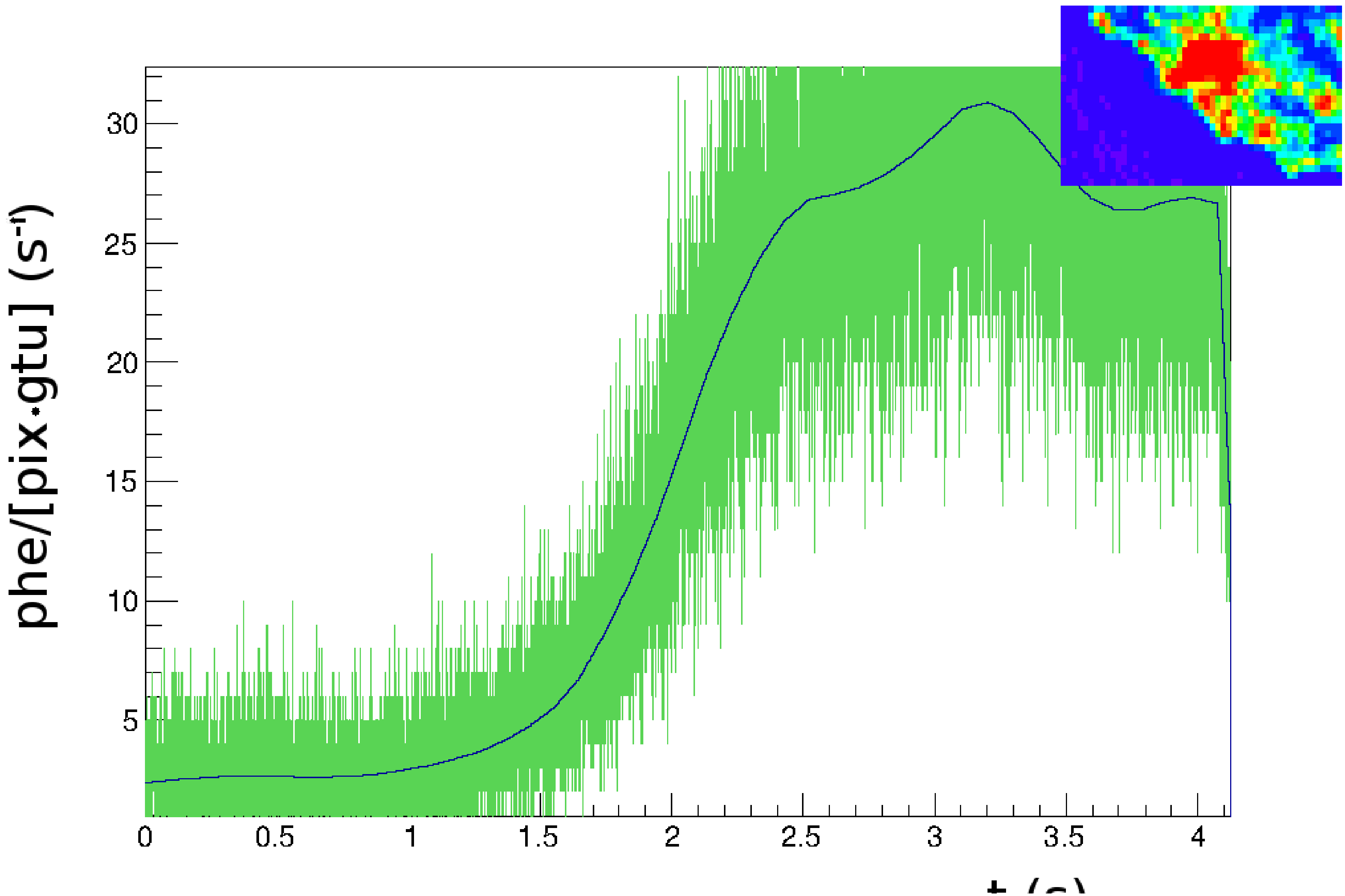
- Visible pixels are relative value ranging from 0 to 63

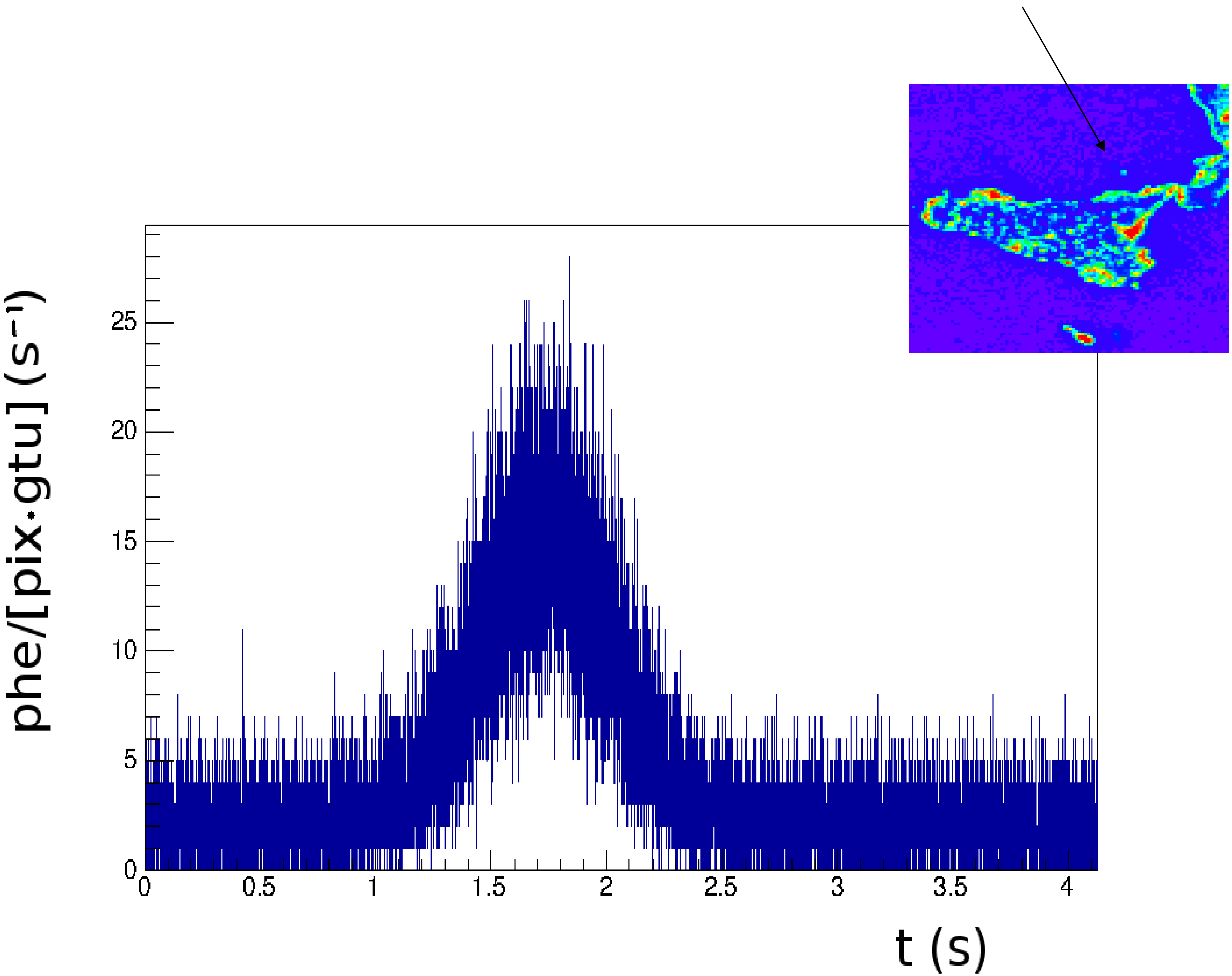
- the visible telescope is sensitive to radiation from (0.35-2) μm

- telescope resolution : 0.60 km

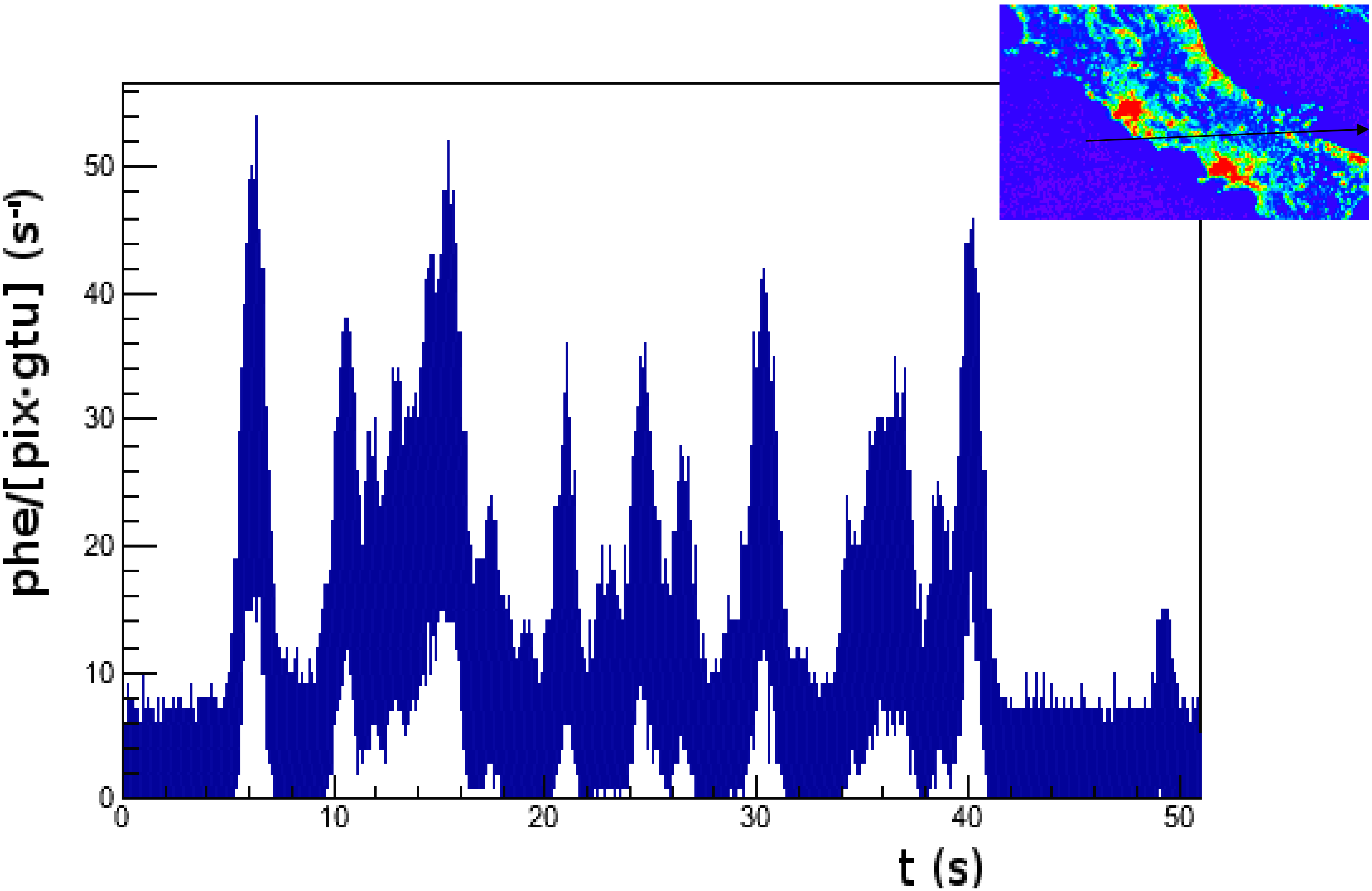
$$\frac{V_{DMSP}\ x}{2.7} = \frac{}{1.4(\mathrm{phe/pix/gtu})}$$

Background simulation of Rome Area
Example of 1 pixel



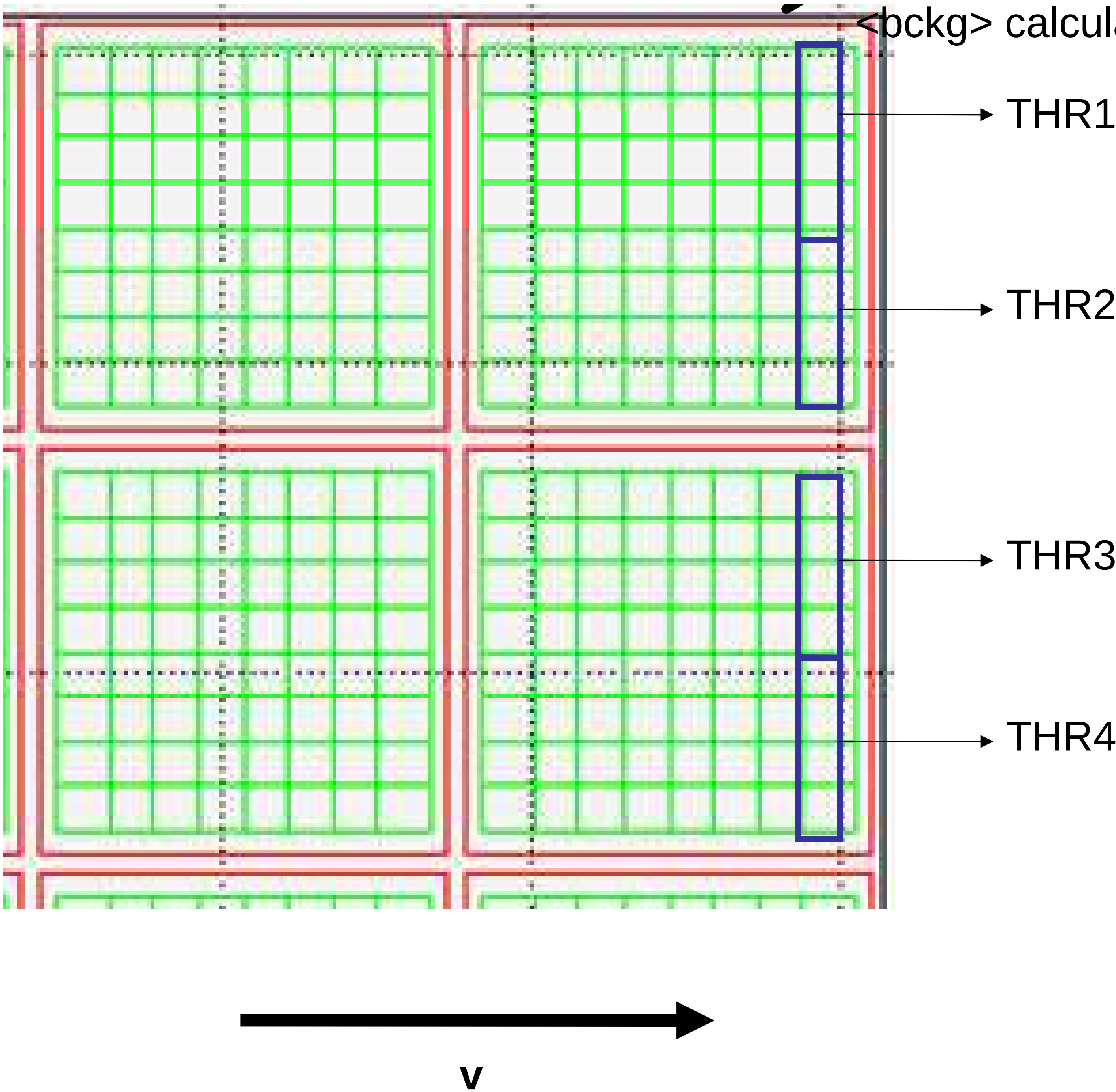


phe/[pix·gtu] (s⁻¹)
0
5
10
15
20
25
0
0.5
1
1.5
2
2.5
3
3.5
4
t (s)



phe/[pix·gtu] (s⁻¹)
0
10
20
30
40
50
t (s)

<bckg> calculated on 1024GTU (2.56ms)



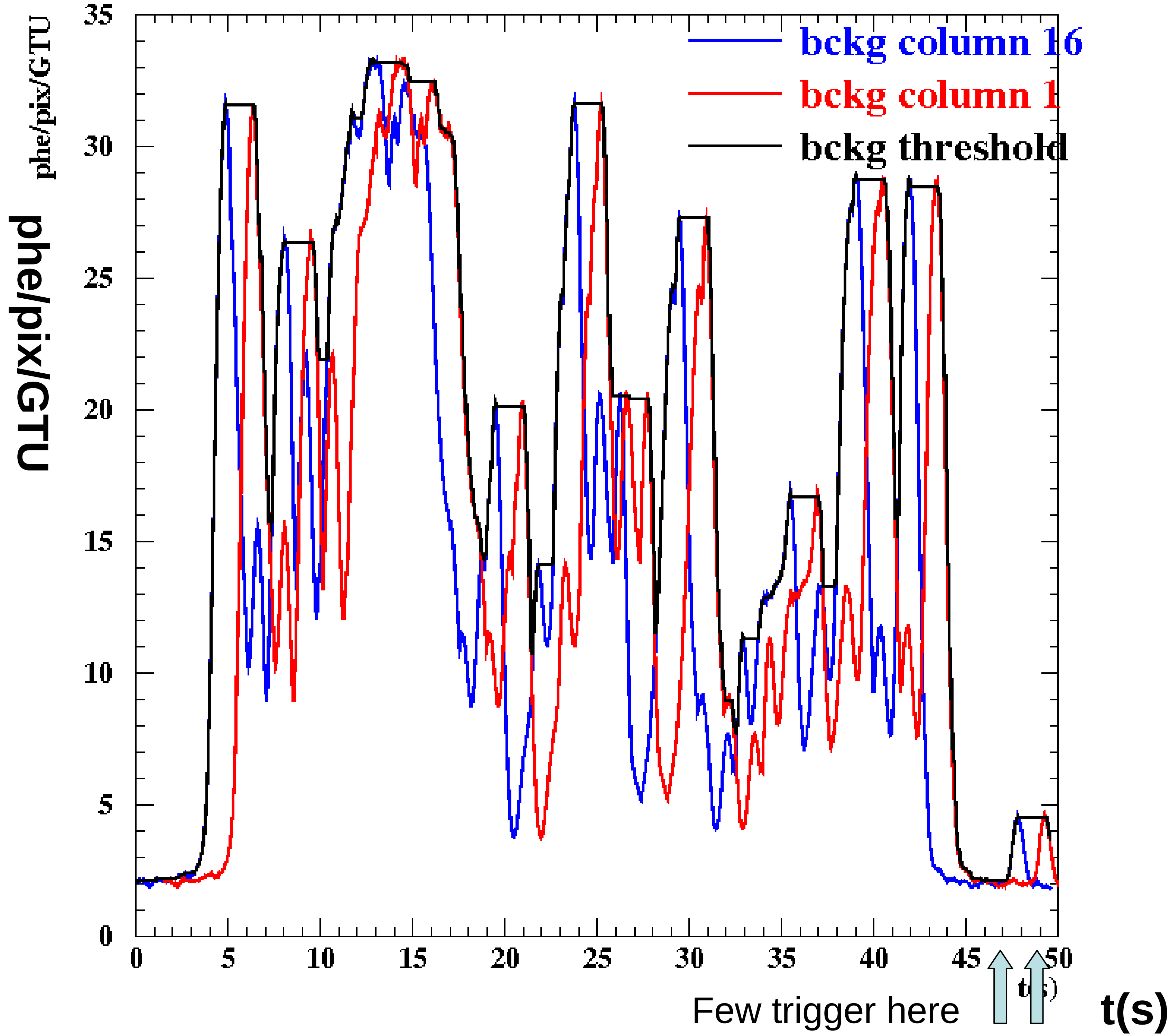
Take the highest value among THR1-4 = THR_{1024}

If THR_{1024} > THR

=> THR = THR_{1024}

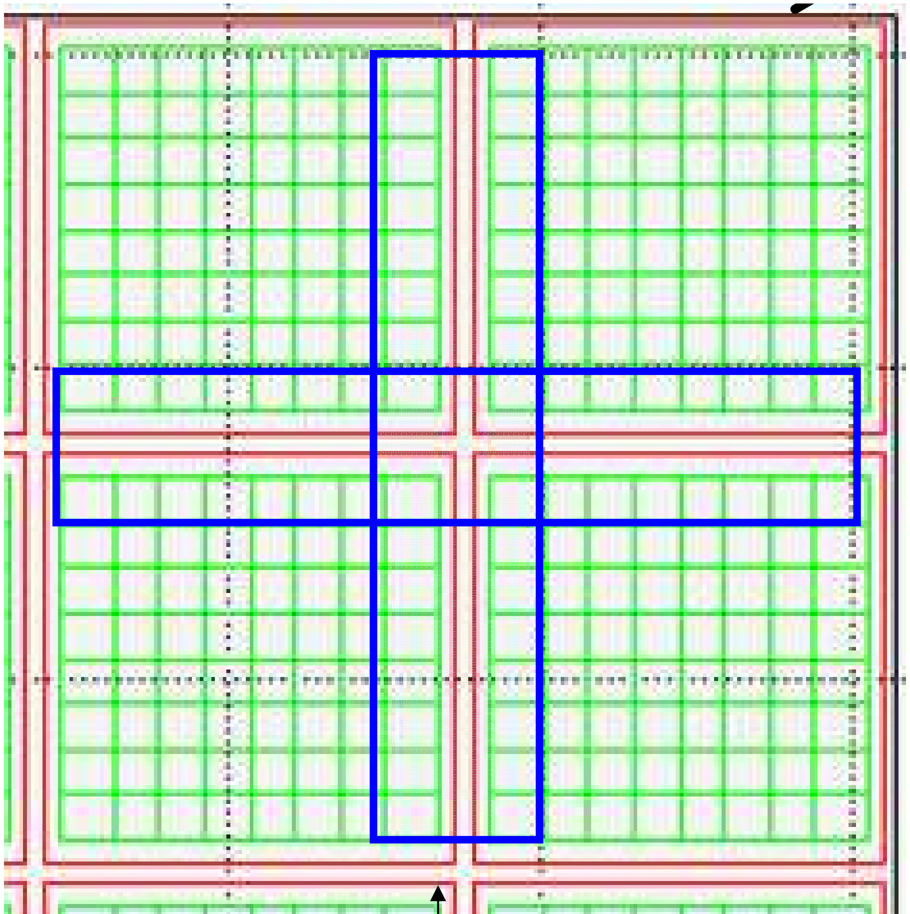
Every 31 cycles (=79.36ms) store THR1024 in a 16 values deep cycle memory.

This is the time that a pixel takes to change completely its FoV. In this way we have 16 values that give the <bckg> in each column of pixels



phe/pix/GTU
phe/pix/GTU
bckg column 16
bckg column 1
bckg threshold
0
5
10
15
20
25
30
35
0
5
10
15
20
25
30
35
40
45
50
t(s)
Few trigger here
t(s)

Optimization of power consumptions for FPGA



1 EC

FPGA use : 9 %

Static Power: 3131 mW

Dynamic Power : 149 mW

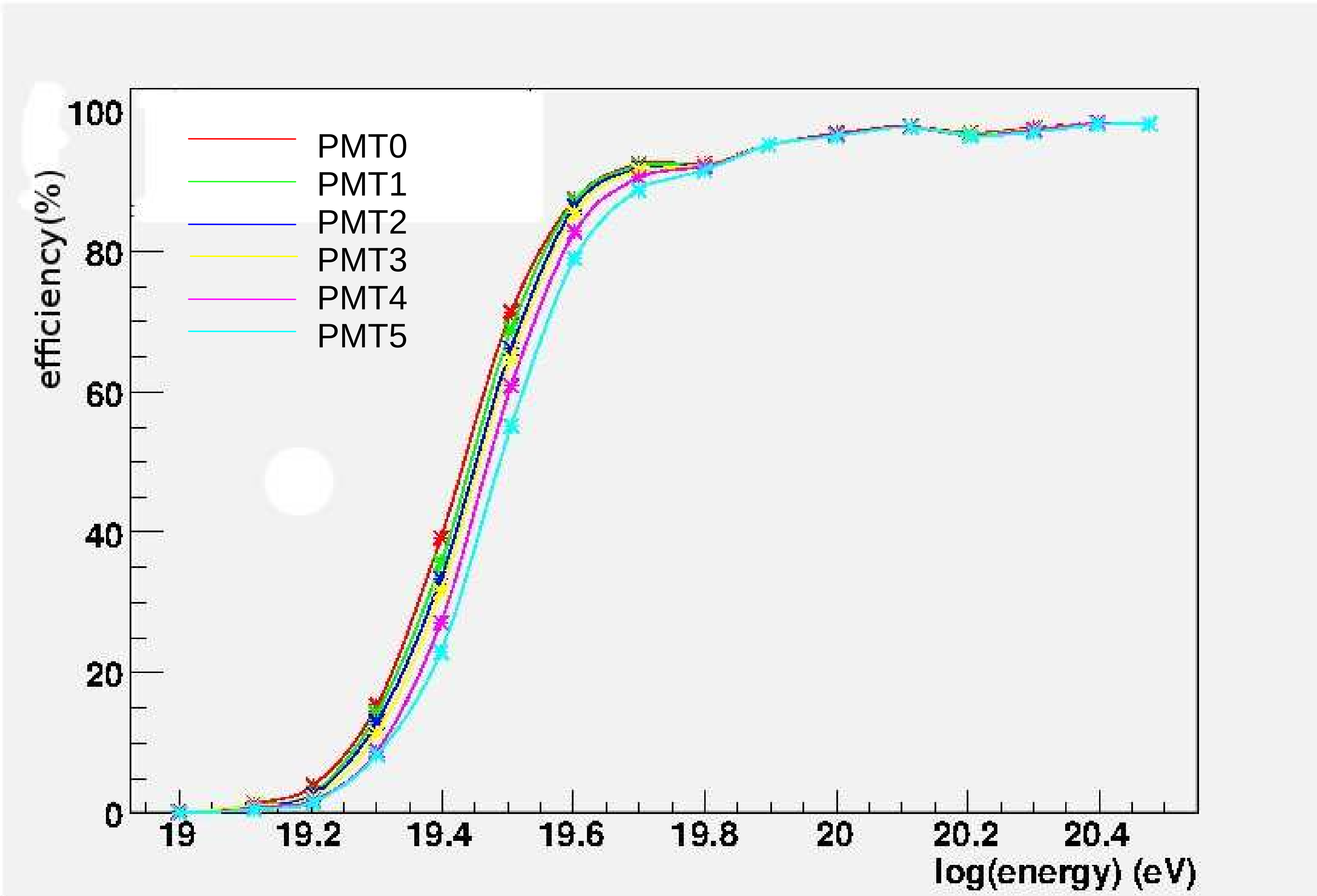
1 PDM (9 EC)

FPGA use : 80 %

Total Power: 4768 mW

Dynamic Power : 1588 mW

PMT1 Configuration → FPGA use: 60%



PMT0
PMT1
PMT2
PMT3
PMT4
PMT5
efficiency(%)
100
80
60
40
20
0
19
19.2
19.4
19.6
19.8
20
20.2
20.4
log(energy) (eV)

Conclusions

- it was simulated a change of background due the presence of cities

- it was realized that the trigger algorithm was inefficient for a sudden background increase

- trigger algorithm has been modified in order to have a dynamic setting of the threshold value adapting to the Background conditions

- to limit the consumption of FPGA resources new configuration were tested, PMT1 in particular does not preclude the trigger efficiency

Ringraziamenti

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Dott. Luca Latronico