JEM-EUSO

Extreme Universe Space Observatory onboard Japanise Experiment Module

Issues related to the observation of cosmic rays and meteors from space by means of the JEM-EUSO telescope

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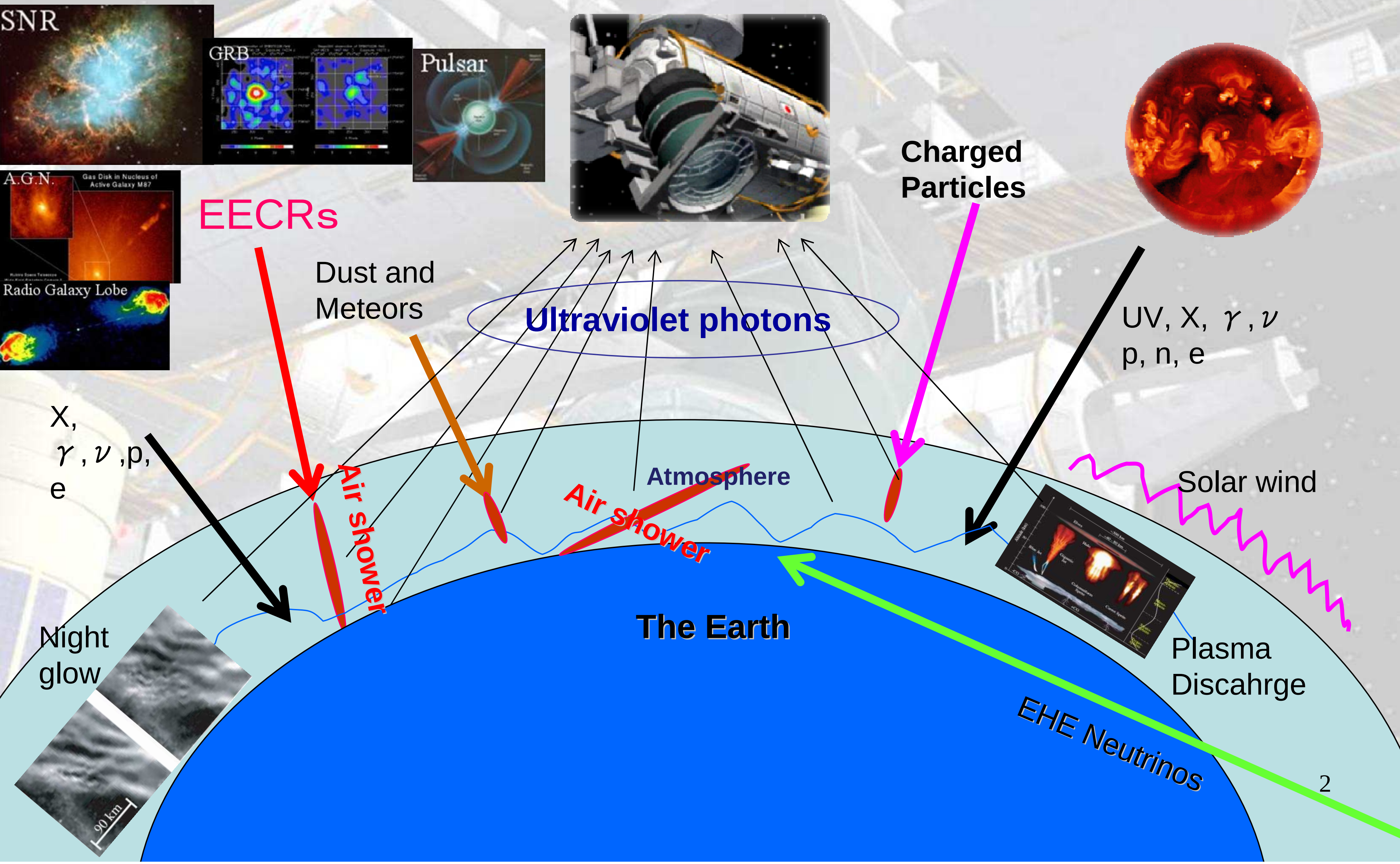
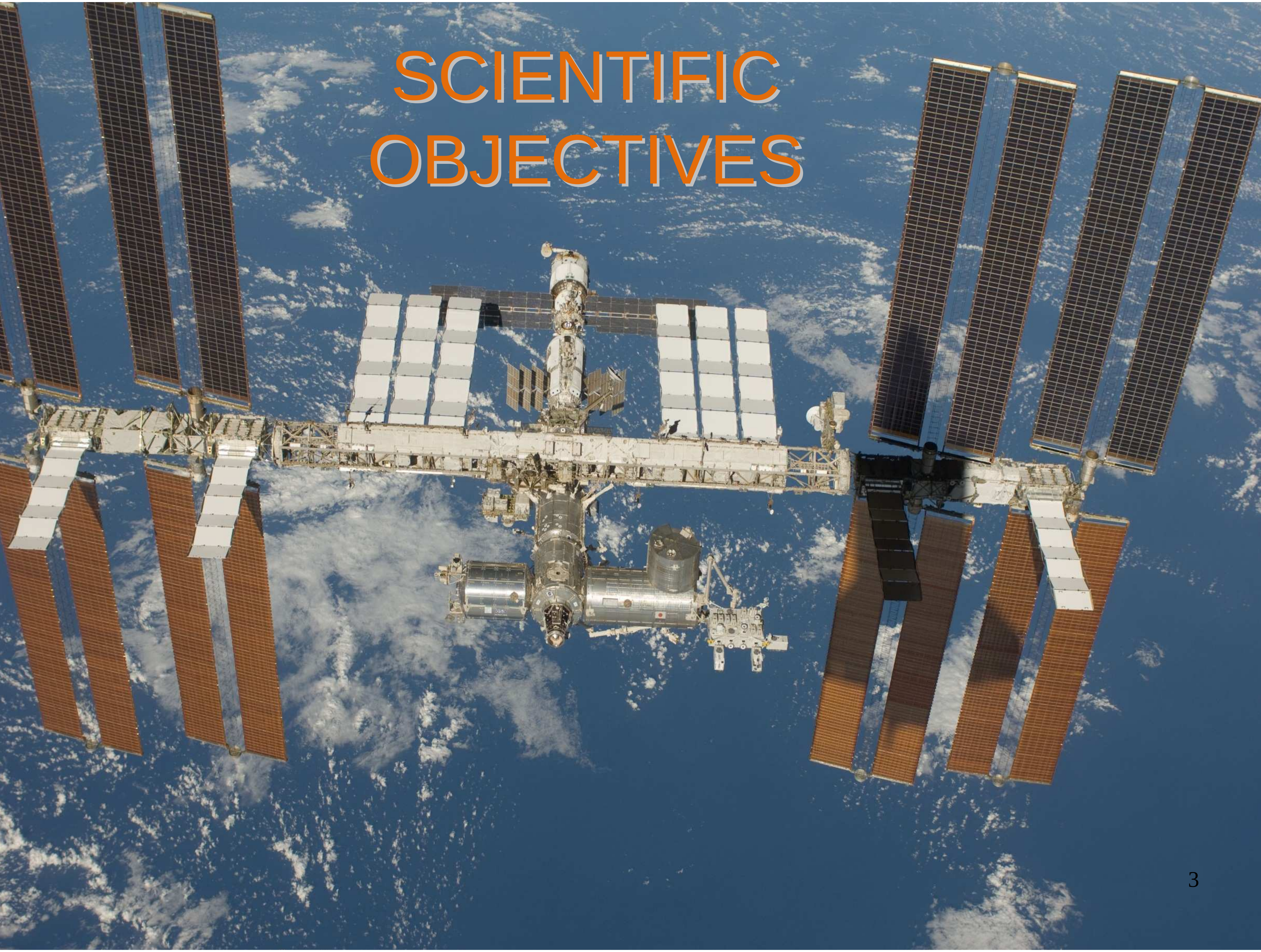
RELATORE: dott. M. E. Bertaina

CONTRORELATORE: prof. D. Marocchi

JEM-EUSO is the Astronomical Earth Observatory



SCIENTIFIC OBJECTIVES



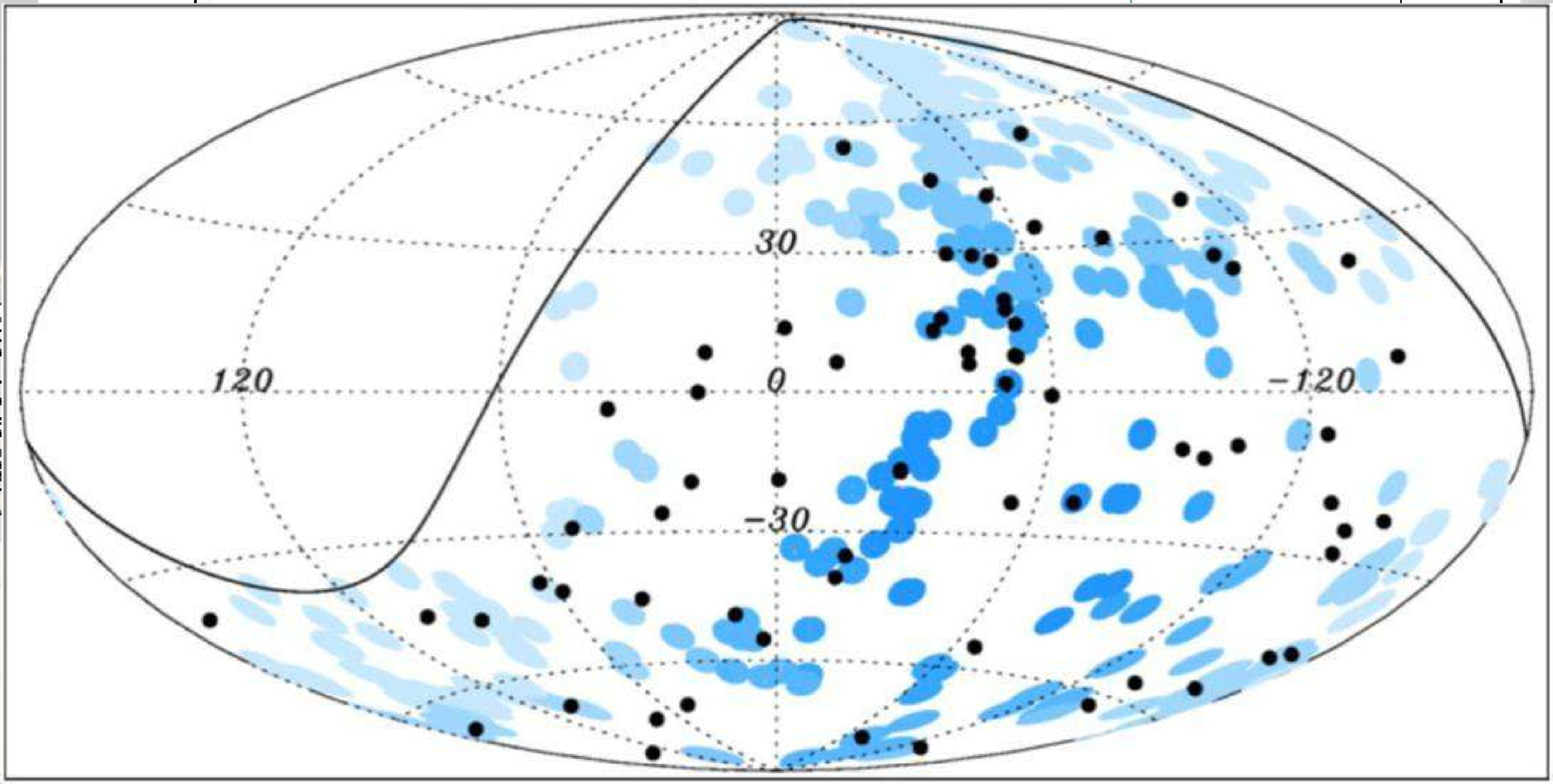
Main Objective *:*

Astronomy and astrophysics through particle channel with extreme energies (> $5 \cdot 10^{19}$ eV)

- Possible identification of the particle and energy sources based on the analysis of the arrival direction
- Possible identification of the acceleration and radiation mechanisms with the measurement of energy spectrum from individual sources

Exploratory objective *:*

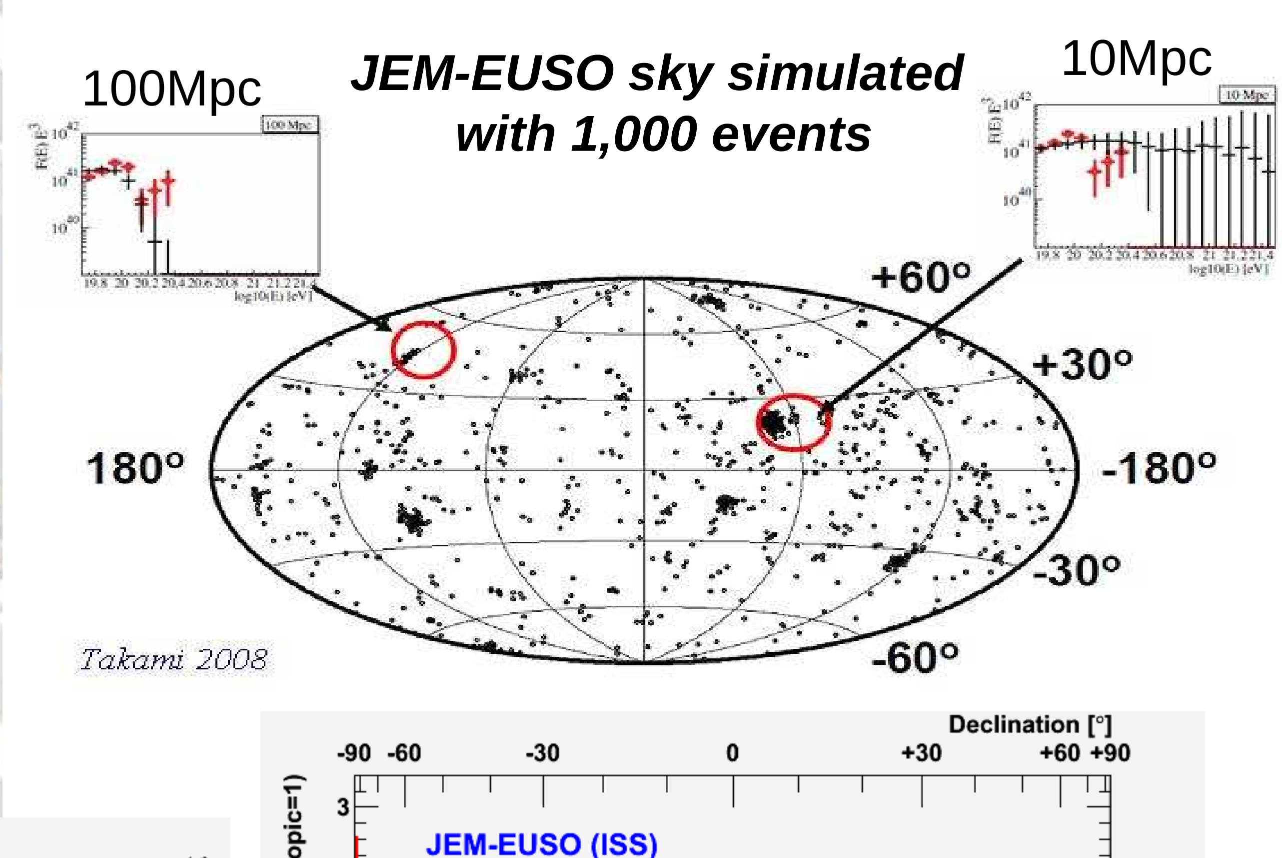
- Measurement of extreme energy gamma rays
- Detection of extreme energy neutrinos
- Estimation of the structure of galactic magnetic field and its intensity
- Identification of relativity and quantum gravitational effect
- Study of atmospheric luminous phenomena (meteors and TLEs)



From

Abreu P. et al. (Pierre Auger Collaboration), Update on the correlation of the highest energy cosmic rays with nearby extragalactic matter, Astroparticle Physics, 34, 314326 (2010)

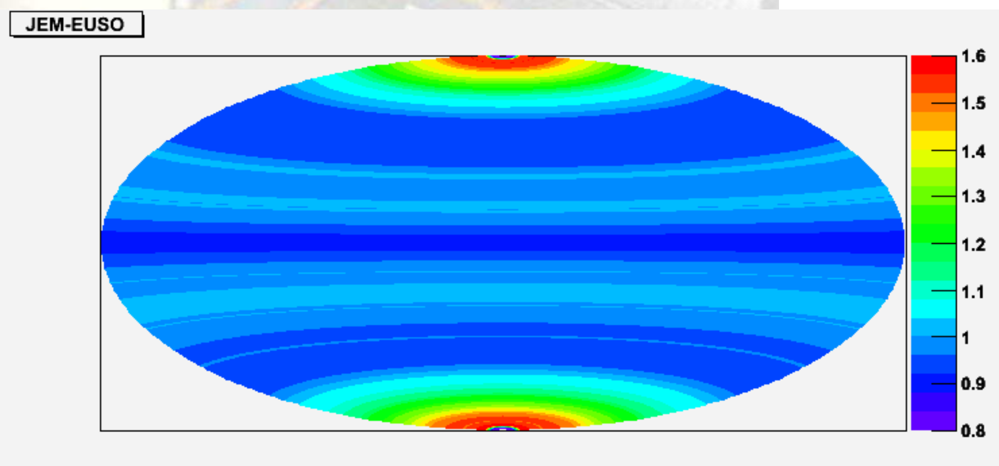
GOAL: detect 500 - 1000 events ≥ GZK energies

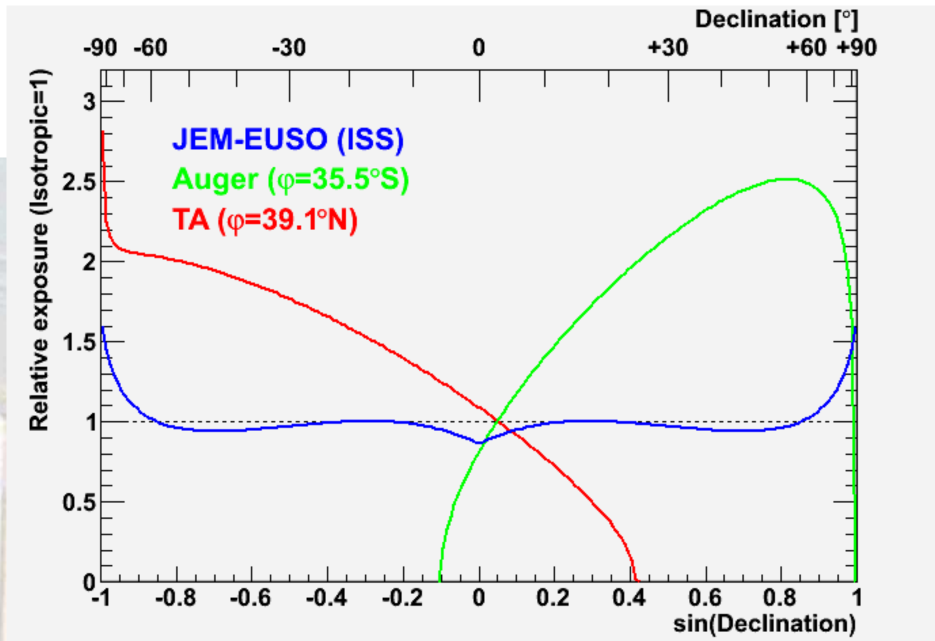


•Analysis of the arrival direction of particles
Uncertainty of the determination of the arrival direction: less than 2.5°

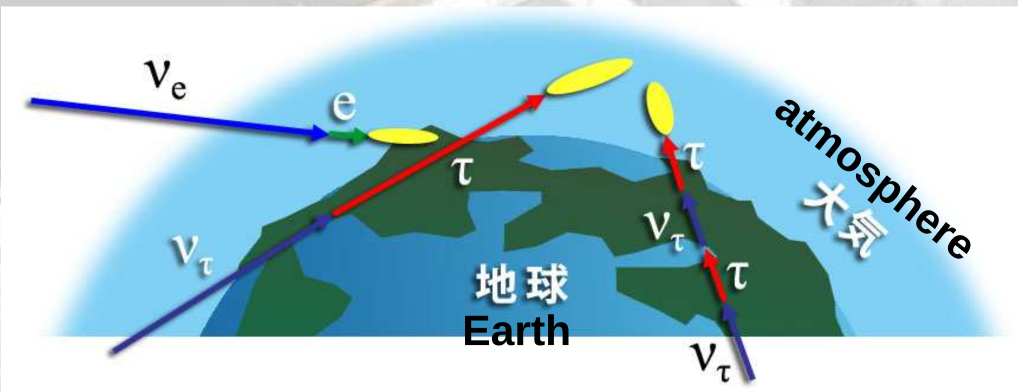
•Analysis of spectrum
Uncertainty of the energy determination: less than 30%

•Identification of Hadron/ photon/ neutrino:
Uncertainty of the Xmax determination: <120 g /cm^2

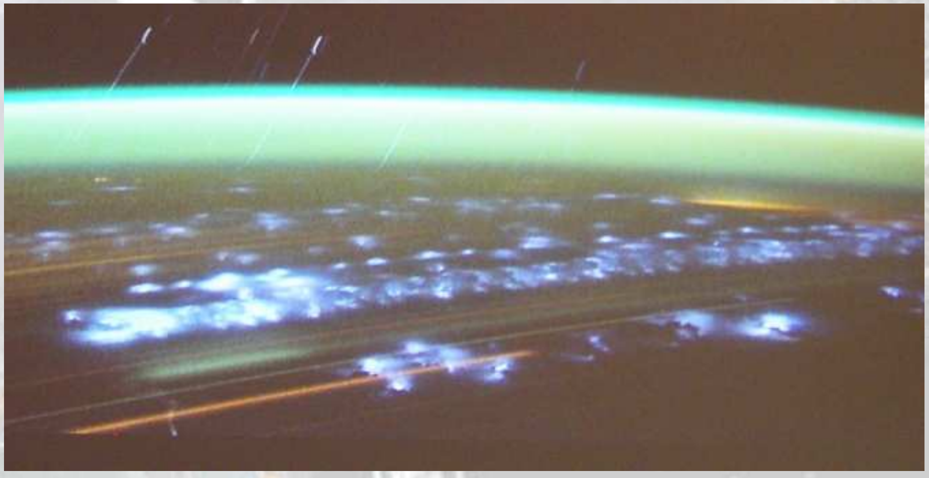




Various Phenomena

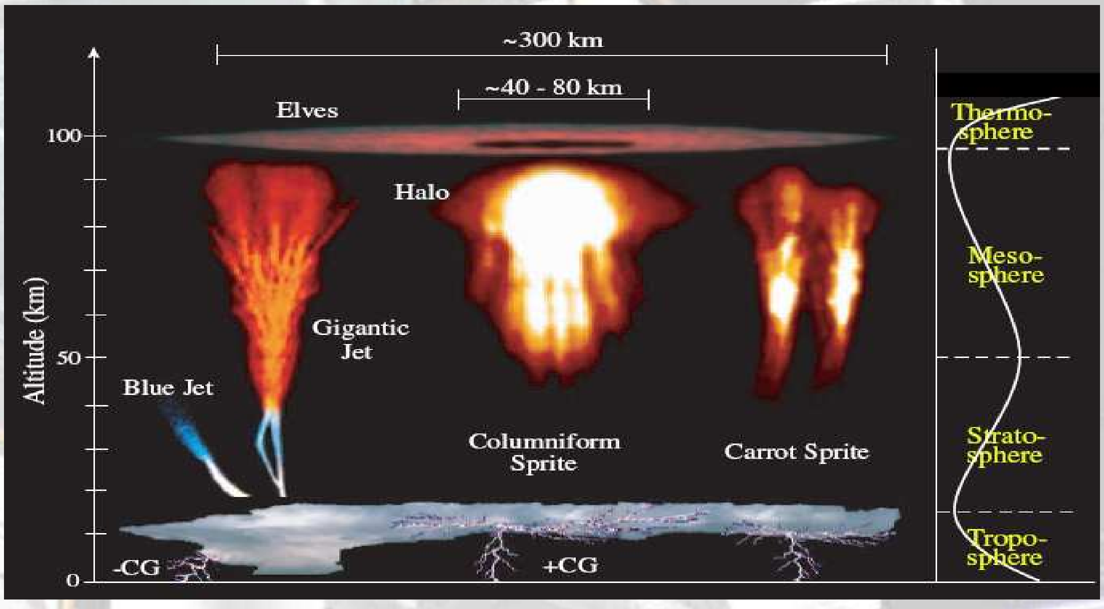


Air showers initiated by different kind of neutrinos



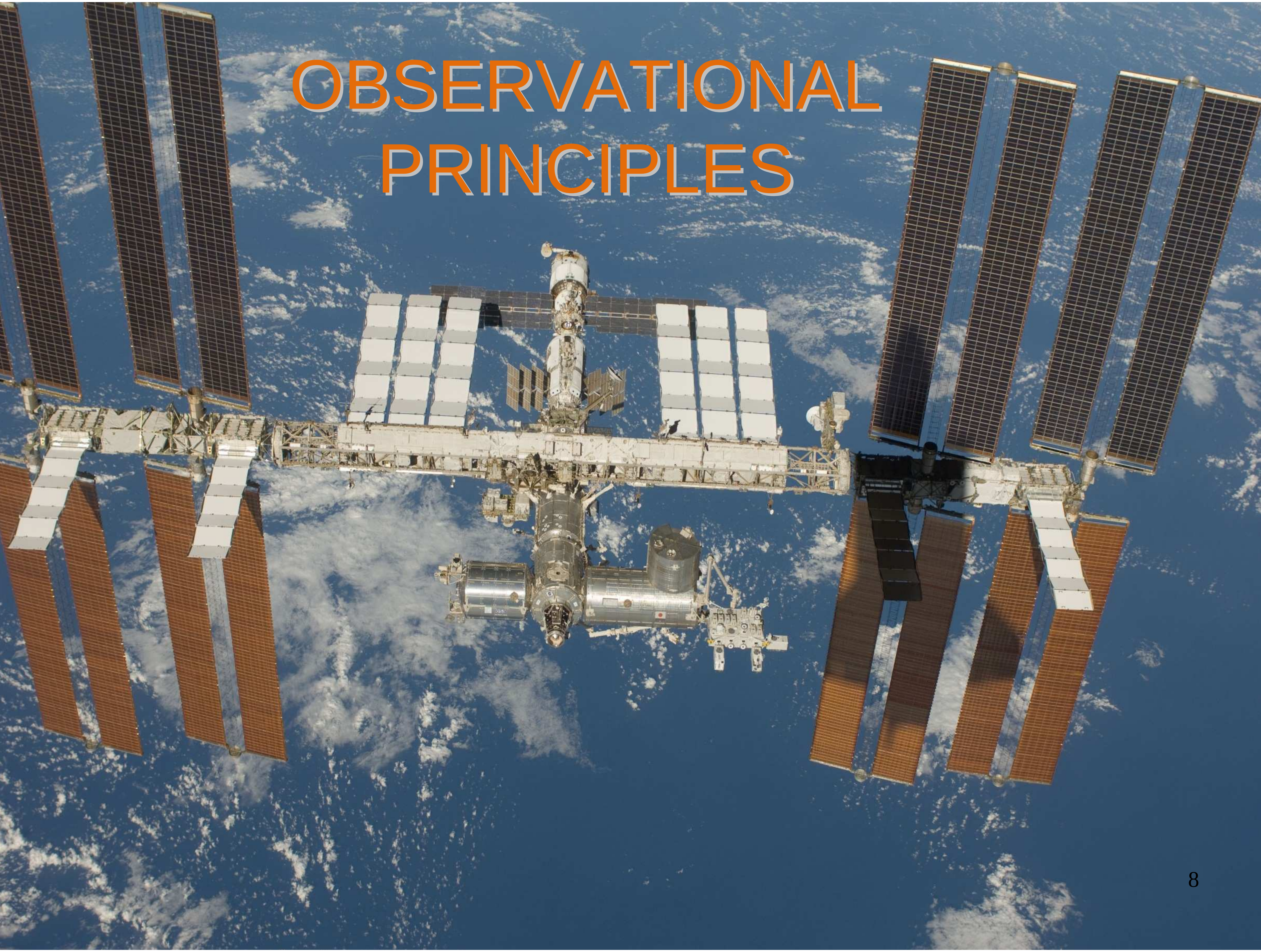
Lightning picture observed from ISS

Leonid meteor swarm in 2001 taken by Hivison camera



Various transient airglows

OBSERVATIONAL PRINCIPLES

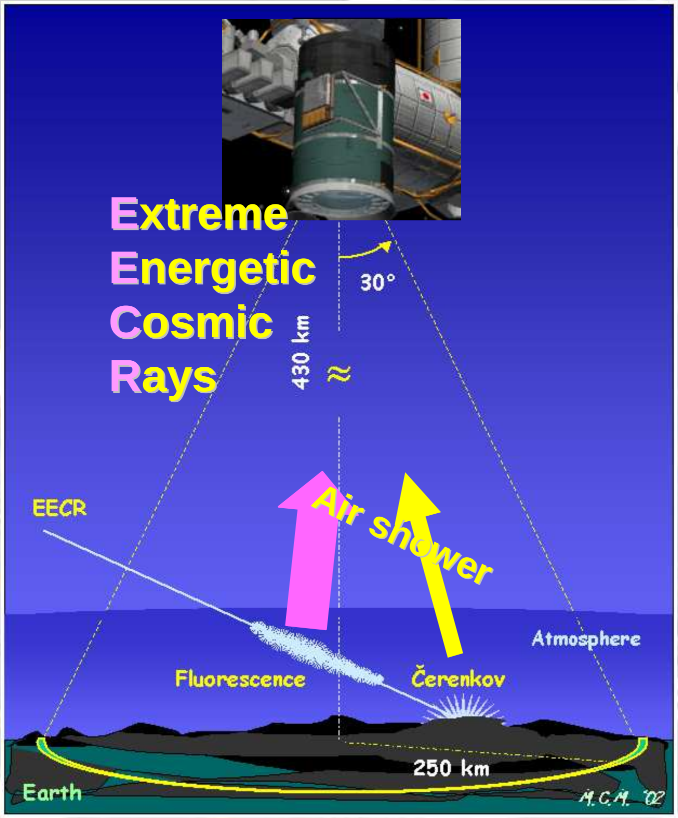


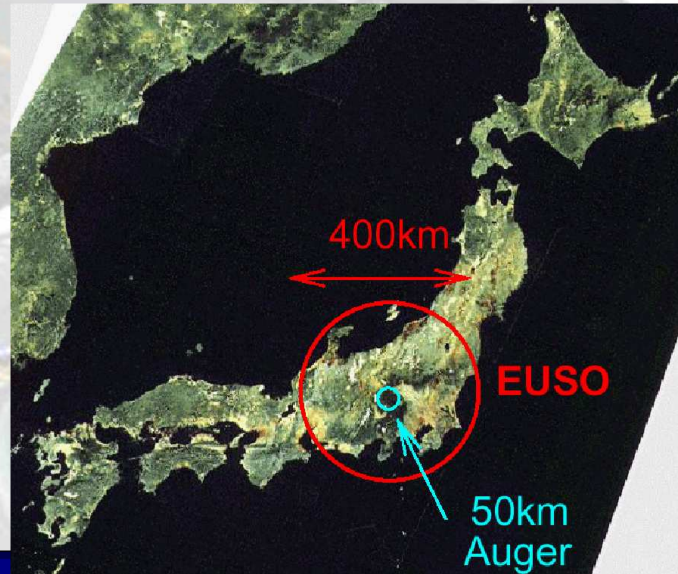
International Space Station-aboard EECR observatory

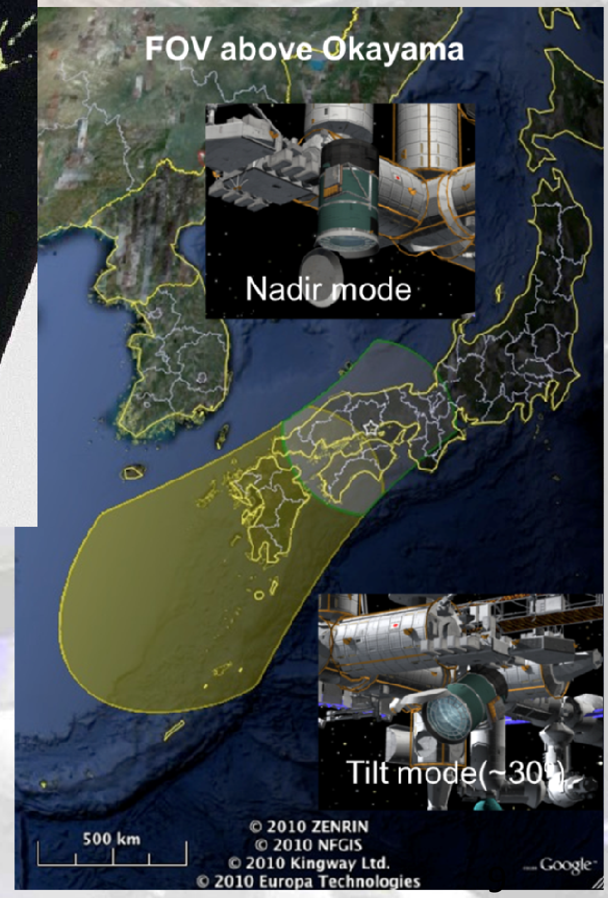
- Orbiting at ~400 km
  in ±51.6 degrees latitudes
- Covers both northern and southern hemisphere
- 1 orbit every 90 minutes

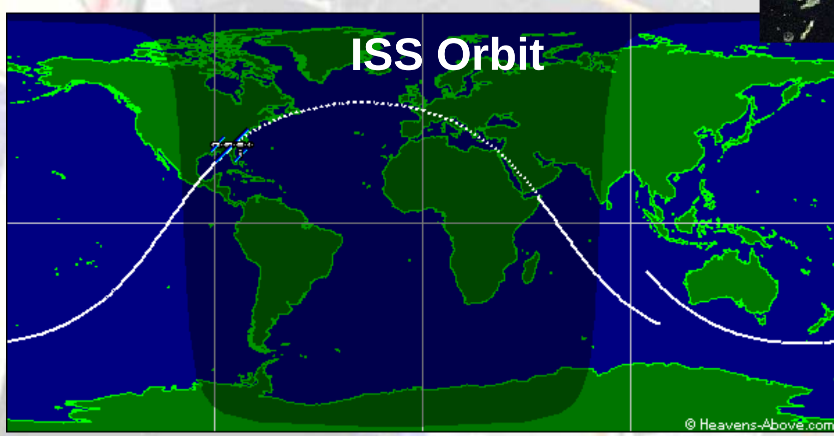
Viewing night atmosphere in > $2 \cdot 10^5$ km2 area
(instantaneous aperture 66 times grater than Auger)

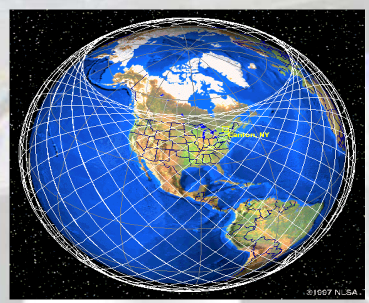
- Target volume about 10^{12} tons (1000 km^3 of H_2O)



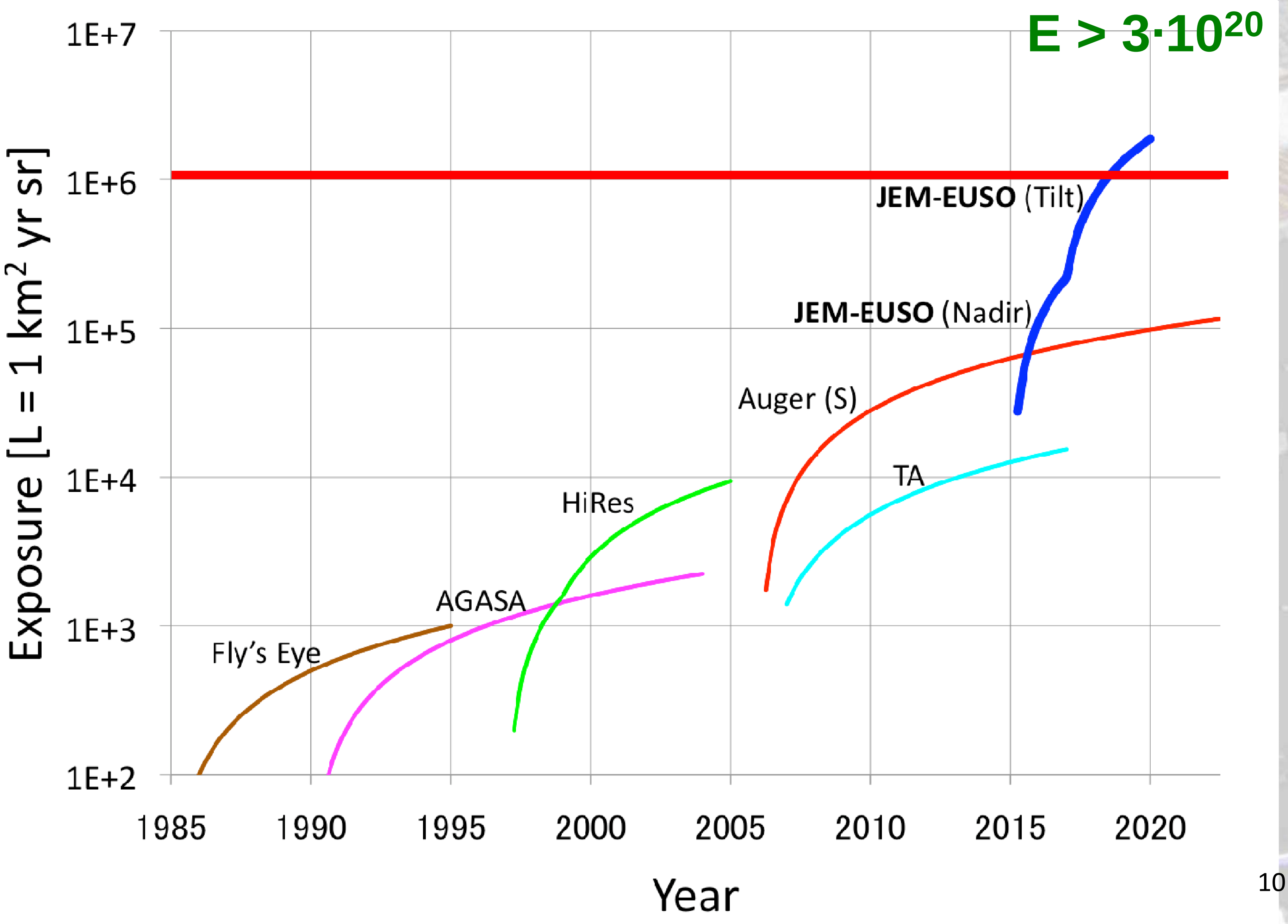




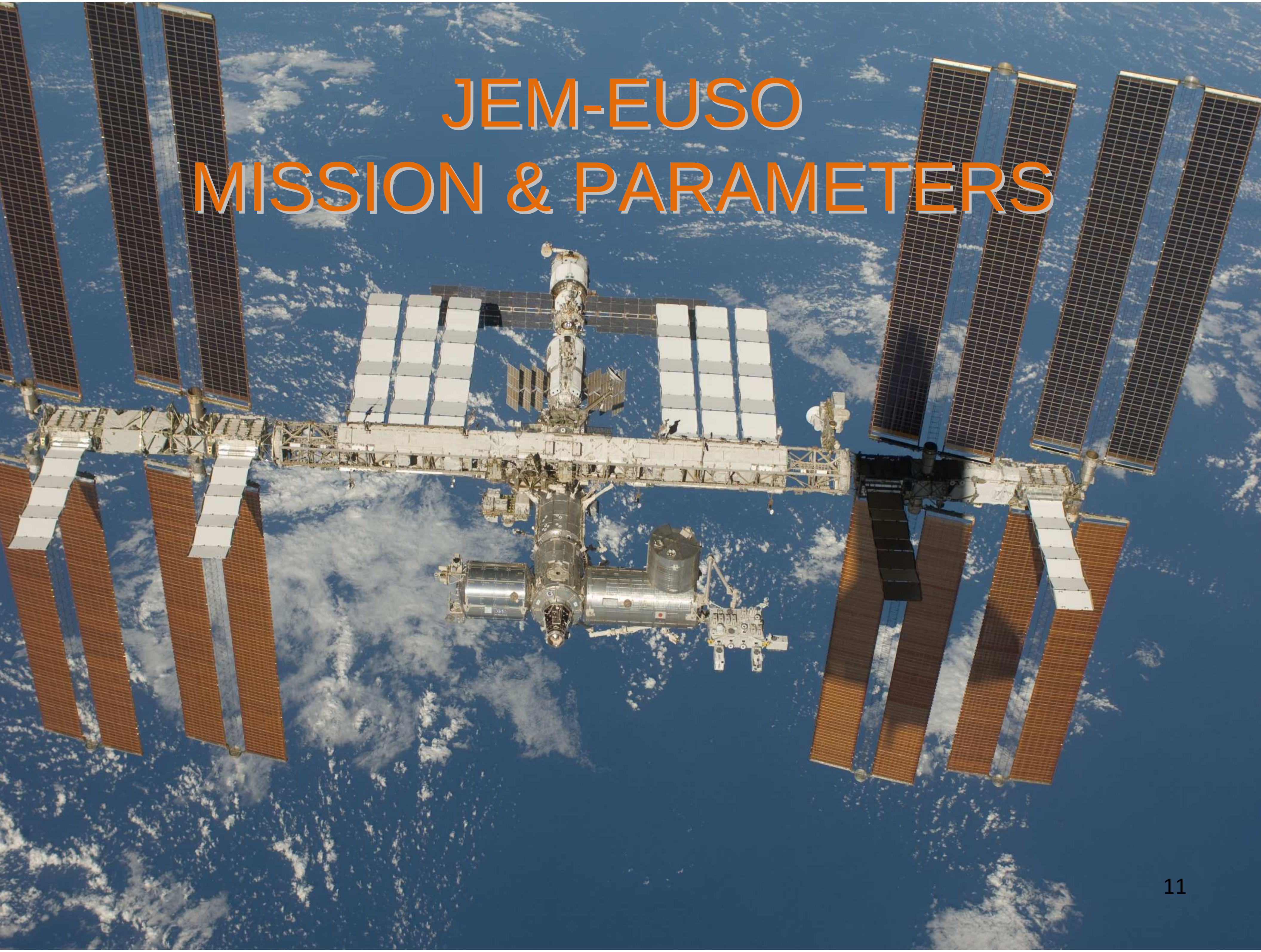


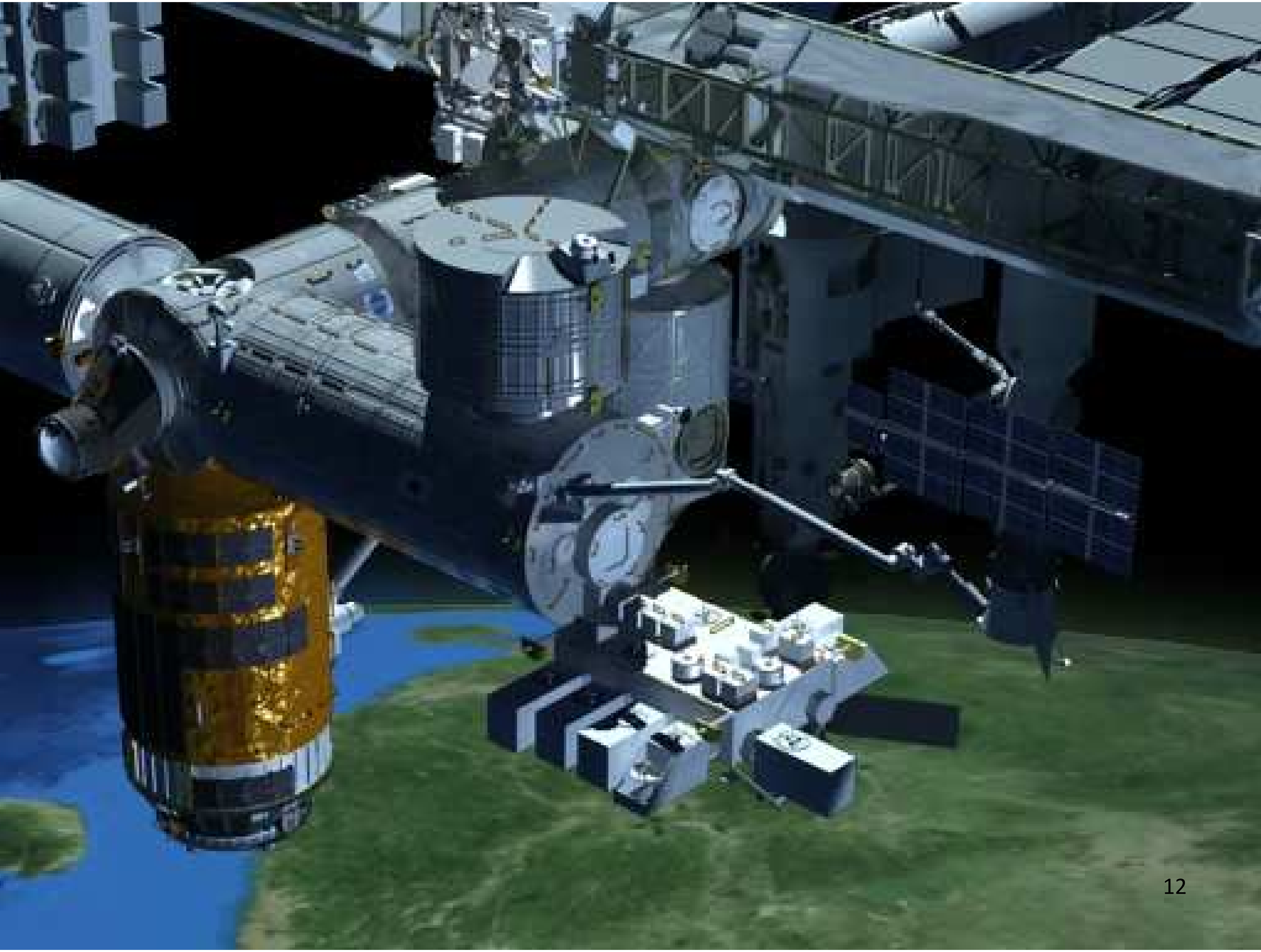


Exposure Evolution



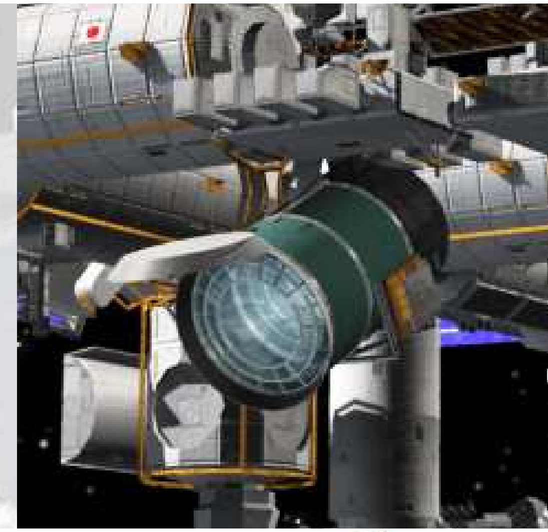
JEM-EUSO
MISSION & PARAMETERS

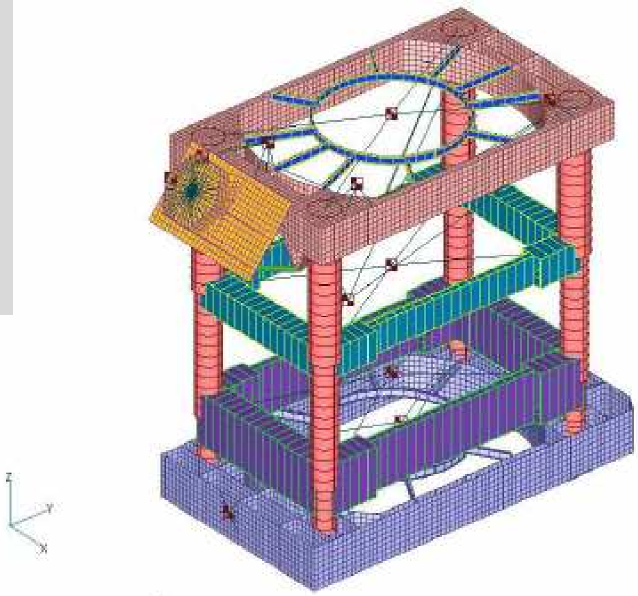




MISSION PARAMETERS

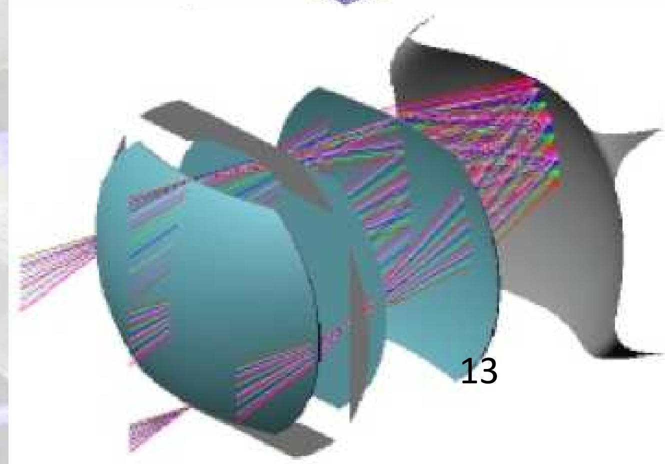
- Time of launch: year 2016 - 2017
- Operation Period: 3 years (+ 2 years)
- Launching Rocket : H2B
- Transportation to ISS: un-pressurized Carrier of H2 Transfer Vehicle (HTV)
- Site to Attach: Japanese Experiment Module/ Exposure Facility #2
- Height of the Orbit: ~400km
- Inclination of the Orbit: 51.64°
- Mass: 1983 kg
- Power: 926 W (operative), 352 W (non-operative)
- Data Transfer Rate: 285 kpbs + on-board storage

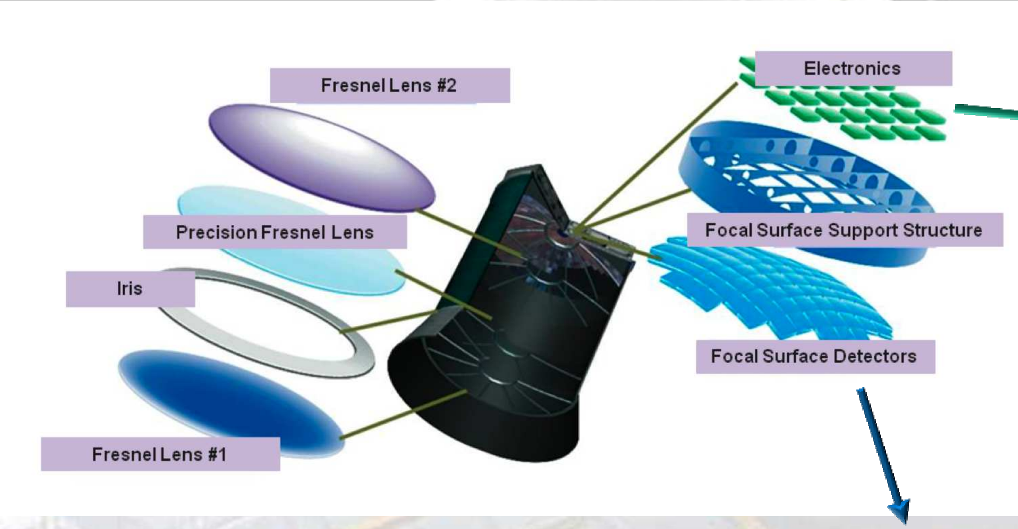


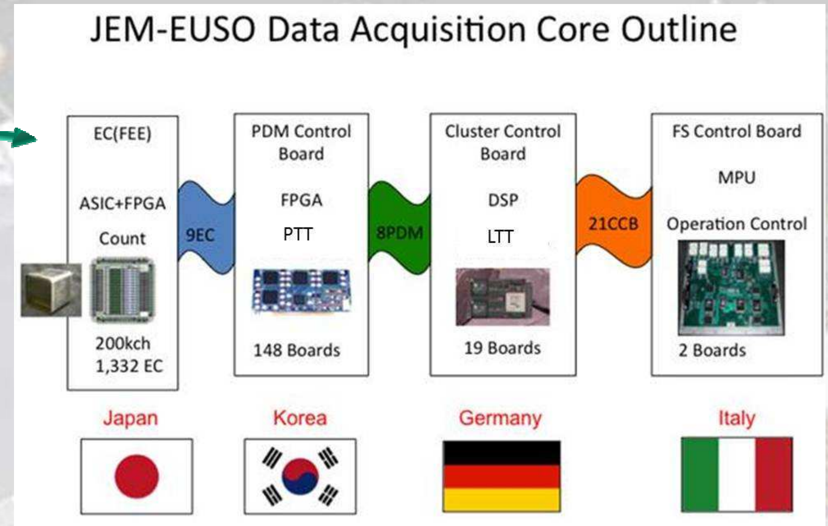


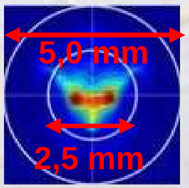
INSTRUMENTS PARAMETERS

- Field of view: $\pm 30^\circ$
- Aperture diameter: 2.5 m
- Optical bandwidth: 330 – 400 nm
- Angular resolution: 0,1°
- Pixel size: 2,9 mm
- Number of pixels: $\sim 3.0 \times 10^5$
- Pixel size at ground: ~500 m
- Duty cycle: ~20%
- Observational area: 1.9×10^5 km^2

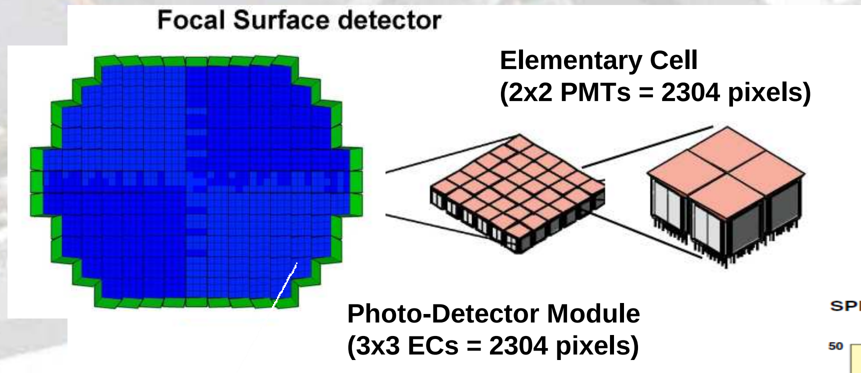


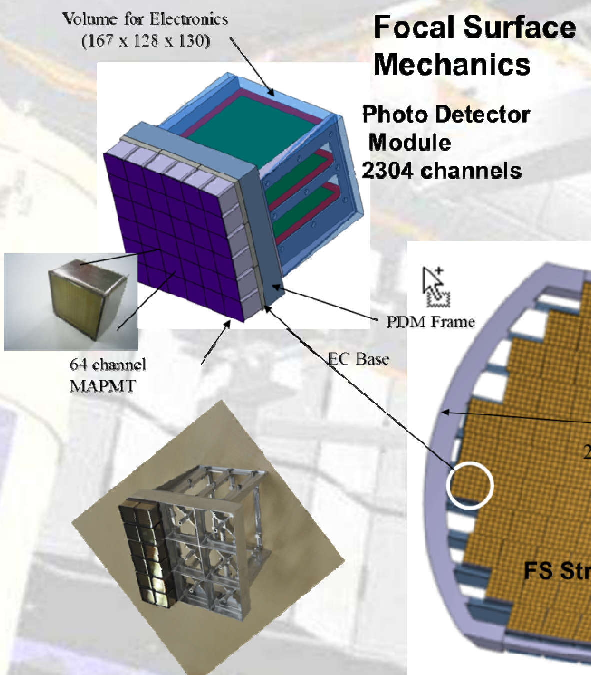


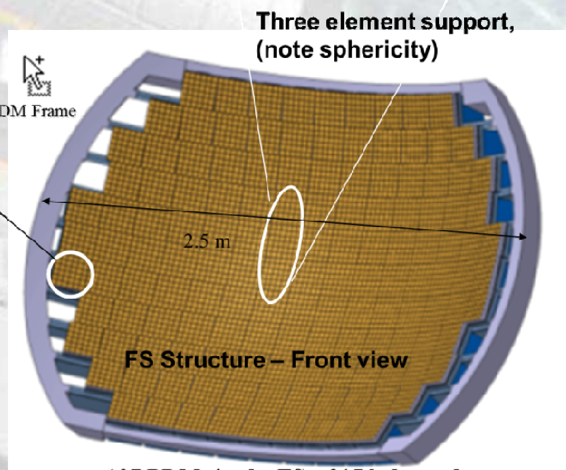




SPOT SIZE



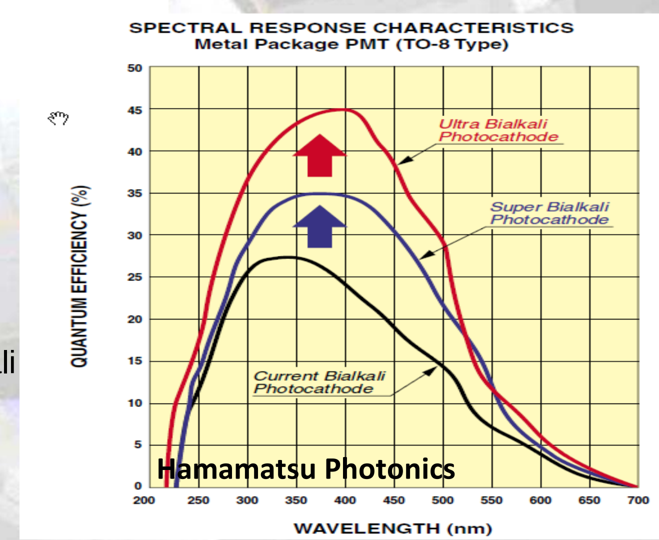




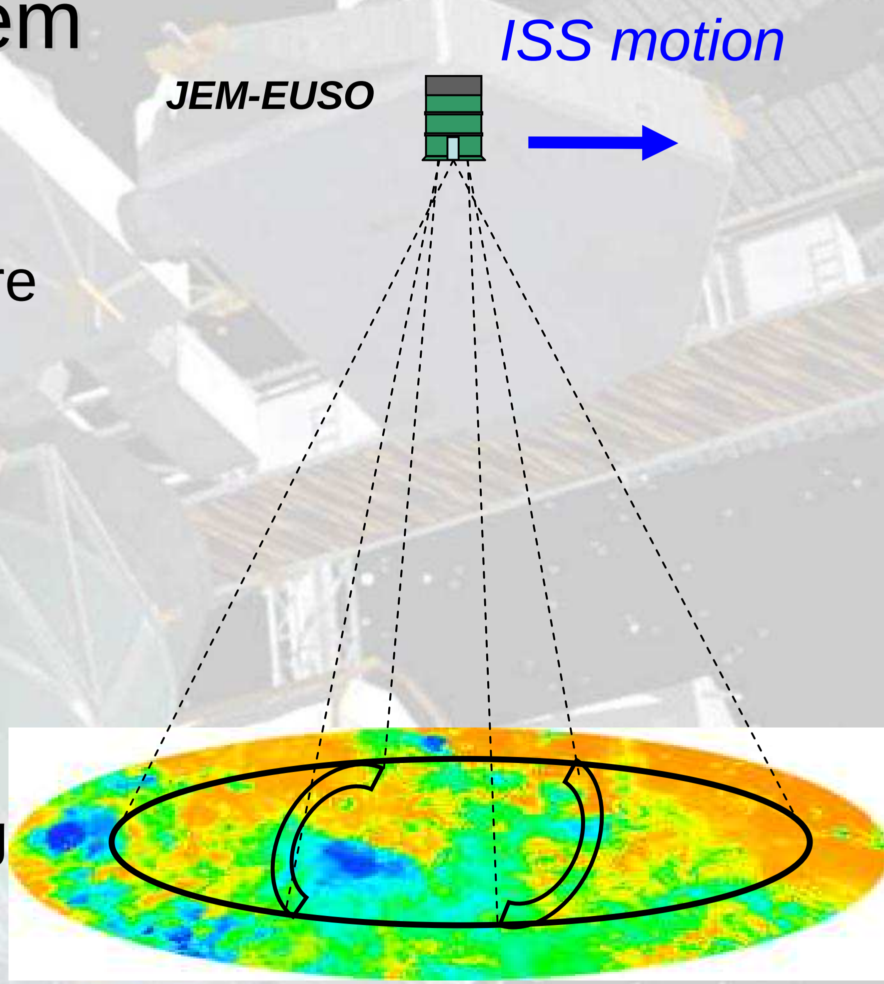
137 PDMs in the FS – 315 kchannels

PMTs

Hamamatsu Ultra Bialkali high efficiency MAPMT M64 64 channels in 8*8 grid Arranged in 6*6 in PDM structure



Atmospheric Monitoring System



- *IR Camera*

  Imaging observation of cloud temperature inside FOV of JEM-EUSO

- *Lidar*

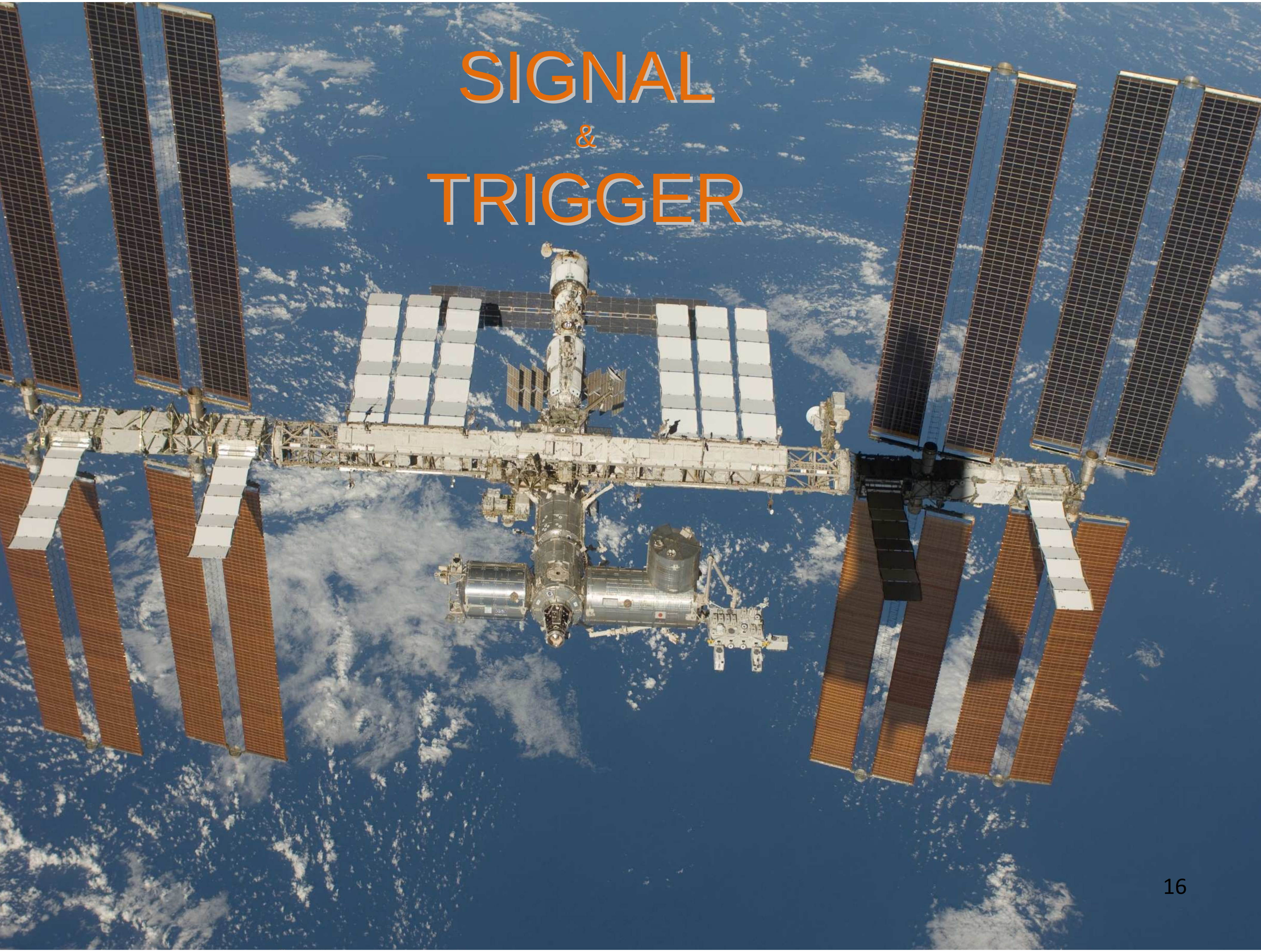
  Ranging observation using UV laser

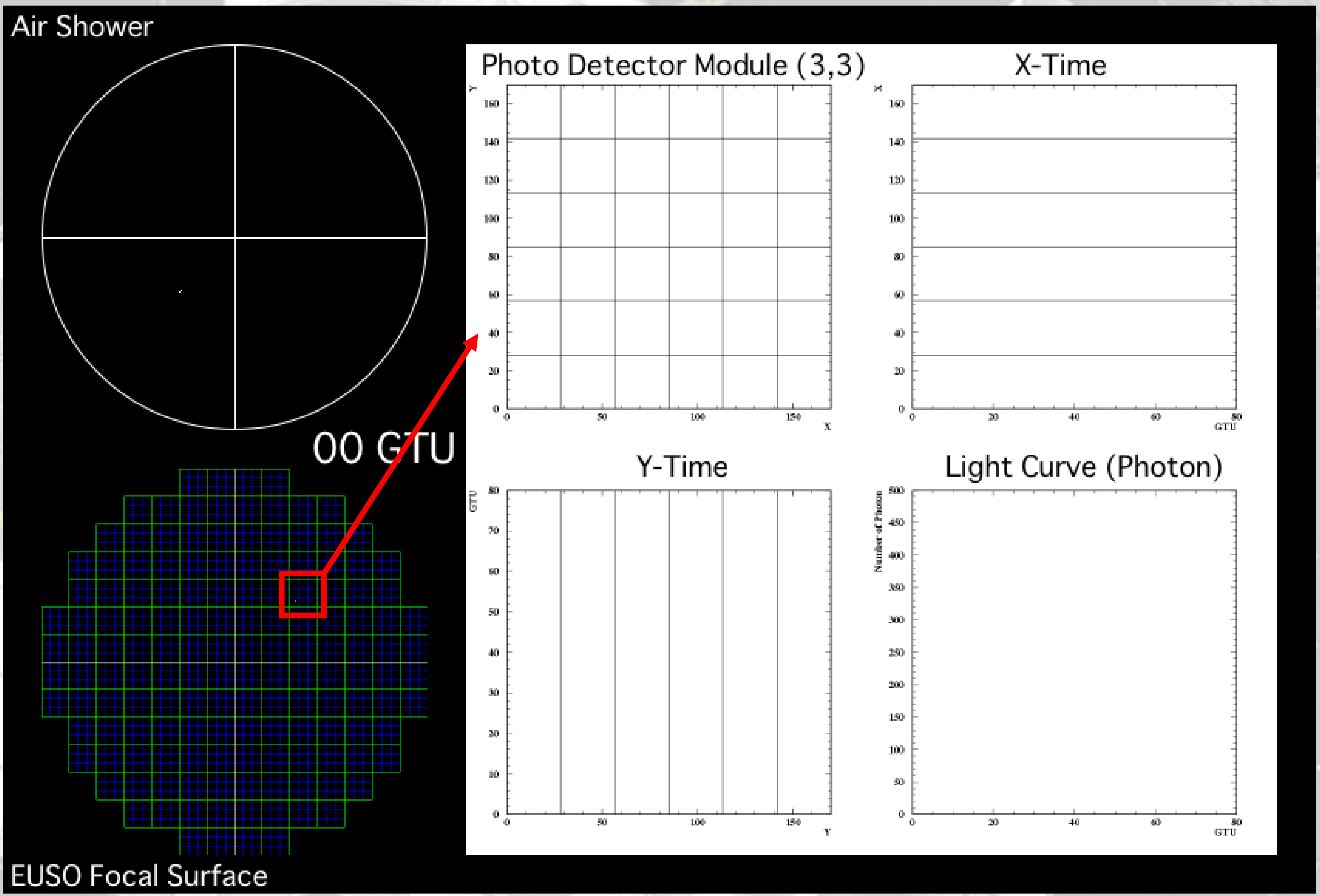
- *JEM-EUSO “slow-data”*

  Continuous background photon counting

- Cloud amount, cloud top altitude: (IR cam., Lidar, slow-data)
- Airglow: (slow-data)
- Calibration of telescope: (Lidar)

SIGNAL & TRIGGER

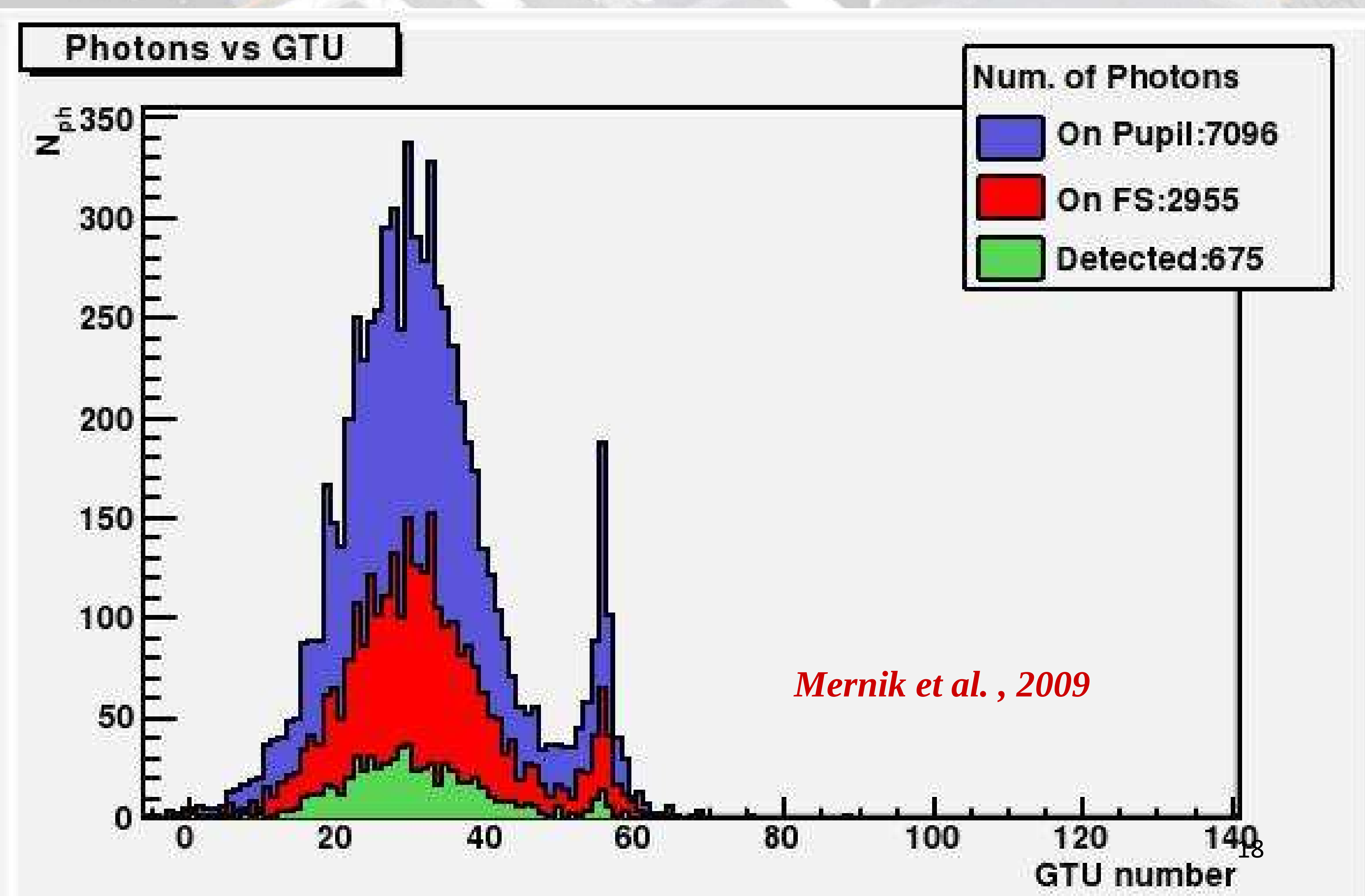




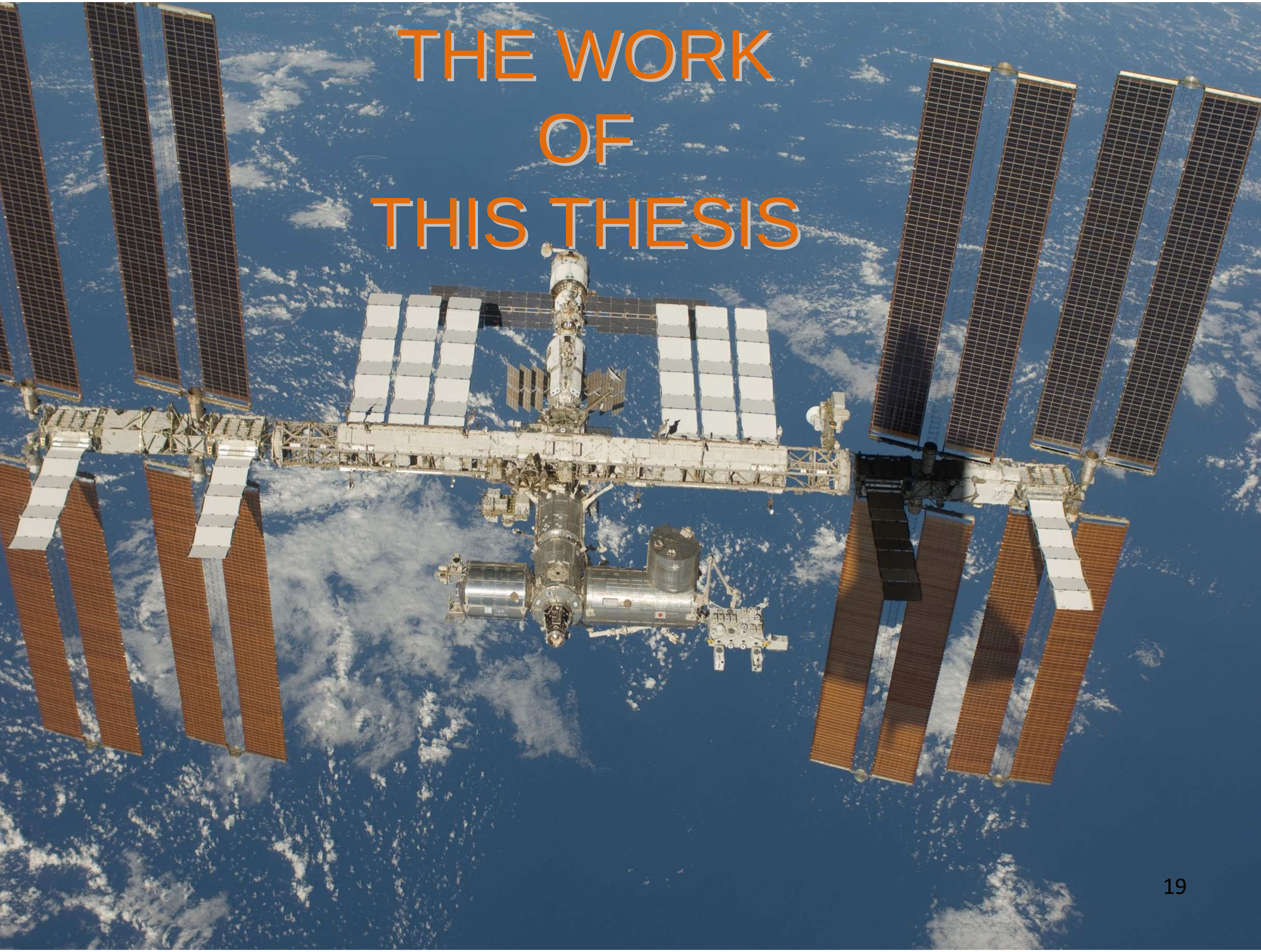
GTU

Gate Time Unit = 2.5 μs

End-to-End Simulations (ESAF): Signal for a p shower (60 deg, 10^{20}eV)



THE WORK OF THIS THESIS



3 DIFFERENT STUDIES

- data analysis (clouds coverage and its implication for cosmic rays observation - duty cycle)

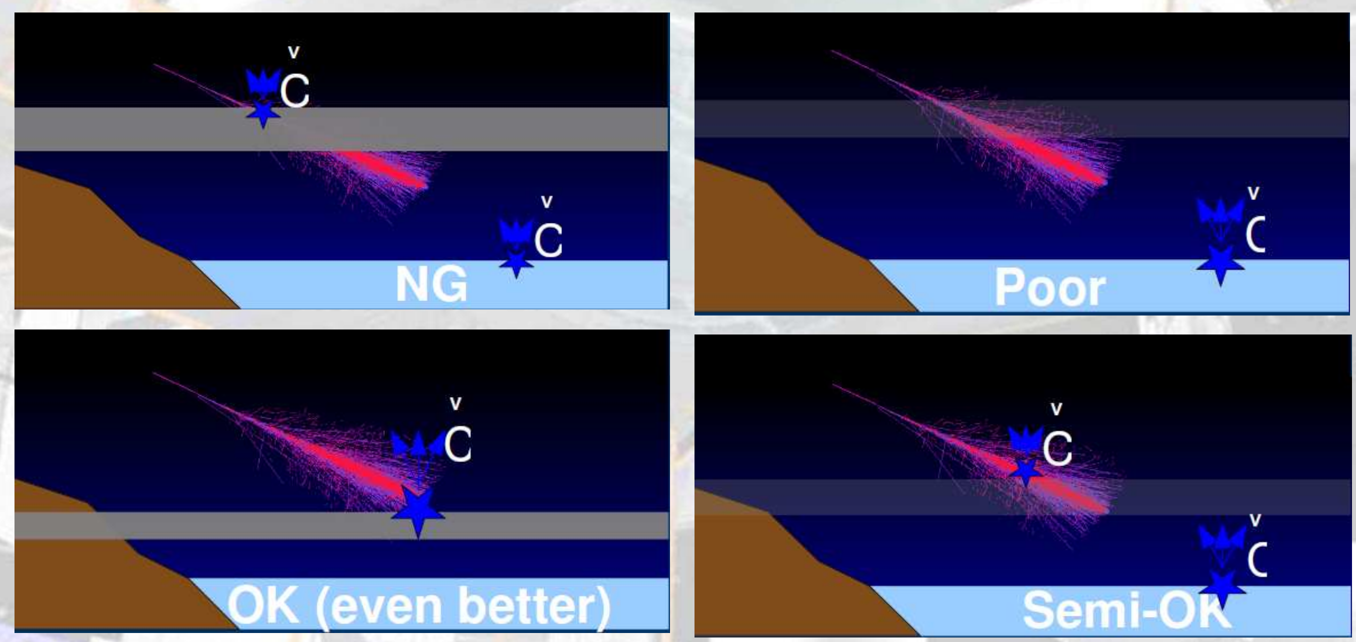
- studies concerning problematics of the experiment
  - ✓ trigger algorithm
  - ✓ sensitivity to meteors detection and trigger

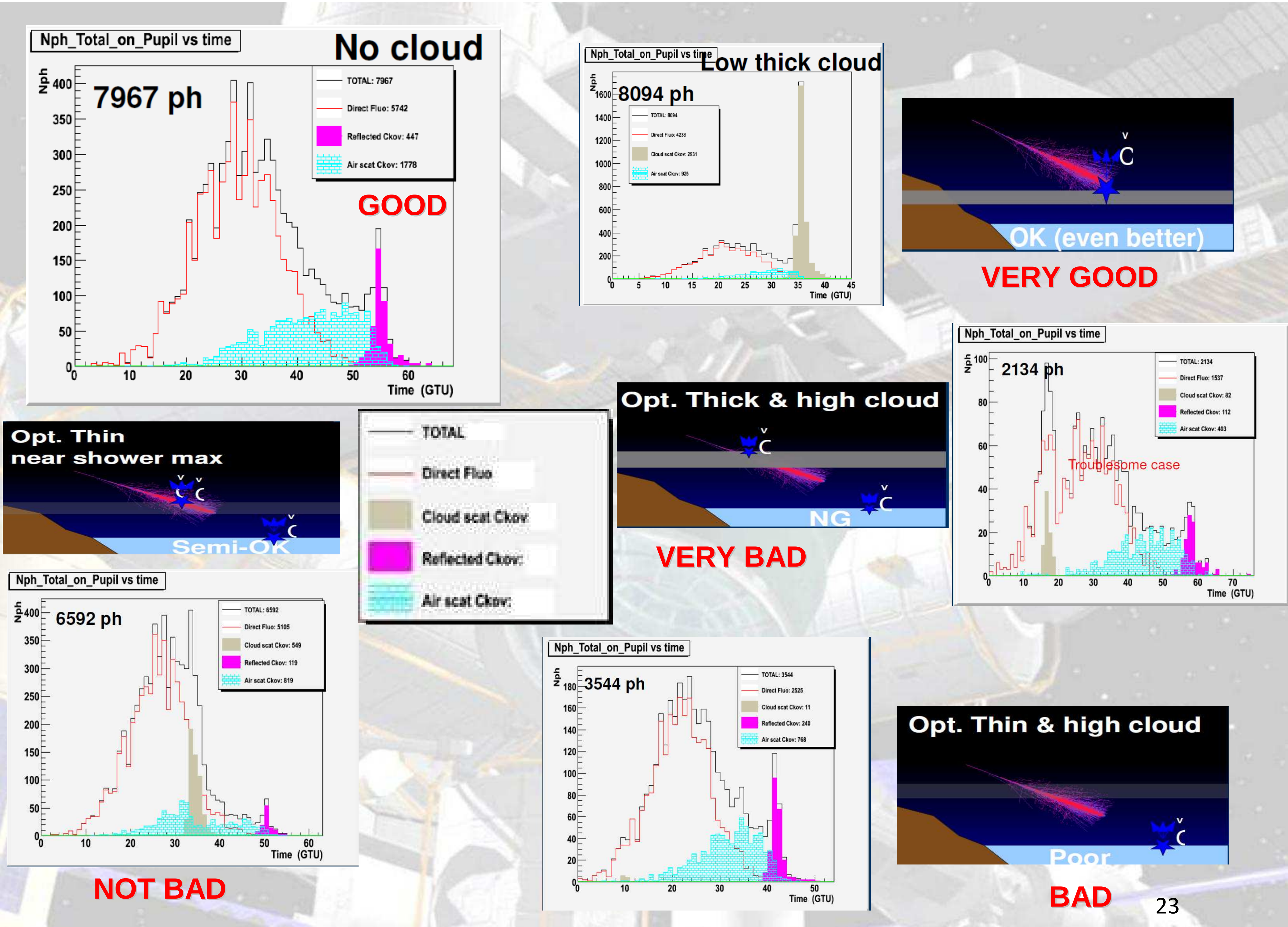
CLOUDS COVERAGE AND ITS IMPLICATION FOR COSMIC RAYS OBSERVATION – DUTY CYCLE

Work presented at The 7th International JEM-EUSO Meeting in Huntsville (U.S.), 21-25 June 2010 understanding local atmospheric condition is a key parameter (70% of the FoV of JEM-EUSO could be covered by clouds) to reconstruct shower profile

↓

effect of cloud needs to be measured in reconstruction




Nph_Total_on_Pupil vs time
No cloud
7967 ph
TOTAL: 7967
Direct Fluo: 5742
Reflected Ckov: 447
Air scat Ckov: 1778
GOOD
Time (GTU)
Nph
Nph_Total_on_Pupil vs time
Low thick cloud
8094 ph
TOTAL: 8094
Direct Fluo: 4238
Cloud scat Ckov: 2931
Air scat Ckov: 925
Time (GTU)
OK (even better)
VERY GOOD
Opt. Thin
near shower max
Semi-OK
TOTAL
Direct Fluo
Cloud scat Ckov
Reflected Ckov:
Air scat Ckov:
Opt. Thick & high cloud
NG
VERY BAD
Nph_Total_on_Pupil vs time
2134 ph
TOTAL: 2134
Direct Fluo: 1537
Cloud scat Ckov: 82
Reflected Ckov: 112
Air scat Ckov: 403
Troublesome case
Time (GTU)
Nph_Total_on_Pupil vs time
6592 ph
TOTAL: 6592
Direct Fluo: 5105
Cloud scat Ckov: 549
Reflected Ckov: 119
Air scat Ckov: 819
Time (GTU)
NOT BAD
Nph_Total_on_Pupil vs time
3544 ph
TOTAL: 3544
Direct Fluo: 2525
Cloud scat Ckov: 11
Reflected Ckov: 240
Air scat Ckov: 768
Time (GTU)
Opt. Thin & high cloud
Poor
BAD

CPD X ID = FCR

CPD = Cloud Properties Distribution
ID = Identification Probability of a CR with a determinate kind of cloud coverage
FCR = Fraction of Reconstructed CRs

FCR assumed by the JEM-EUSO collaboration = 70%

- Verify **cloud properties distribution** by:
  a) using same dataset
  b) using different datasets

- Understand the uncertainties on the **cloud properties distribution**

- From previous points derive an uncertainty on the total fraction of detectable events, by assuming the correctness of table **identification probability**

DATA SETS

TRIOS Operational Vertical Sounder

ocean/land division

Good spectral resolution,polar satellites, radiative transfer model, irregularly distributed, optical depth

International Satellite Cloud Climatology Project

monthly, seasonal and annual means data

cloud types defined by the VIS/IR cloud top pressure and optical depth (low, middle, high) (poorer spectral resolution: VIS + IR), geostationary and polar satellites

- low clouds → top pressures >= 680 mb (3.2 Km)
- high clouds → top pressures < 440 mb(6.5 Km)
- middle clouds are in between

no division ocean/land

Climatic Atlas of Clouds Over Land and Ocean

Visual cloud observations from ships and ground weather stations

database includes multi-year annual, seasonal and monthly averages

TOVs: daytime -50° < lat < +50°

CONTINENTS only

LOW: 22.5% , MIDDLE: 8.2%
HIGH: 33.2% , CLEAR: 36.1%

	<3 Km	3-7 Km	7-10 Km	>10 Km
>2	13.5	6.8	5.8	6.4
1-2	3.0	2.8	3.9	2.9
0.1-1	4.4	1.6	3.4	6.4
<0.1	36.8(0.8)	0.1	0.01	2.4

FCR: 66.5%

OCEANS only

LOW(<3.2 Km): 30.6%, MIDDLE(3.2-6.5 Km): 8.5%
HIGH(>6.5 Km): 32.4% , CLEAR: 28.5%

	<3 Km	3-7 Km	7-10 Km	>10 Km
>2	17.2	5.2	6.4	6.1
1-2	5.9	2.9	3.5	3.1
0.1-1	6.4	2.4	3.7	6.8
<0.1	29.2(0.8)	0.03	0.01	1.2

FCR: 67.0%

CONTINENTS+OCEANS

LOW: 28.4% , MIDDLE: 8.4%
HIGH: 32.7% , CLEAR: 30.5%

	<3 Km	3-7 Km	7-10 Km	>10 Km
>2	16.2	5.6	6.2	6.2
1-2	5.1	2.9	3.6	3.1
0.1-1	5.8	2.2	3.6	6.7
<0.1	31.2(0.8)	0.04	0.01	1.5

FCR: 66.7%

TOVs: continents -50° < lat < +50°

Daytime

LOW: 22.5% , MIDDLE: 8.2%
HIGH: 33.2% , CLEAR: 36.1%

	<3 Km	3-7 Km	7-10 Km	>10 Km
>2	13.5	6.8	5.8	6.4
1-2	3.0	2.8	3.9	2.9
0.1-1	4.4	1.6	3.4	6.4
<0.1	36.8(0.8)	0.1	0.01	2.4

FCR: 66.5%

Nighttime

LOW: 21.9% , MIDDLE: 7.8%
HIGH: 36.4% , CLEAR: 33.9%

	<3 Km	3-7 Km	7-10 Km	>10 Km
>2	12.1	6.3	5.8	8.6
1-2	3.1	2.7	3.9	3.4
0.1-1	4.8	1.7	3.4	6.7
<0.1	34.9(1.0)	0.03	0.01	2.6

FCR: 64.5%

LOCATION	*TIME*	FCR
lands	day (6am – 6pm LT)	66.5%
oceans	day (6am – 6pm LT)	67.0%
lands and oceans	day (6am – 6pm LT)	66.7%
lands	night (6pm – 6am LT)	64.5%
oceans	night (6pm – 6am LT)	66.5%
lands and oceans	night (6pm – 6am LT)	66.1%
lands	day + night	66.5%
oceans	day + night	67.0%
lands and oceans	day + night	66.7%

- Slight differences among the tables exist, however, the general trend seems to be independent from the geographical and temporal conditions
- As JEM-EUSO will be measuring during night time only, we can assume that the most appropriate result on the FCR during the operational time (lands and oceans during night time) will be (66.1 ± 1.3)%, where the uncertainty (σ_1 = 1.3%) has been derived as the semidispersion between the spread of the results of the above table.

daytime -50° < lat < +50°

OCEANS ONLY

	TOVs	ISCCP	CACOLO
LOW	30.6	30.1	52.0
MIDDLE	8.5	16.1	26.0
HIGH	32.4	22.0	12.7
CLEAR	28.5	31.8	9.3
FCR	66.7	69.4	73.9
FCRref.	67.0		

CONTINENTS ONLY

	TOVs	ISCCP	CACOLO
LOW	22.5	17.3	28.8
MIDDLE	8.2	15.7	24.1
HIGH	33.2	26.1	23.1
CLEAR	36.1	40.9	24.0
FCR	66.1	67.2	68.8
FCRref.	66.5		

CONTINENTS & OCEANS

	TOVs	ISCCP	CACOLO
LOW	28.4	26.0	40.4
MIDDLE	8.4	16.0	25.0
HIGH	32.7	23.3	17.9
CLEAR	30.5	34.7	16.7
FCR	66.5	68.7	71.2
FCRref.	66.7		

- Different data sets which use different instruments and way of classification provide significant different results in each cloud layer

- Despite the differences in each cloud layer, the convolution of **cloud properties distribution** with **identification probability** gives quite similar results for all 3 data sets

- The semi-dispersion between the results on the FCR obtained by the three data-sets on the ocean data ($\sigma_2 = 3.6\%$) can be considered as an estimation of the intrinsic uncertainty of a single technique.

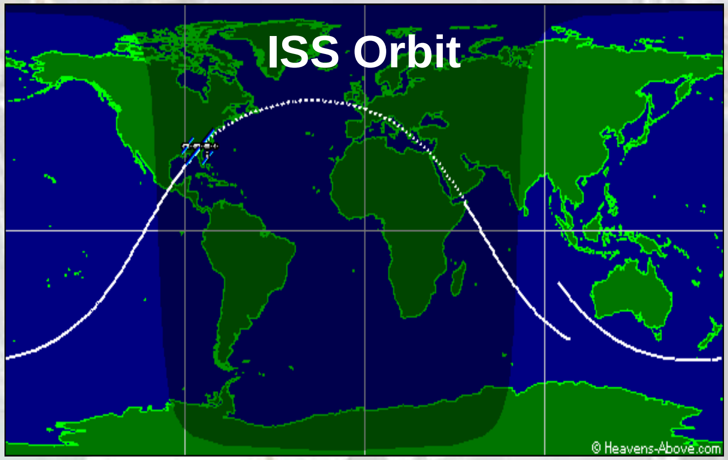
- A conservative estimation of the FCR, based on TOVS data is: **(66.1 ± 3.8)%** → error = $\sqrt{(\sigma_1^2 + \sigma_2^2)}$

our most conservative assumption is at about 1 σ from 70%

daytime -50° < lat < +50°

ISCCP

	OCEANS					CONTINENTS				
	50 → 35	35 → 15	15 → -15	-15 → -35	-35 → -50	50 → 35	35 → 15	15 → -15	-15 → -35	-35 → -50
LOW	35.7	28.7	21.0	33.1	38.9	18.4	18.6	15.2	16.0	22.8
MID	24.2	12.4	12.1	13.6	24.2	22.0	12.4	14.8	11.8	18.9
HIGH	23.5	18.9	27.8	17.2	20.1	26.1	19.4	33.5	24.2	28.1
CLEAR	16.6	40.0	39.1	36.1	16.8	33.5	49.6	36.5	48.0	30.2
FCR	68.4	70.8	66.8	71.8	70.0	66.7	70.1	64.4	68.1	66.9



NOT CONSIDERING JEM-EUSO LOCATION PROBABILITY → **FCR = 68,9**

CONSIDERING JEM-EUSO LOCATION PROBABILITY → **FCR = 68,7**

Probability of JEMEUSO being located within latitude L1 and L2:

$$\left|\left[arcos\left(\frac{\sin(L1)}{\sin(51{,}6)}\right) - arcos\left(\frac{\sin(L2)}{\sin(51{,}6)}\right)\right|/180$$

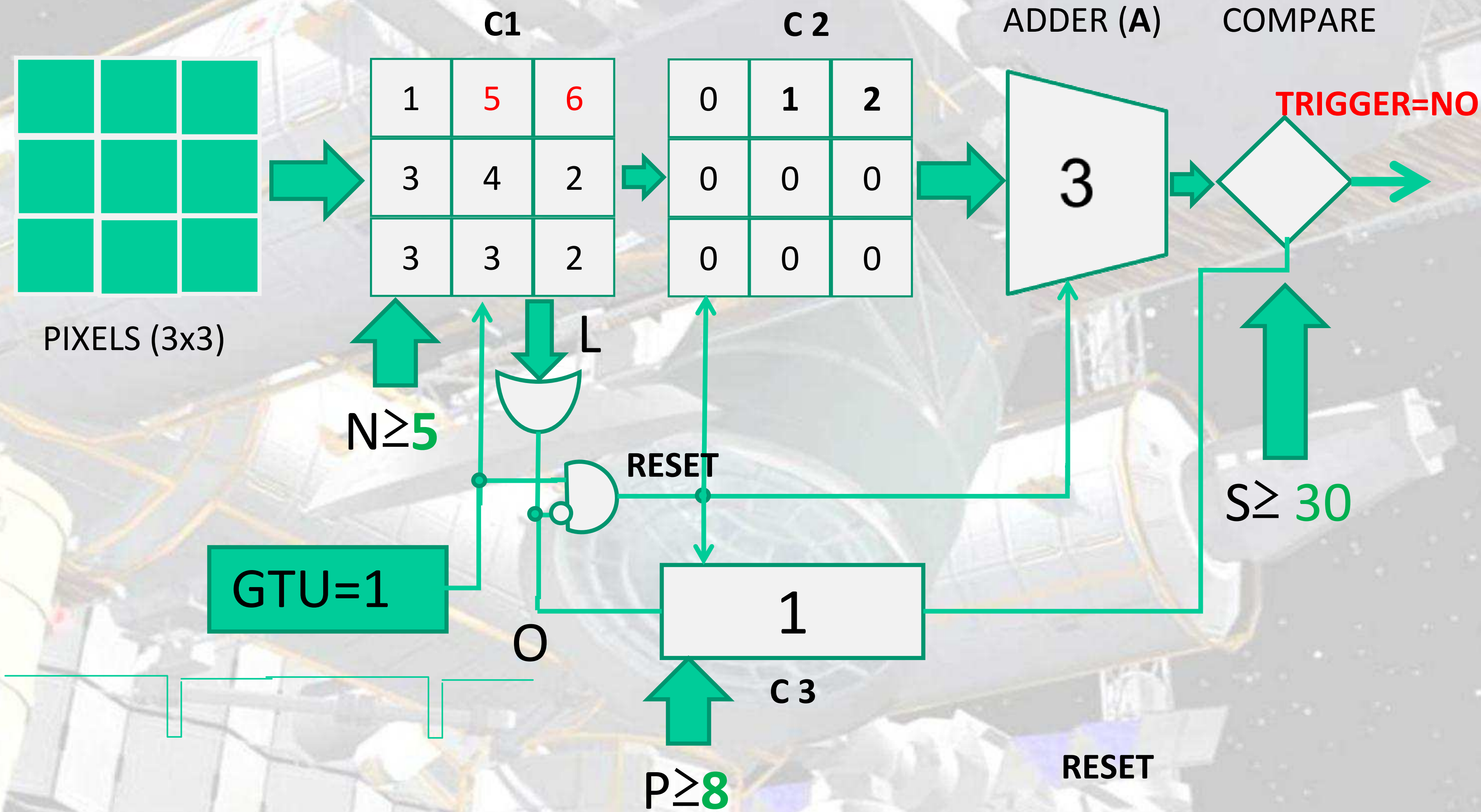
TRIGGER ALGORITHM

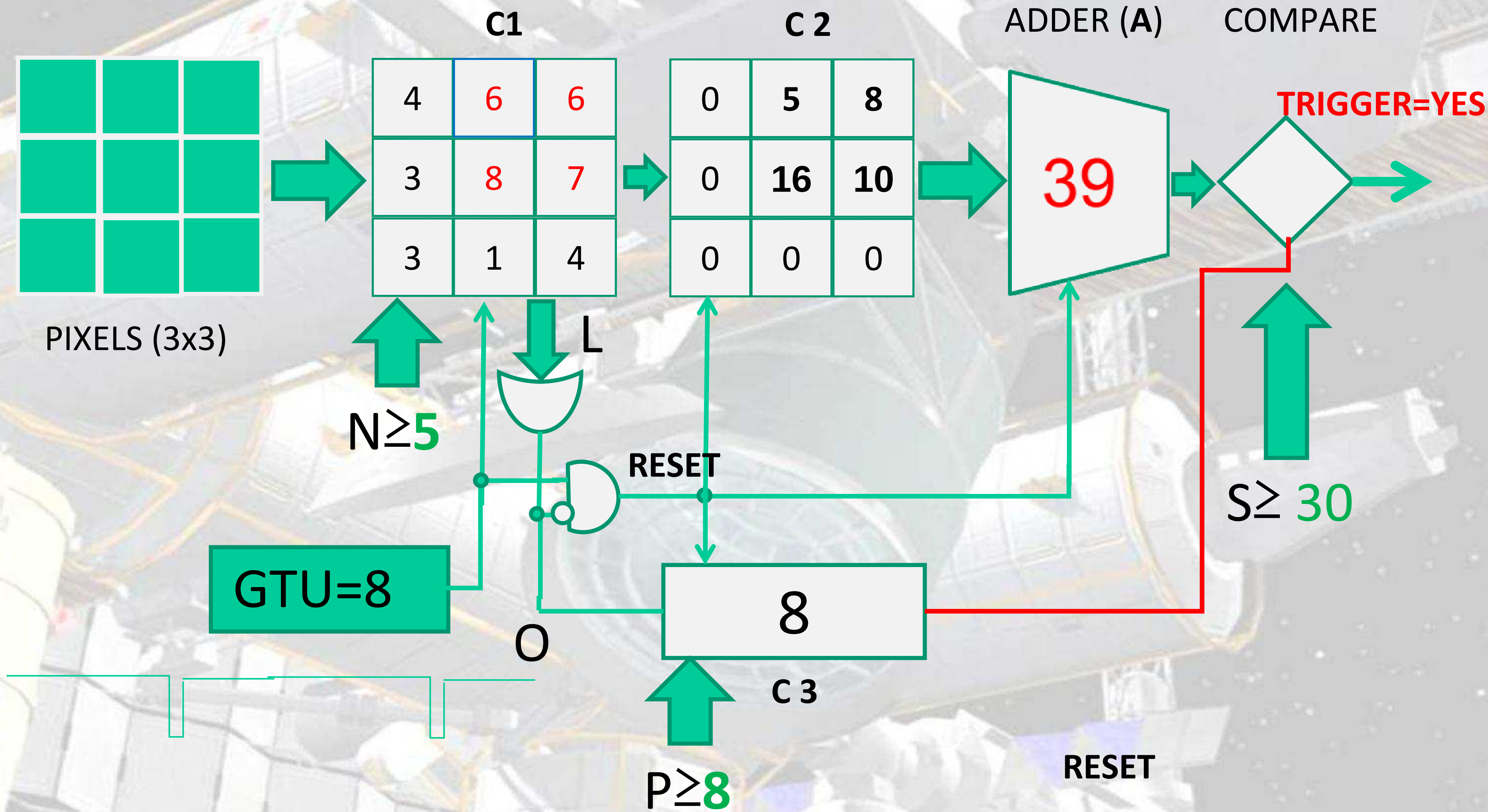
Part of the work presented at JEM-EUSO Simuation Meeting in Tübingen (Germany), 23 – 25 March 2011

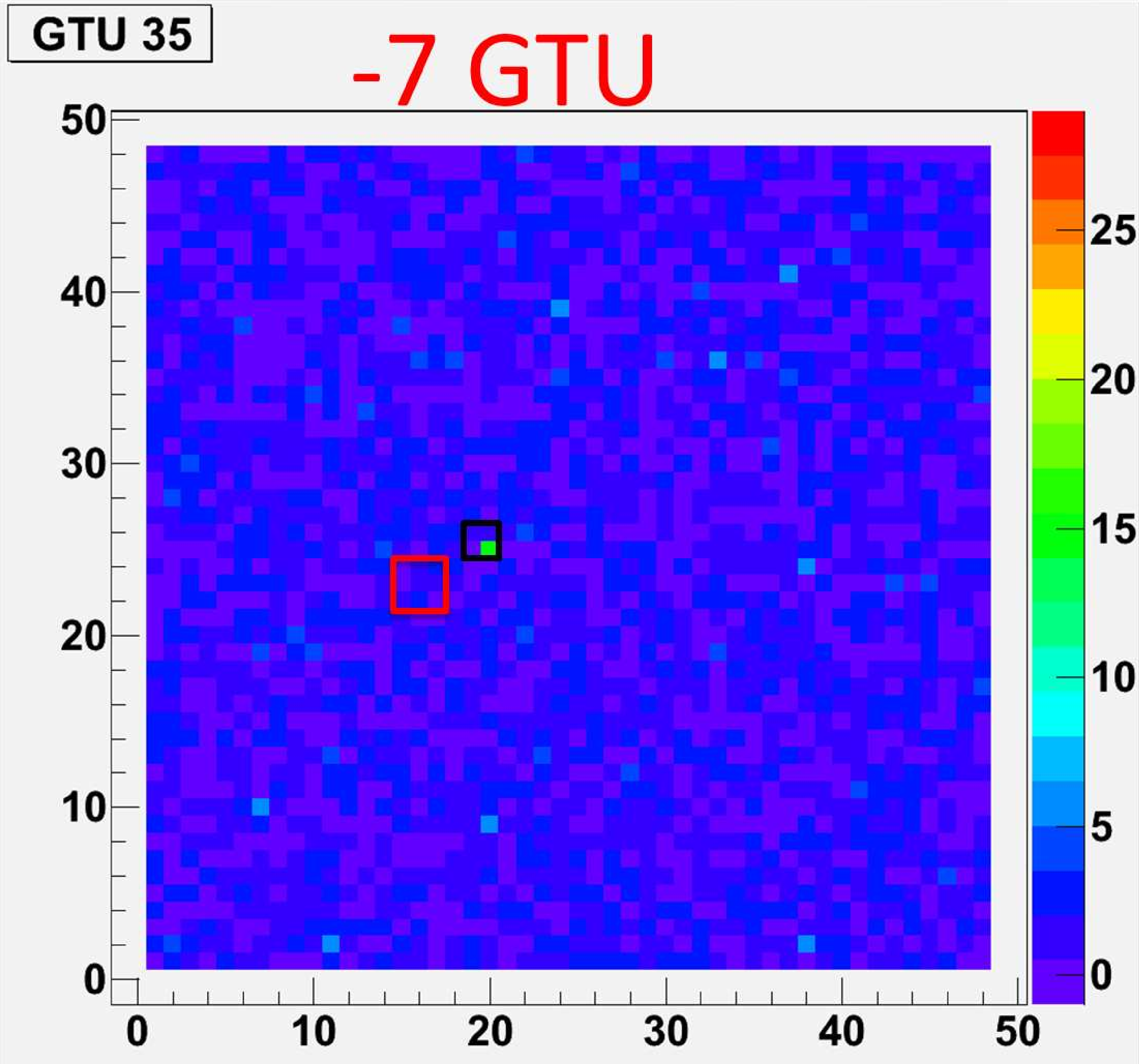
THE GTU COLLECTED FOR AN EVENT OF $1 \cdot 10^{20}$ eV

PROGRESSIVE TRACK TRIGGER – PTT (1st LEVEL TRIGGER – 7Hz/PDM)

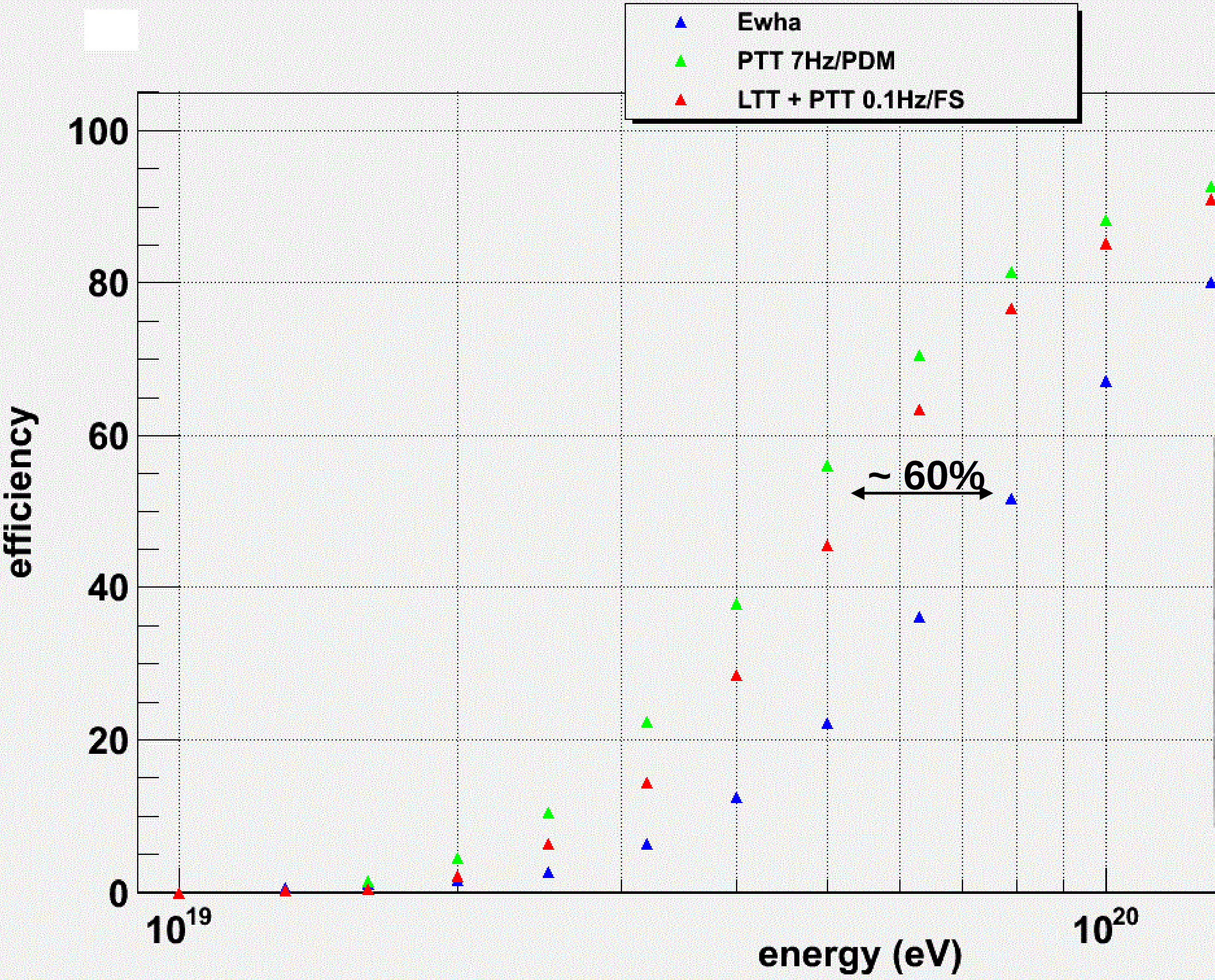
EXAMPLE: TRIGGER

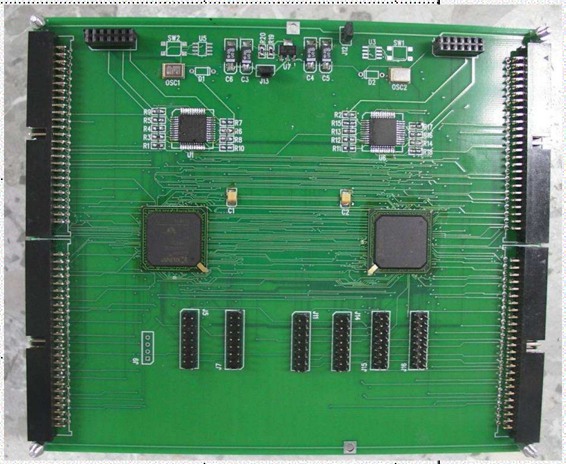



C1
C 2
ADDER (A)
COMPARE
TRIGGER=YES
4 6 6
3 8 7
3 1 4
0 5 8
0 16 10
0 0 0
39
PIXELS (3x3)
L
N≥5
RESET
GTU=8
8
S≥ 30
O
C 3
P≥8
RESET

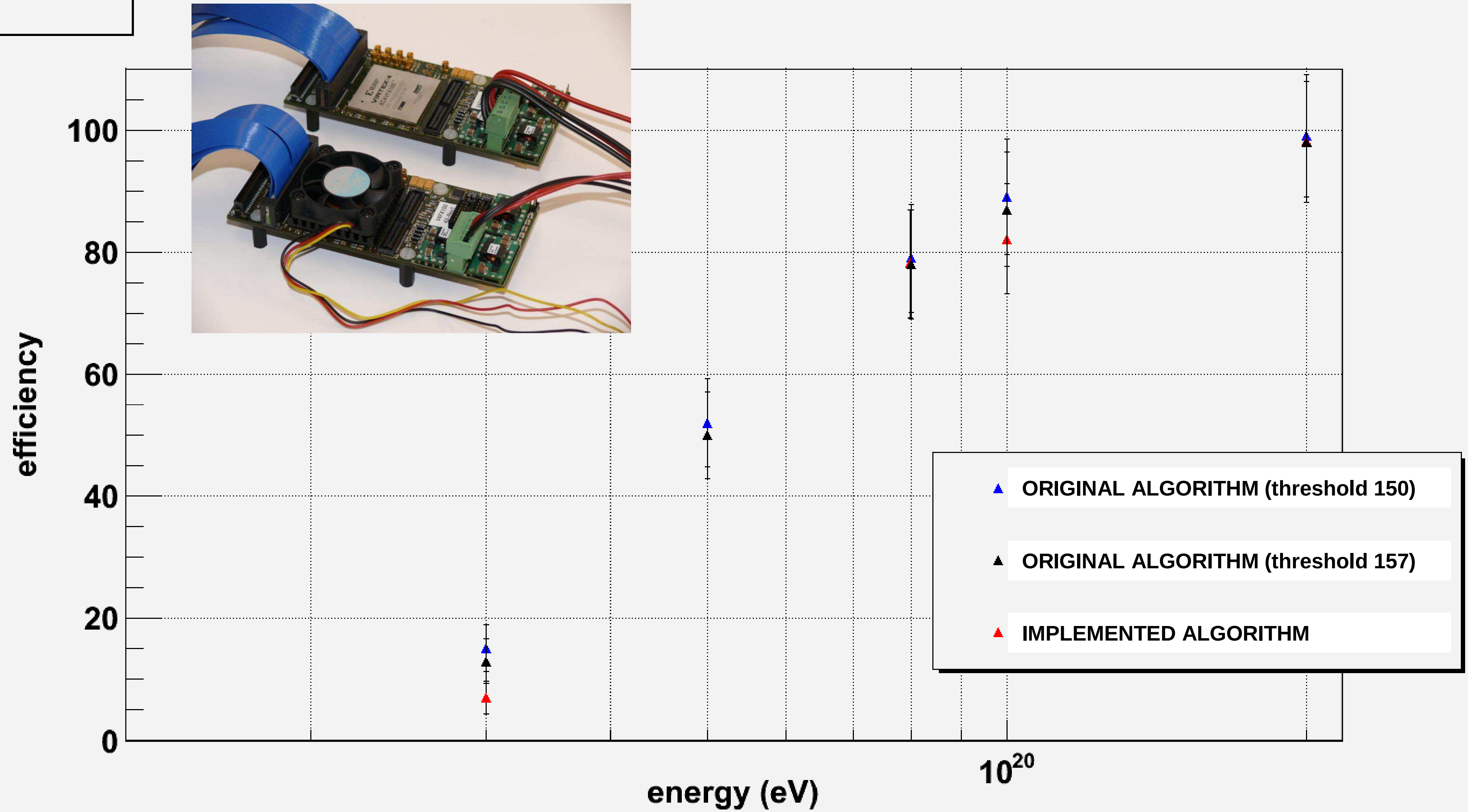

GTU 35
-7 GTU
0
10
20
30
40
50
0
5
10
15
20
25

1st LEVEL TRIGGER IMPLEMETED AT EWHA UNIVERSITY (SOUTH KOREA)

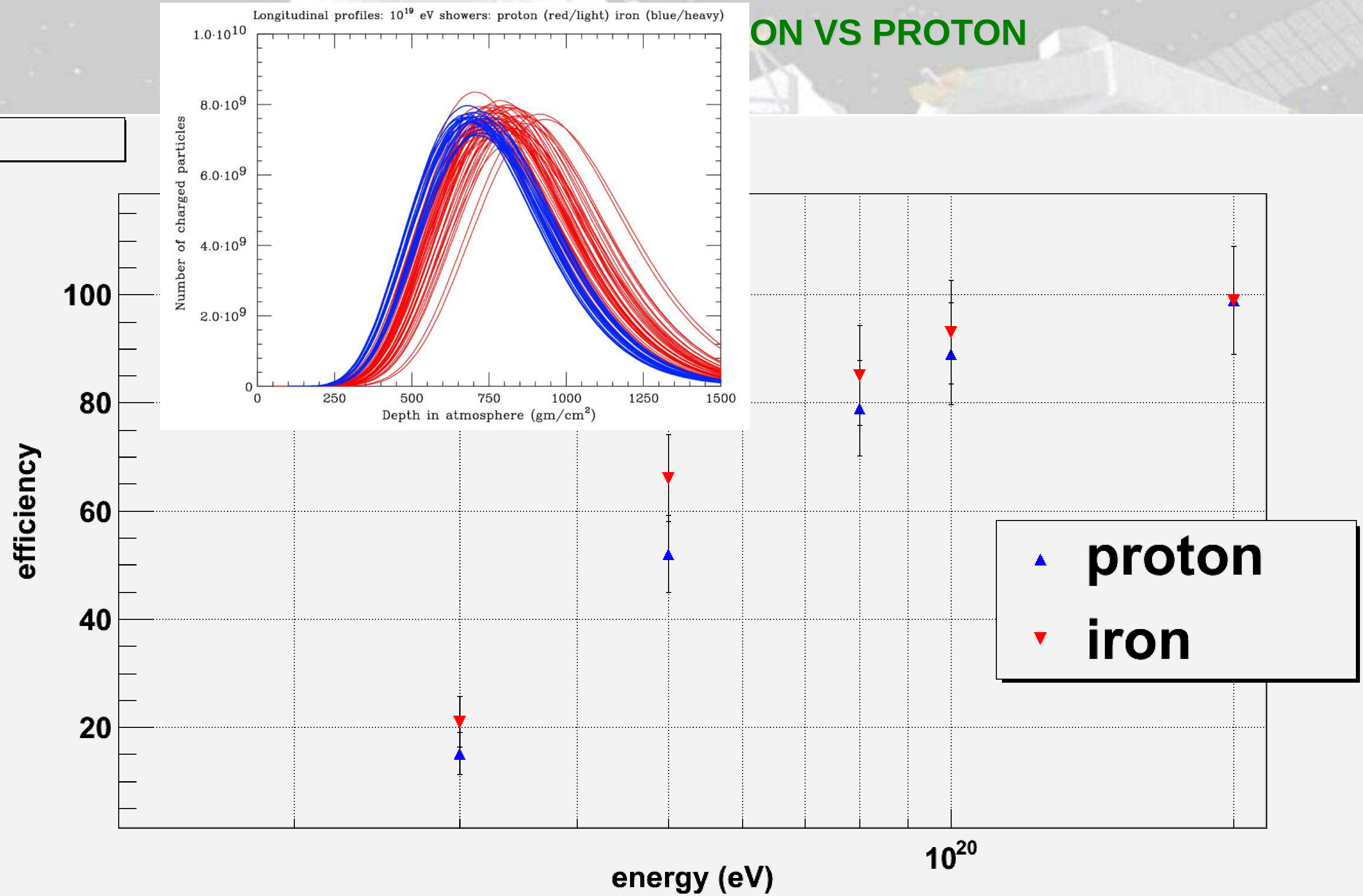




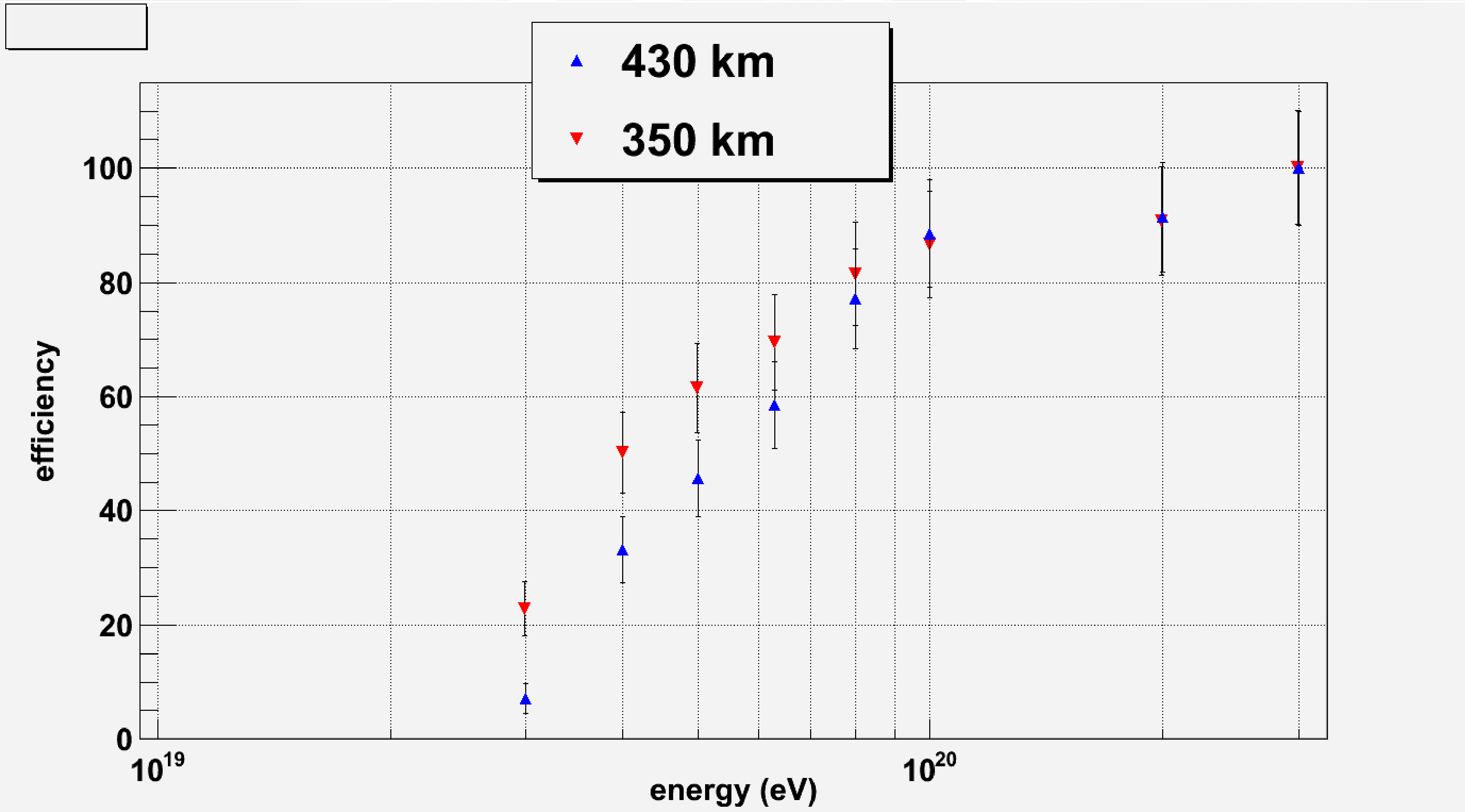
LTT TRIGGER IMPLEMETED AT TÜBINGEN UNIVERSITY (GERMANY)



ON VS PROTON


Longitudinal profiles: 10^{19} eV showers: proton (red/light) iron (blue/heavy)
Number of charged particles
$1.0\cdot10^{10}$
$8.0\cdot10^{9}$
$6.0\cdot10^{9}$
$4.0\cdot10^{9}$
$2.0\cdot10^{9}$
0
0
250
500
750
1000
1250
1500
Depth in atmosphere (gm/cm^2)
efficiency
100
80
60
40
20
10^{20}
energy (eV)
proton
iron

DEPENDENCE OF THE TRIGGER EFFICIENCY CURVE FROM THE ISS HEIGHT



JEM-EUSO SENSITIVITY TO METEOR DETECTION AND TRIGGER

Work presented at JEM-EUSO Atmospheric Monitoring System and Focal Surface Integration Meeting in Torino (Italy), 25 – 29 October 2010 and at the JEM-EUSO Simuation Meeting in Tübingen (Germany), 23 – 25 March 2011

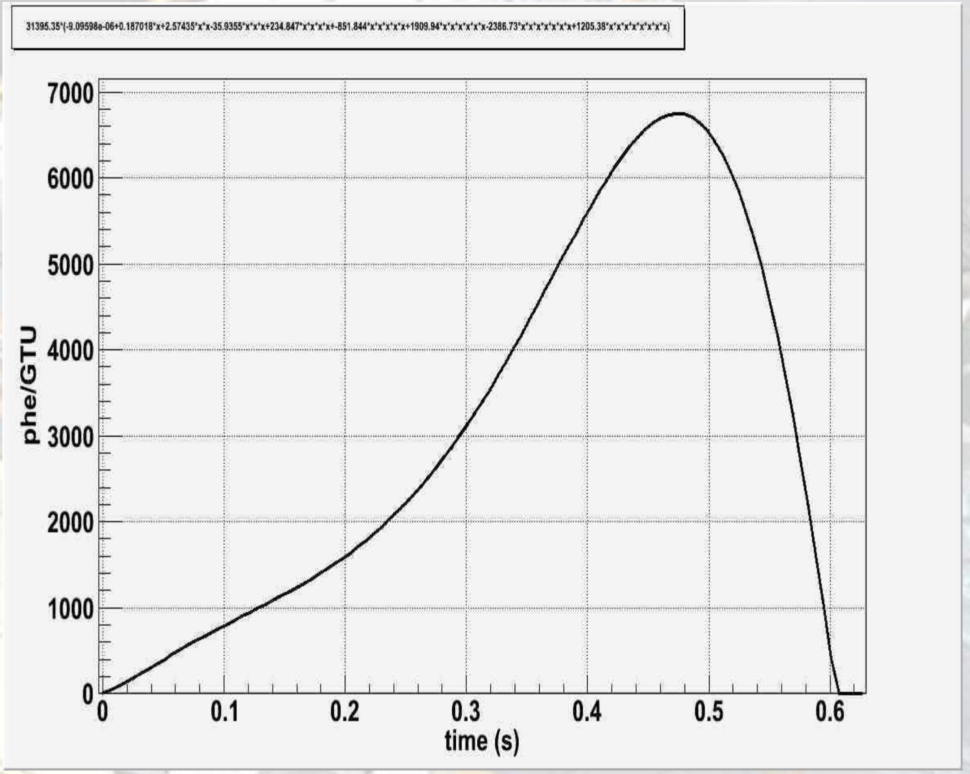
FONT: JEM EUSO Meteor Observation by Watanabe, Ishiguro, Sato (13.06.2009)

flux = flux from Magnitude/Flux Density Converter of Spitzer Science Center (photometric system Johnson UBVRI+ in the U-band)

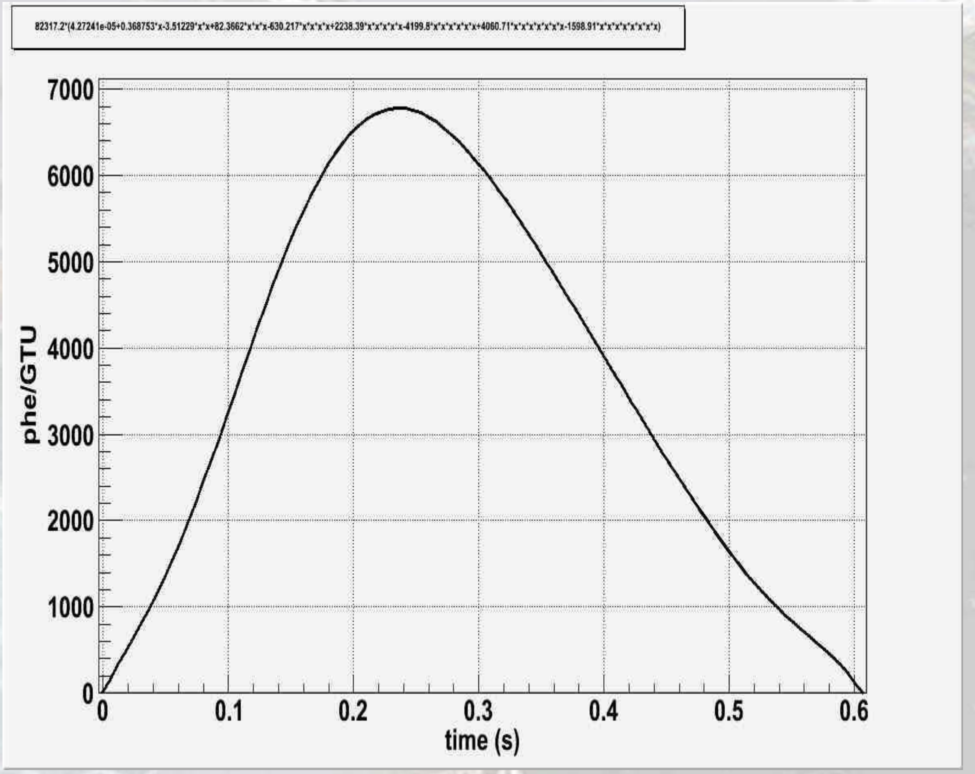
MAGNITUDE	**U-band flux**	**ph/s**	**phe/GTU**	**mass**	**Collisions in the field of view of JEM-EUSO**
7	6.7e-12 erg/s/cm2/A	4.3e7	11	0.002g	1/s
5	4.24e-11 erg/s/cm2/A	2.7e8	68	0.01g	6/min
0	4.24e-9 erg/s/cm2/A	2.7e10	6750	1g	0.27/orbit
-5	4.24e-7 erg/s/cm2/A	2.7e12	675000	100g	6.3/year (duty cycle 0.2)

FONT: On the theory of light curves of video-meteors by P.Pecina and P. Koten on Astronomy and Astophysics (23.02.2009)

MAG: 0



phe/GTU



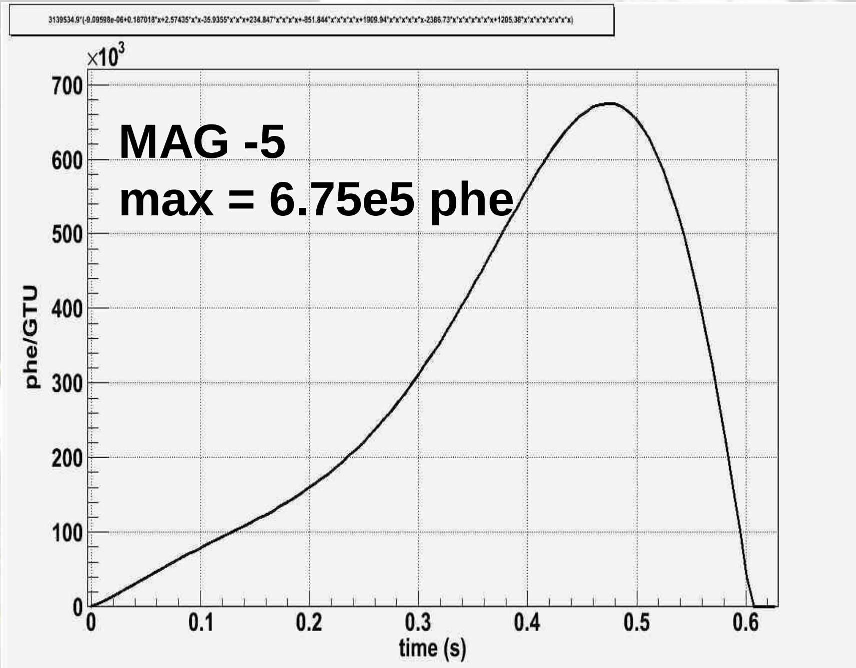
time (s) **time (s)**

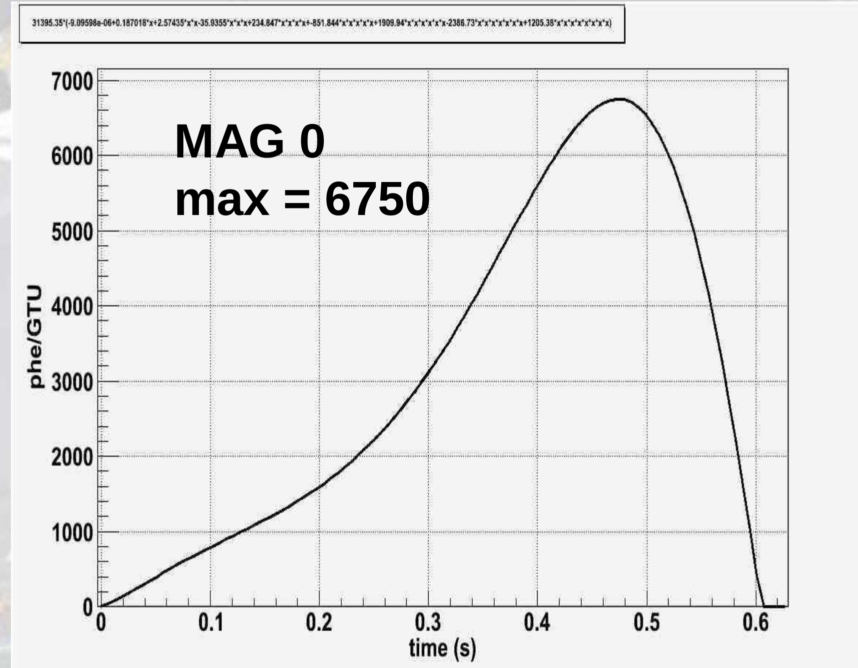
Freq = 0.27/orbit

MAX = 6750 phe/GTU

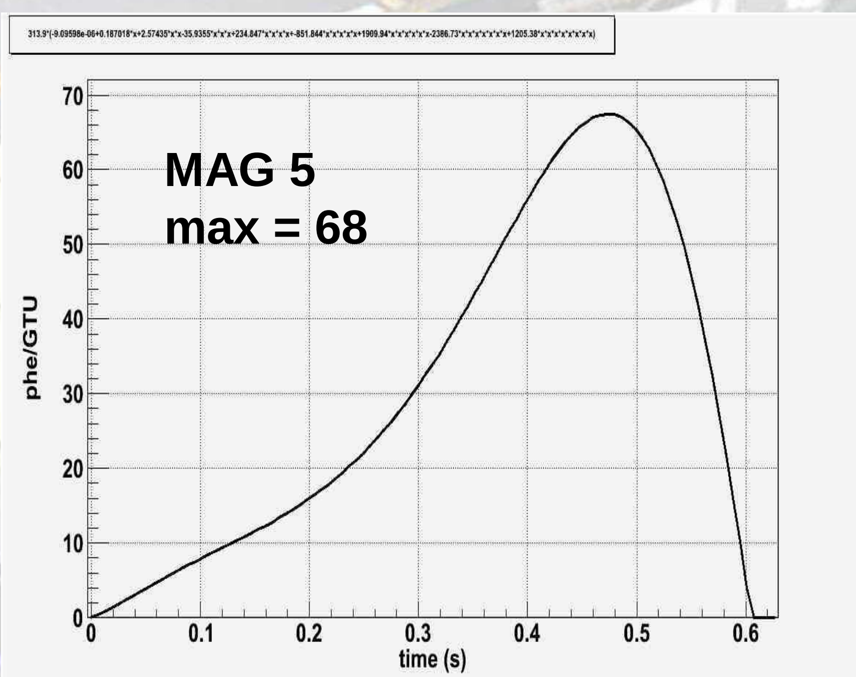
$\Delta t \sim 0.6$ s

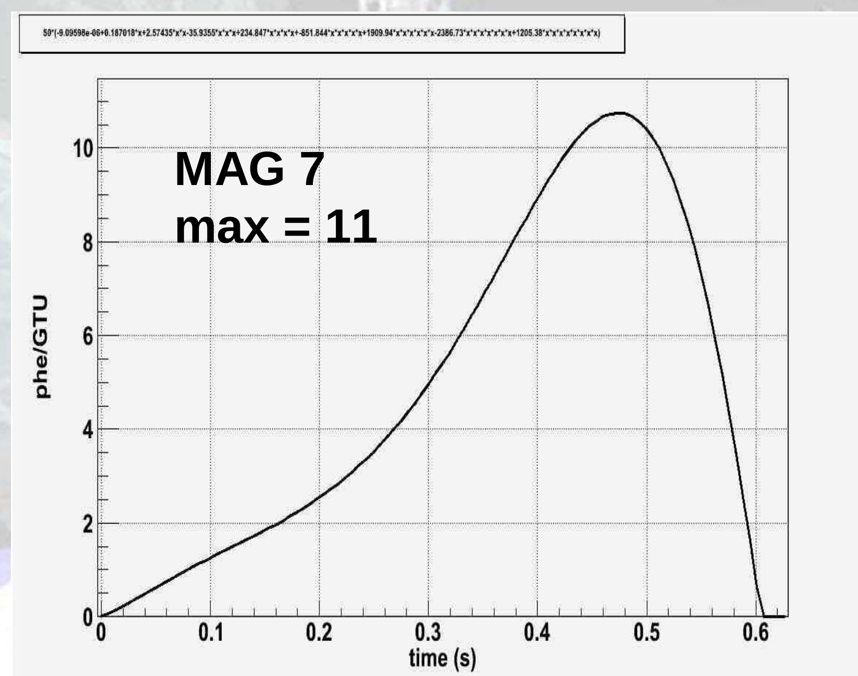
Hp: VISIBLE LIGHT CURVE = UV LIGHT CURVE





phe/GTU

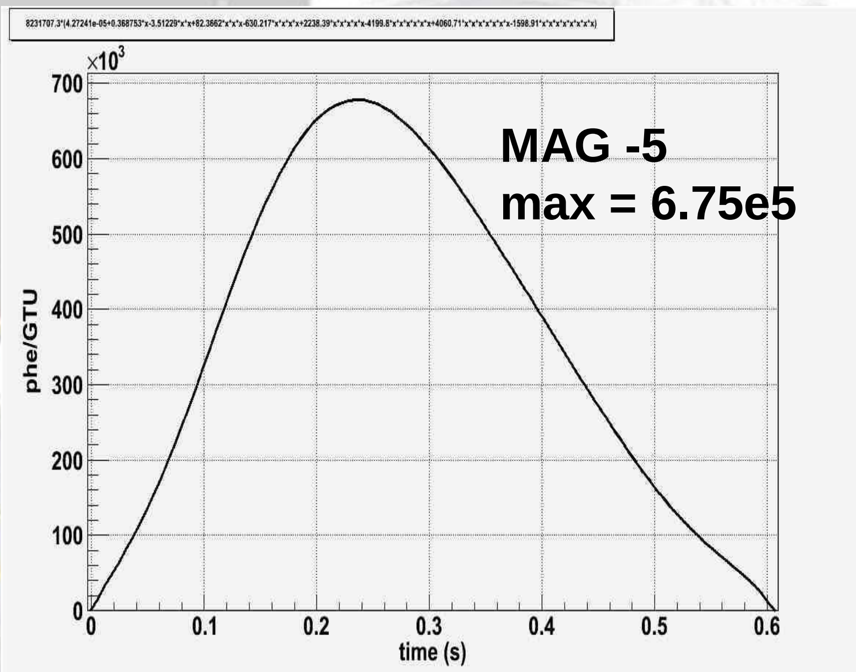




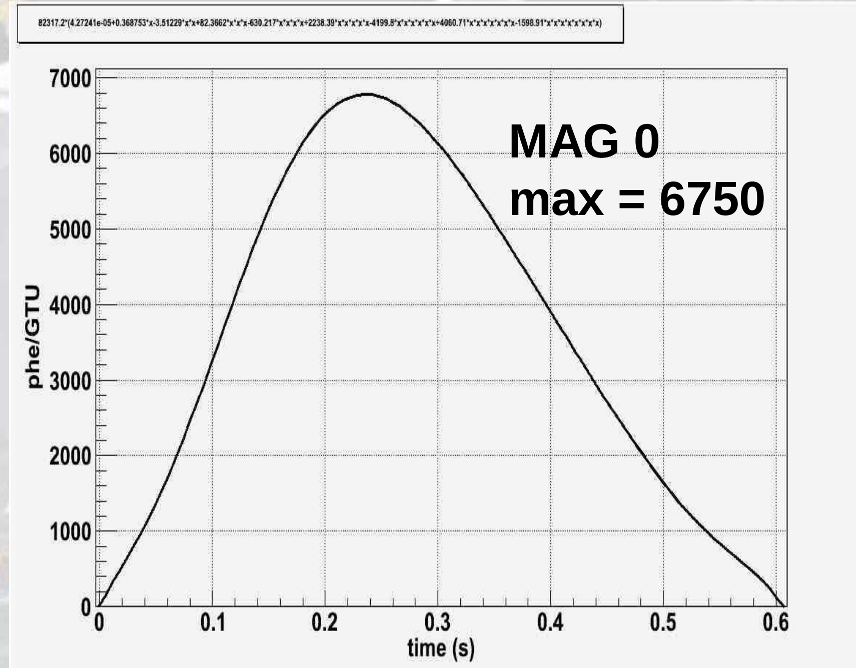
phe/GTU

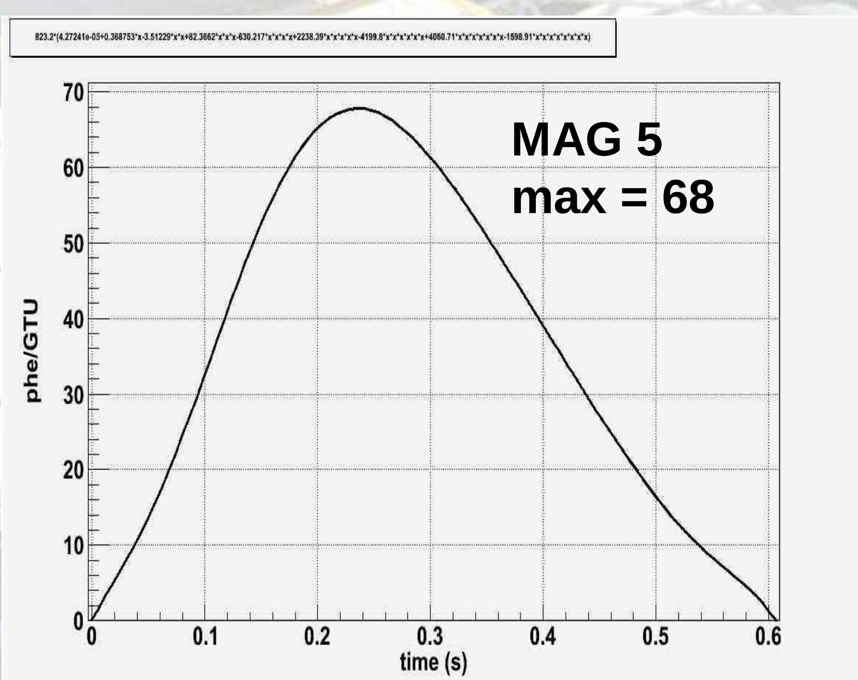
time (s)

time (s)

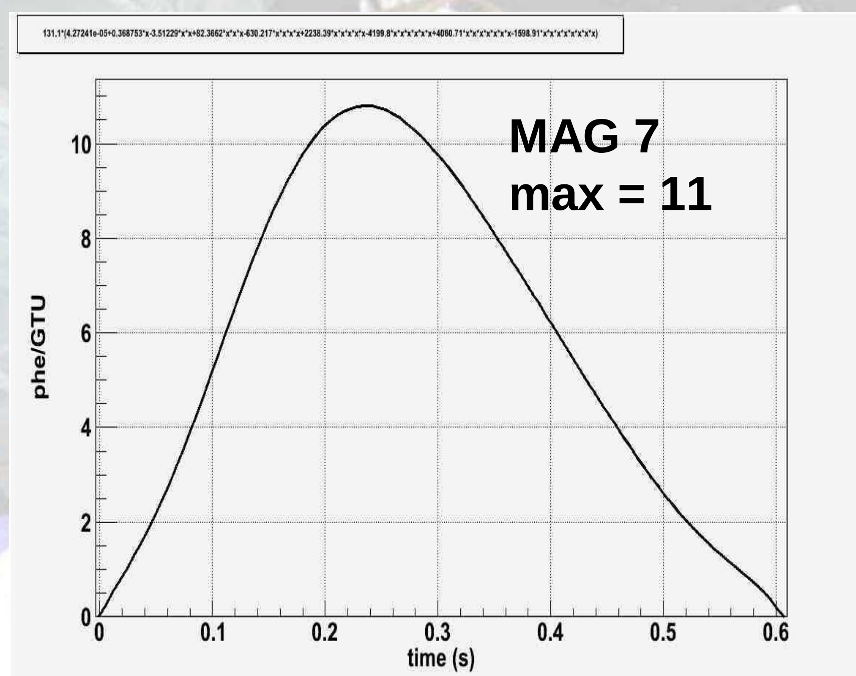


phe/GTU





phe/GTU



time (s)

time (s)

JEM-EUSO triggers meteors with LTT trigger for Cosmic Rays

too many data

exploring an alternative technique:

1 “frame” of 1 GTU (2.5 μs) every 10 ms

useful for background estimation in every PDM

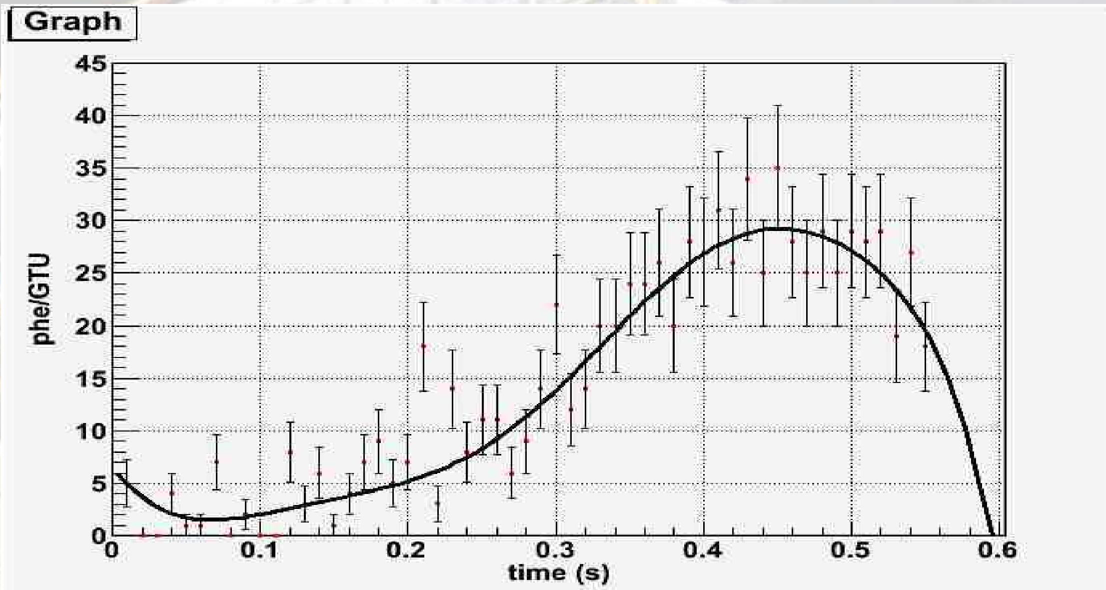
enough for a good reconstruction of meteors till 6.5 mag ?

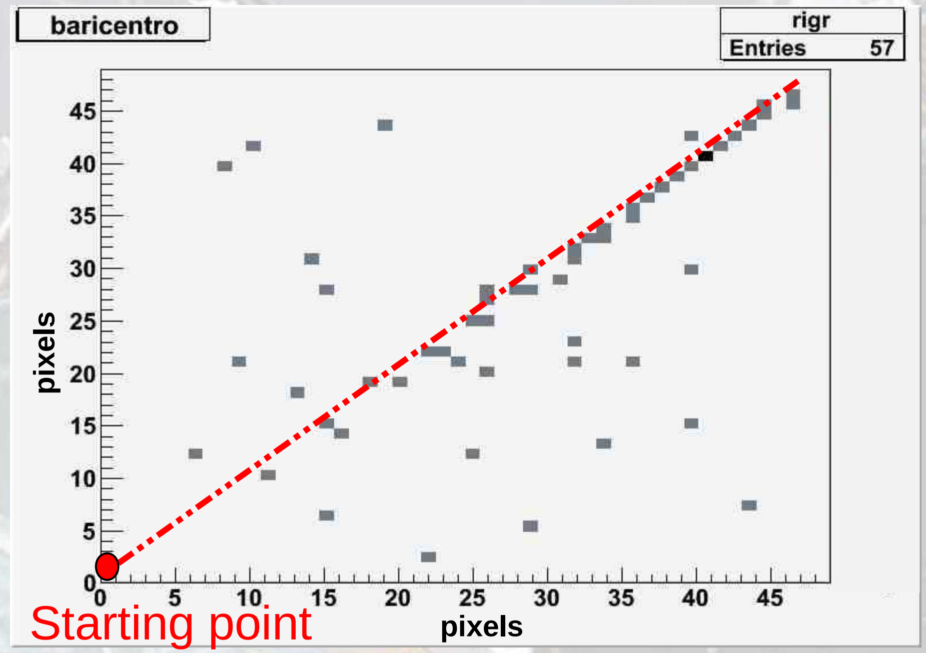
SIMULATION INFOS:
-height → 100km above Earth
-zenith angle → 90° (“flat event”)
-velocity → 35 km/s

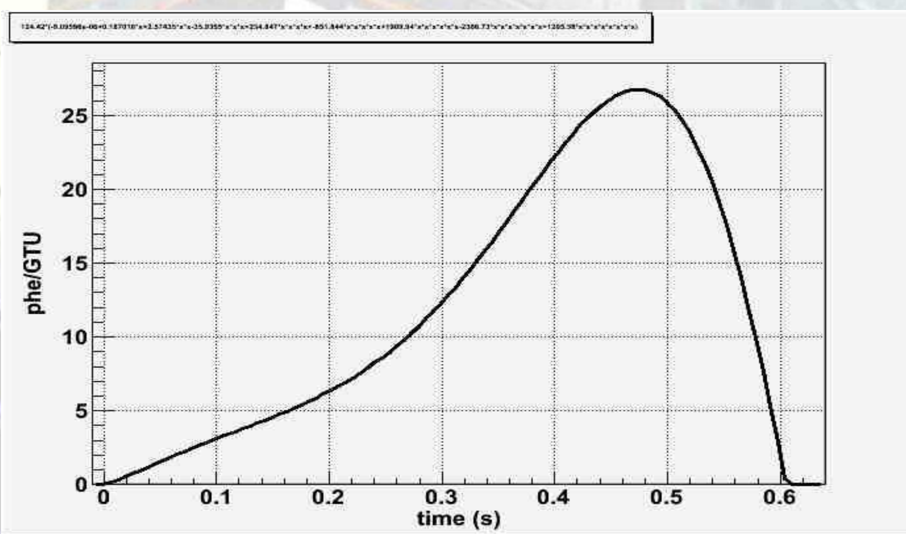
MAG 6 METEOR RECONSTRUCTION

MAX = 27 phe/GTU

Start point pixel (1,1) and direction 45° profile A







INTEGRAL from 0.01s to 0.55s:

SIMULATED → 2.76e6 phe

RECONSTRUCTED → 3.02e6 phe

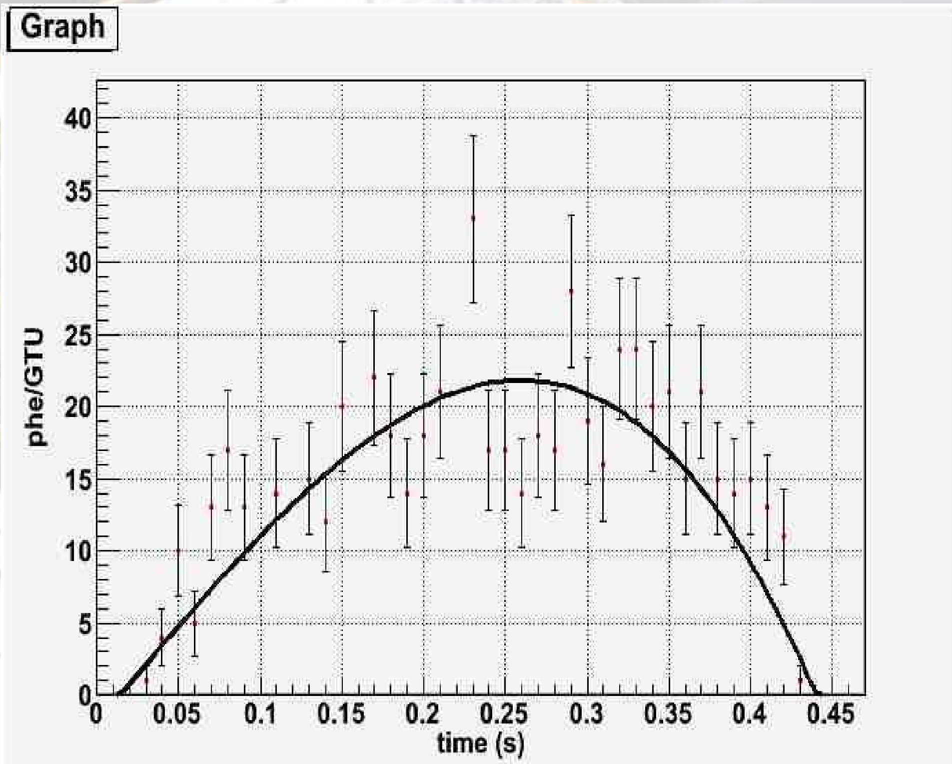
RESOLUTION → 9%

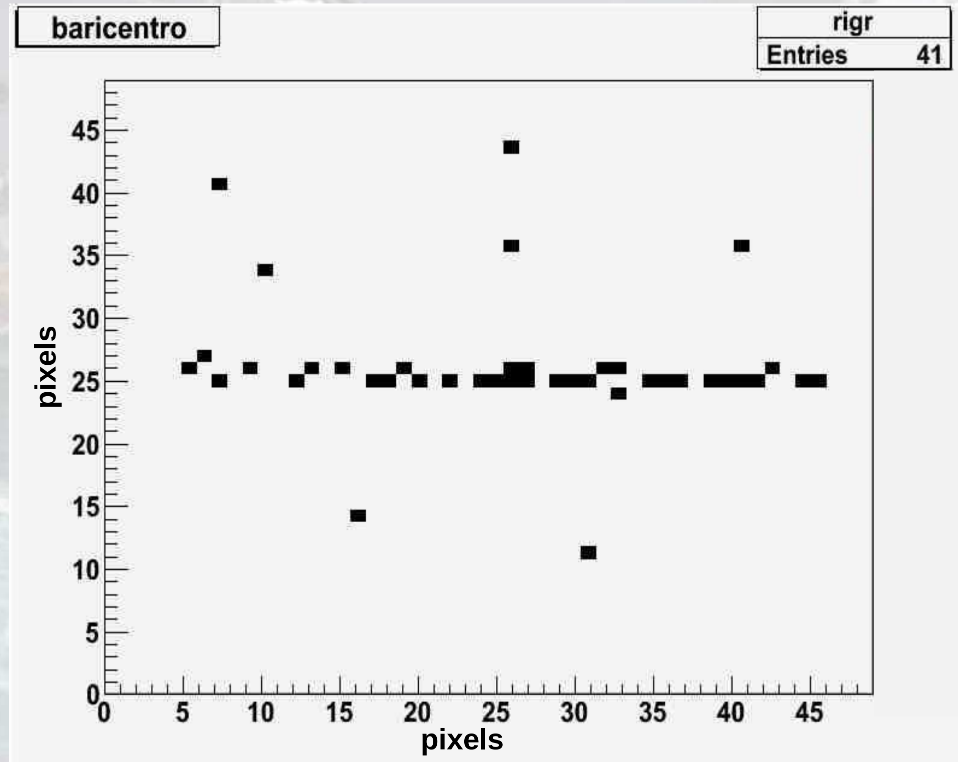
ΔM → 2.5log(MAXreco/MAXsim) = 0.12

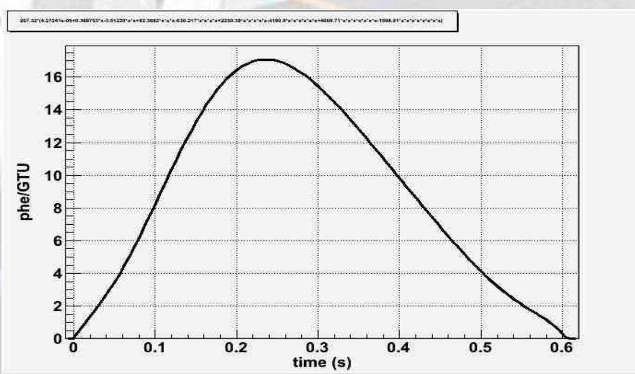
MAG 6.5 METEOR RECONSTRUCTION

MAX = 17 phe/GTU

Start point pixel (-3,25) and direction 0°







INTEGRAL from 0.03s to 0.43s:

SIMULATED → 1.94e6 phe

RECONSTRUCTED → 2.40e6 phe

RESOLUTION → 24%

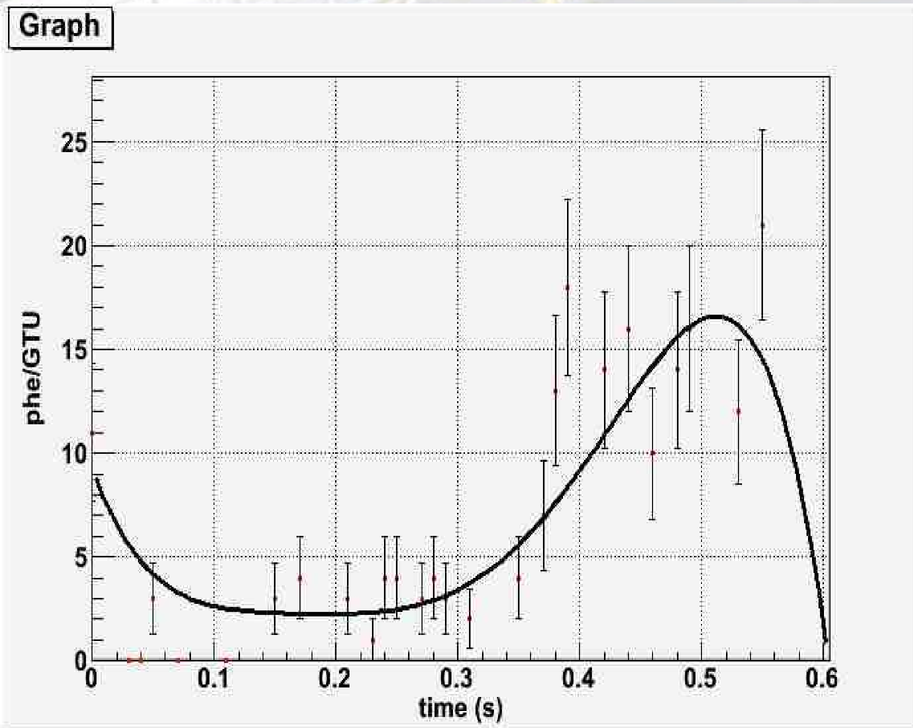
ΔM → 2.5log(MAXreco/MAXsim) = 0.30

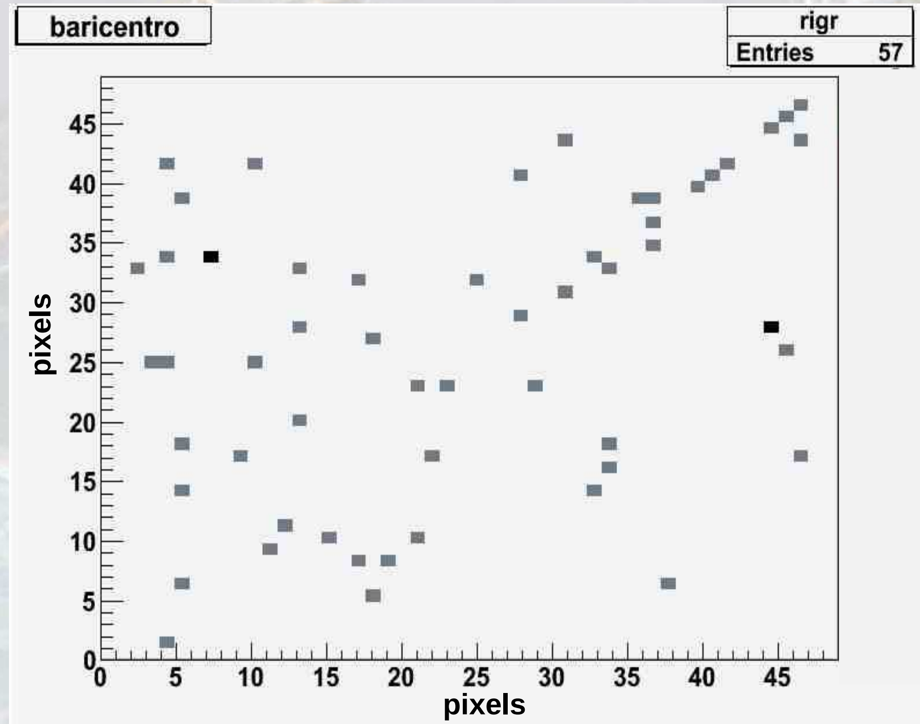
MAG 6.5 METEOR RECONSTRUCTION
MAX = 17 phe/GTU

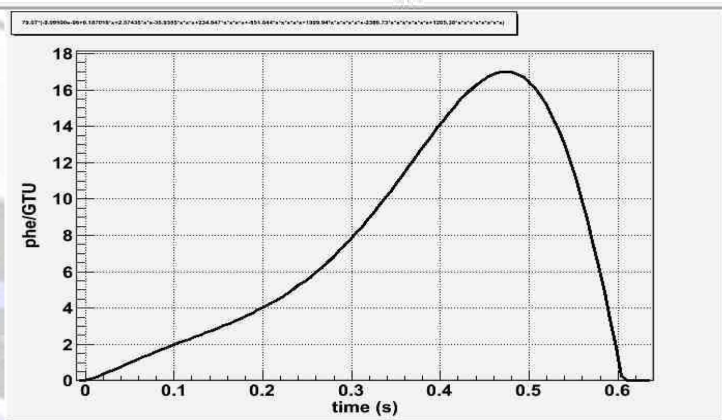
PROFILE	STARTING POINT and DIRECTION	TRAJECTORY RECO	RESOLUTION	ΔM 2,5 log(MAXreco/MAXsim)
A	(1,1) – 45°	YES	1%	0,12
A	(-26,25) – 0°	YES	10%	0,25
B	(1,1) – 45°	YES	13%	0,12
B	(-3,25) – 0°	YES	24%	0,30

MAG 7 METEOR RECONSTRUCTION
MAX = 11 phe/GTU

Start point pixel (1,1) and direction 45°
profile 1







INTEGRAL from 0.03s to 0.55s:
SIMULATED → 1.11e6 phe
RECONSTRUCTED → 1.39e6 phe

RESOLUTION → 25%
ΔM → 2.5log(MAXreco/MAXsim) = 0.50

Preliminary conclusions

JEM-EUSO triggers meteors with LTT trigger for Cosmic Rays

too many data

exploring an alternative technique:
1 “frame” of 1 GTU (2.5 μs) every 10 ms

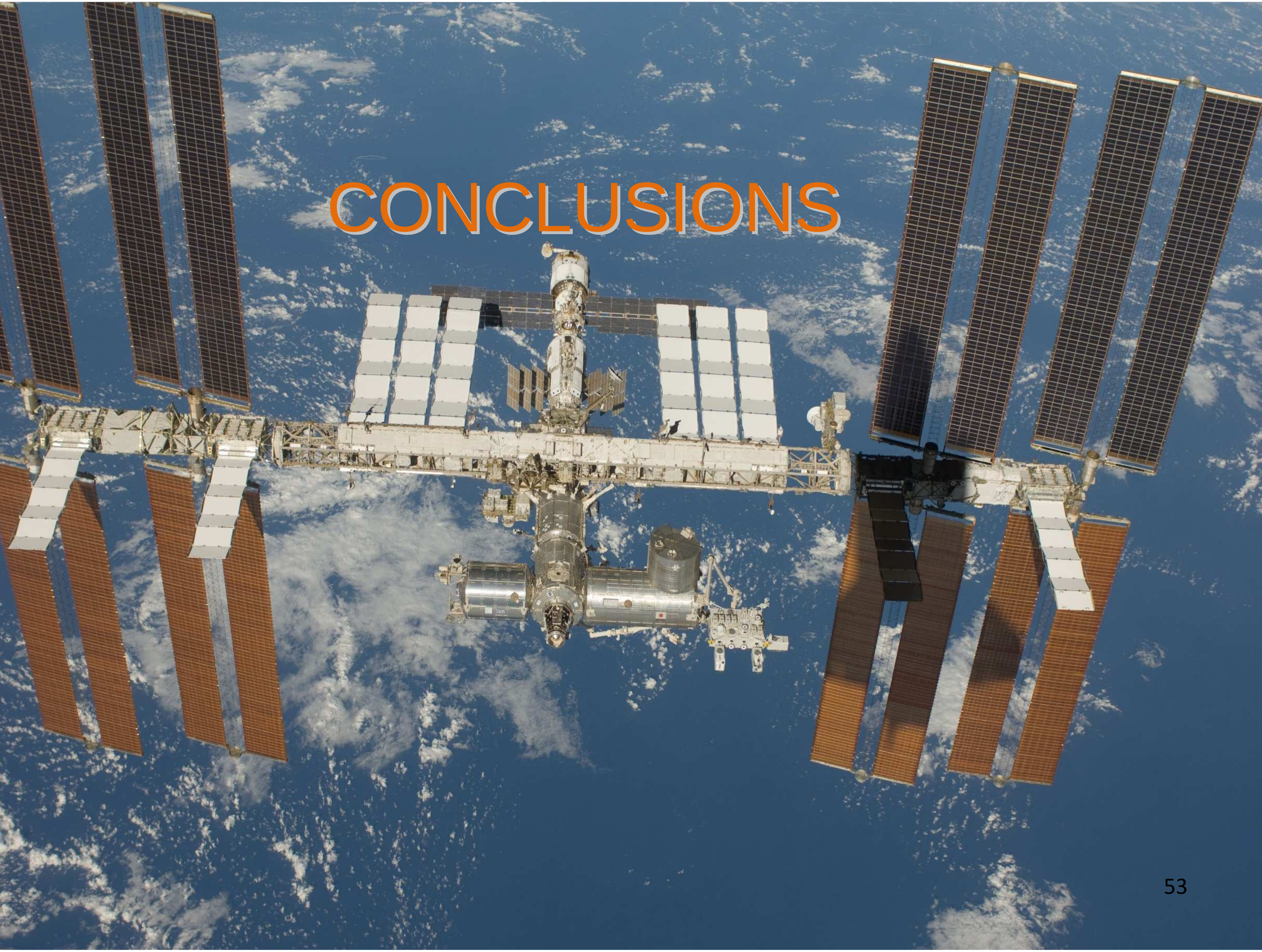
useful for background estimation in every PDM

enough for a good reconstruction of meteors till 6.5 mag ?

YES

- Meteors have linear trajectories like CRs → LTT could be adapted to meteors
- Take 1 GTU of data every 10 ms, store it on a PDM FPGA memory and add it to the main data stream when a trigger is sent to CCB.
- The CCB receives and unpacks data (60s x 100 GTU of data). Every minute the CCB processes the data to look for meteors

CONCLUSIONS

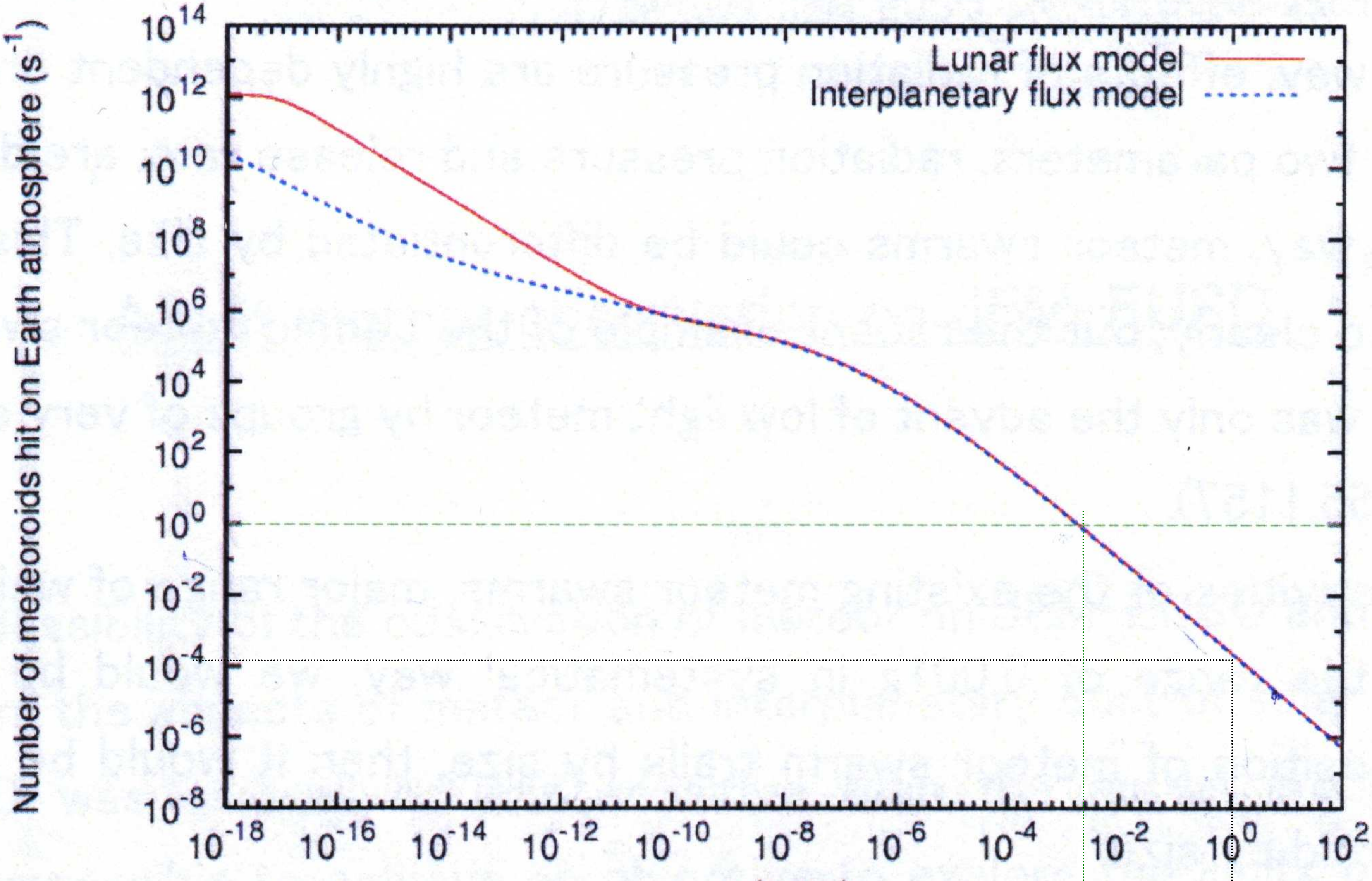


- Study on the clouds distribution **confirmed the FCR = 70 % assumption**.
- Studies on the trigger algorithms showed that **some improvements are still needed** from the **hardware point of view** in the implementation of the **first trigger level**, while the **second level seems to be ready**.
- Studies on the dependance of the trigger efficiency curve as a function of the primary particle and height of the ISS have been studied as well.
- Preliminary study on meteors showed the **feasibility of the observation of meteors with magnitude lower than 6-6.5** and a possible way of collecting the data has been proposed.

- The work on the Duty Cycle has been presented at The 7th International JEM-EUSO Meeting in Huntsville (U.S.), 21-25 June 2010 and taken into account for future studies. It will be presented at the ICRC 2011 this summer.
- The work about trigger has been presented at the JEM-EUSO Simulation meeting in Tübingen (Germany), 23 – 25 March 2011.
- The work about Meteor sensitivity and trigger has been presented at JEM-EUSO Atmospheric Monitoring System and Focal Surface Integration Meeting in Torino (Italy), 25 – 29 October 2010, and at the JEM-EUSO Simulation meeting in Tübingen (Germany), 23 – 25 March 2011 and taken into account for future studies.

THANK YOU

Cumulative number of collisions of meteoroids with the Earth's atmosphere in the field of view of JEM-EUSO

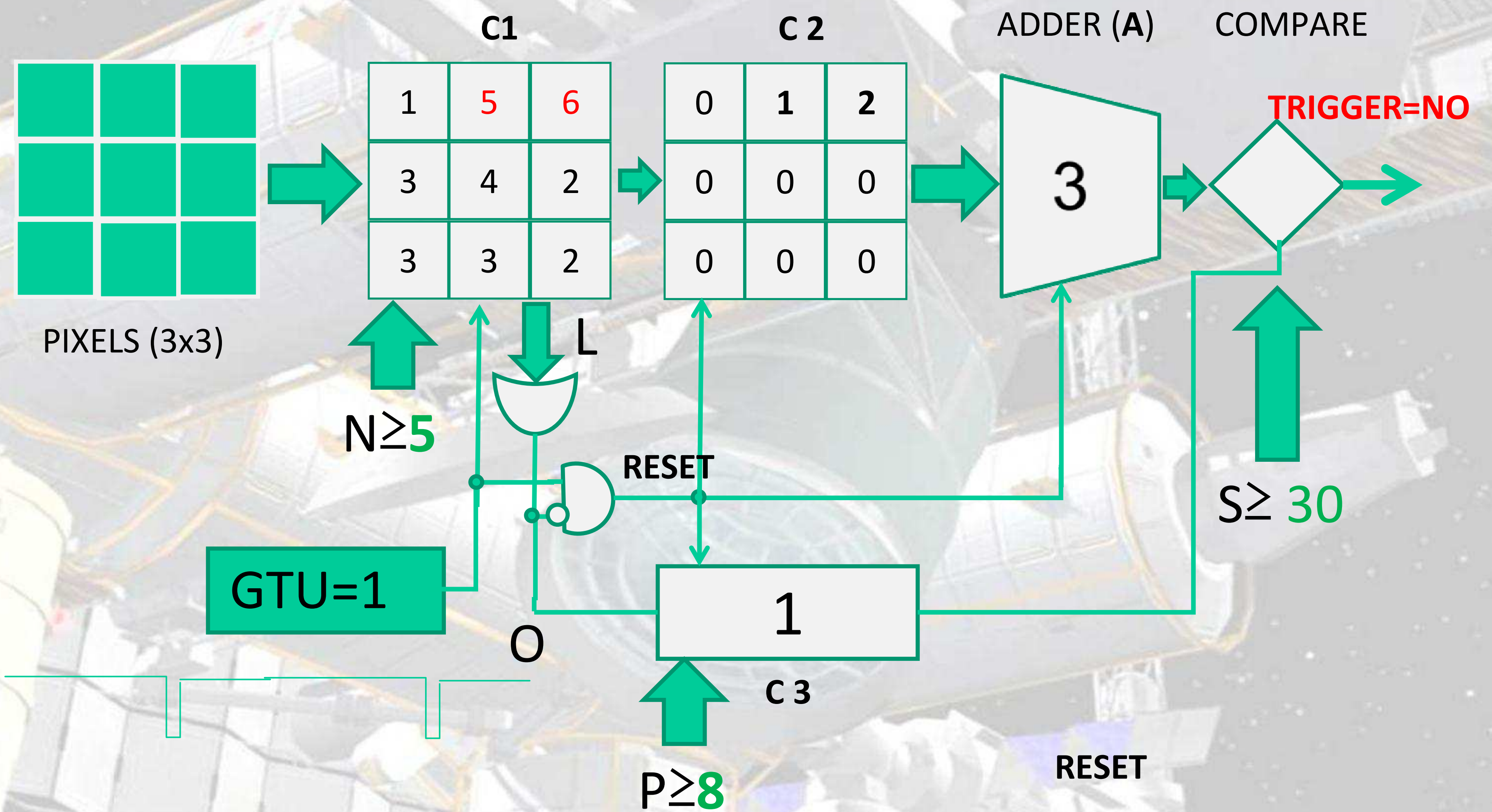


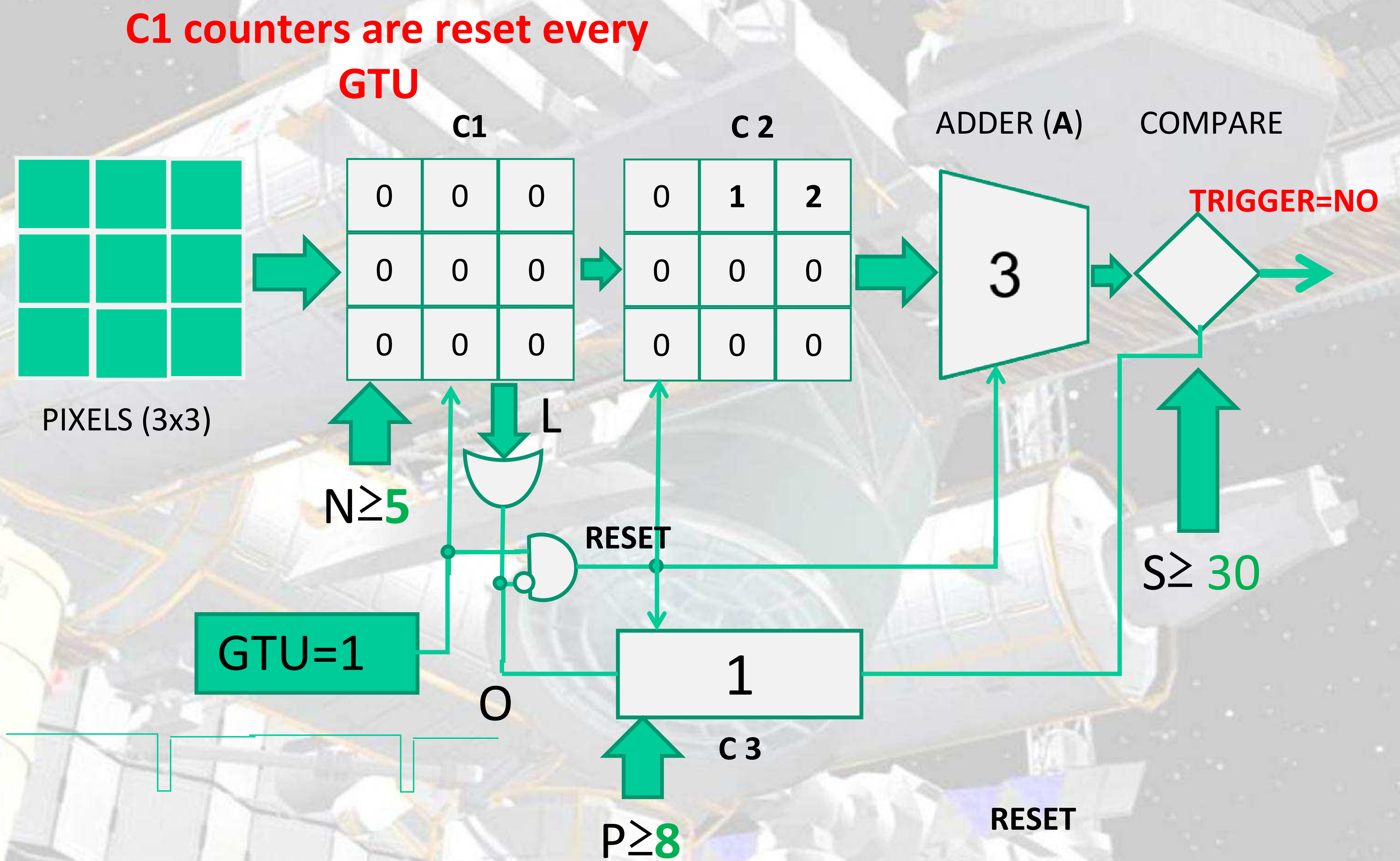
1/s
MAG 7

0.27/orbit
MAG 0

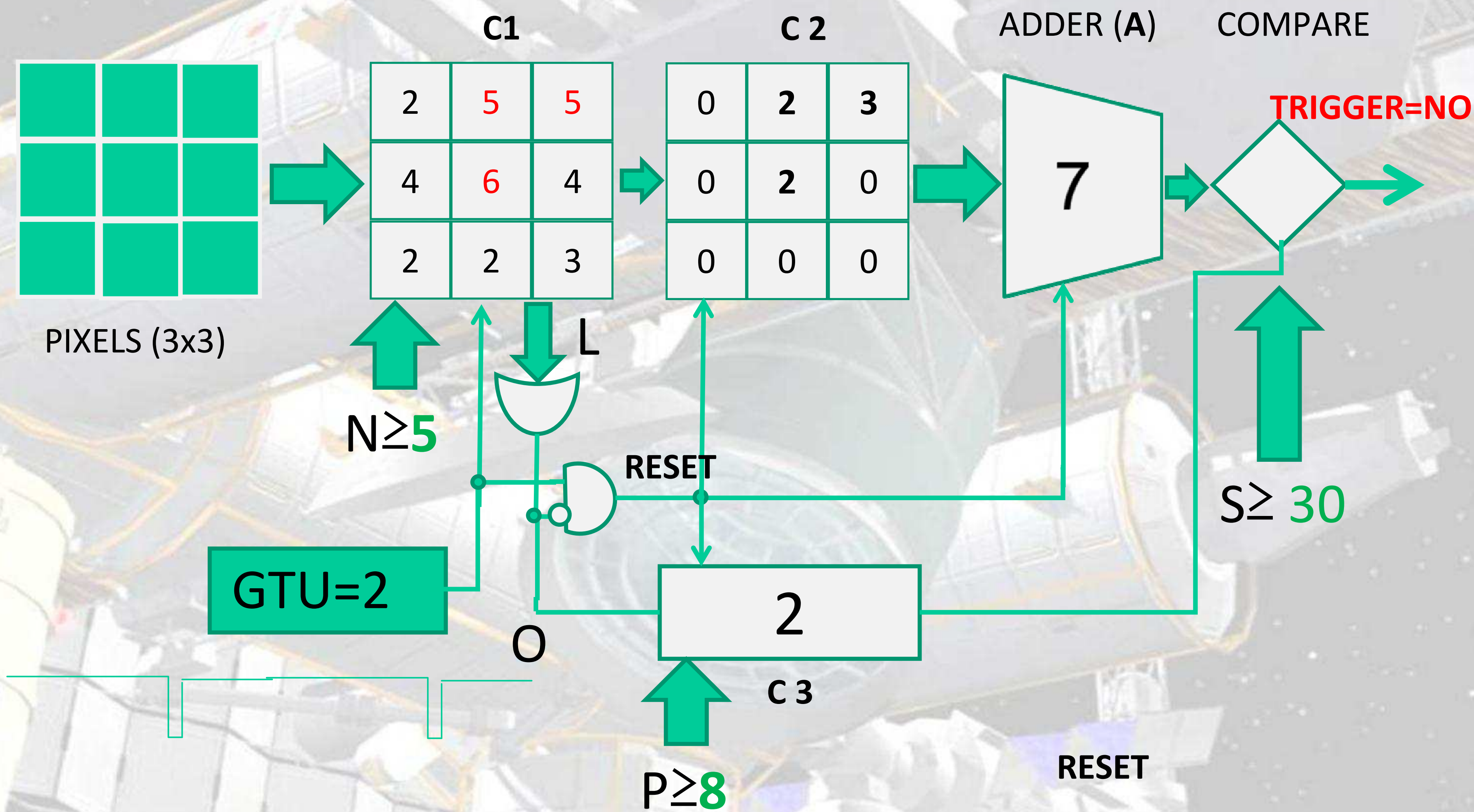
PROGRESSIVE TRACK TRIGGER – PTT (1st LEVEL TRIGGER – 7Hz/PDM)

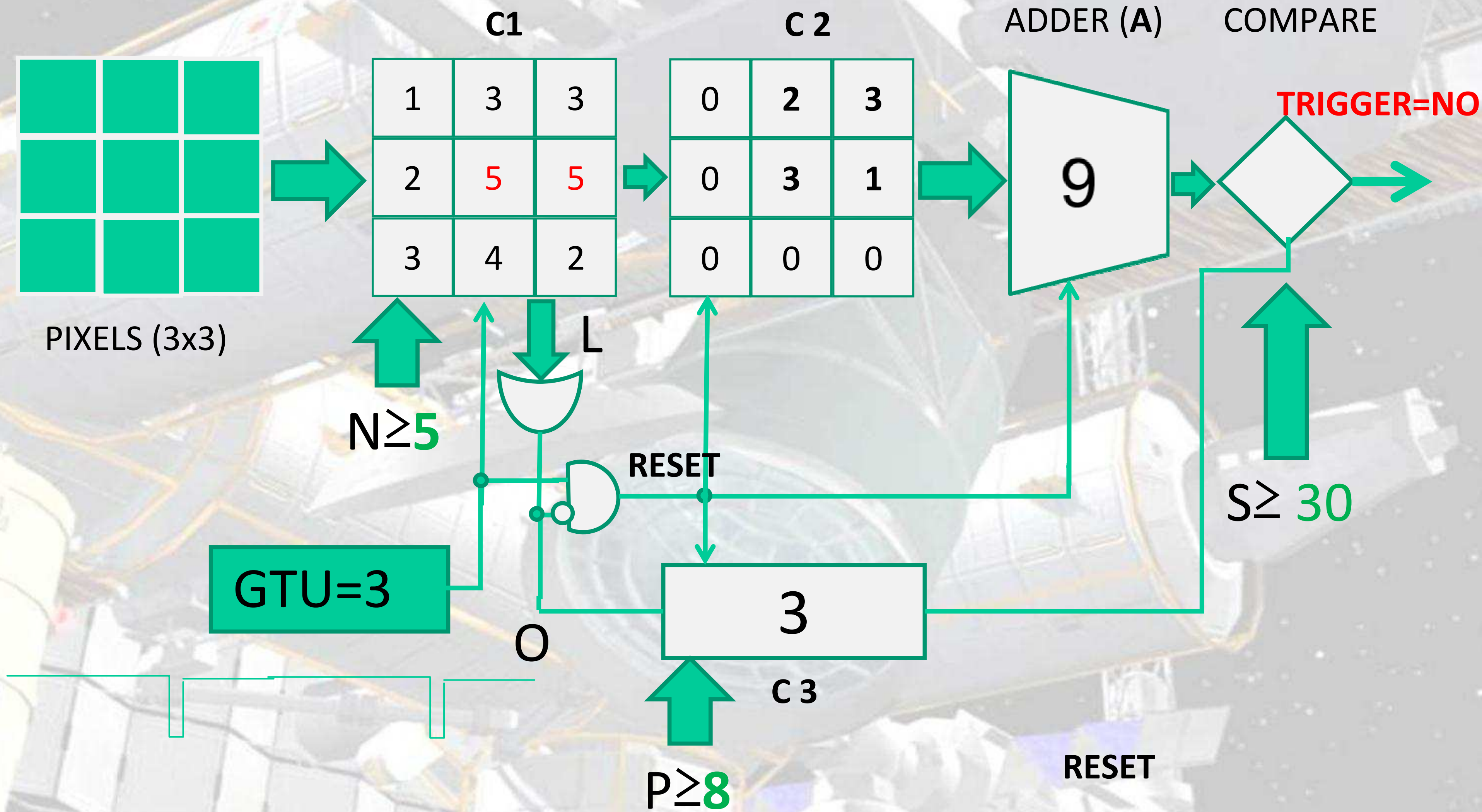
EXAMPLE: TRIGGER



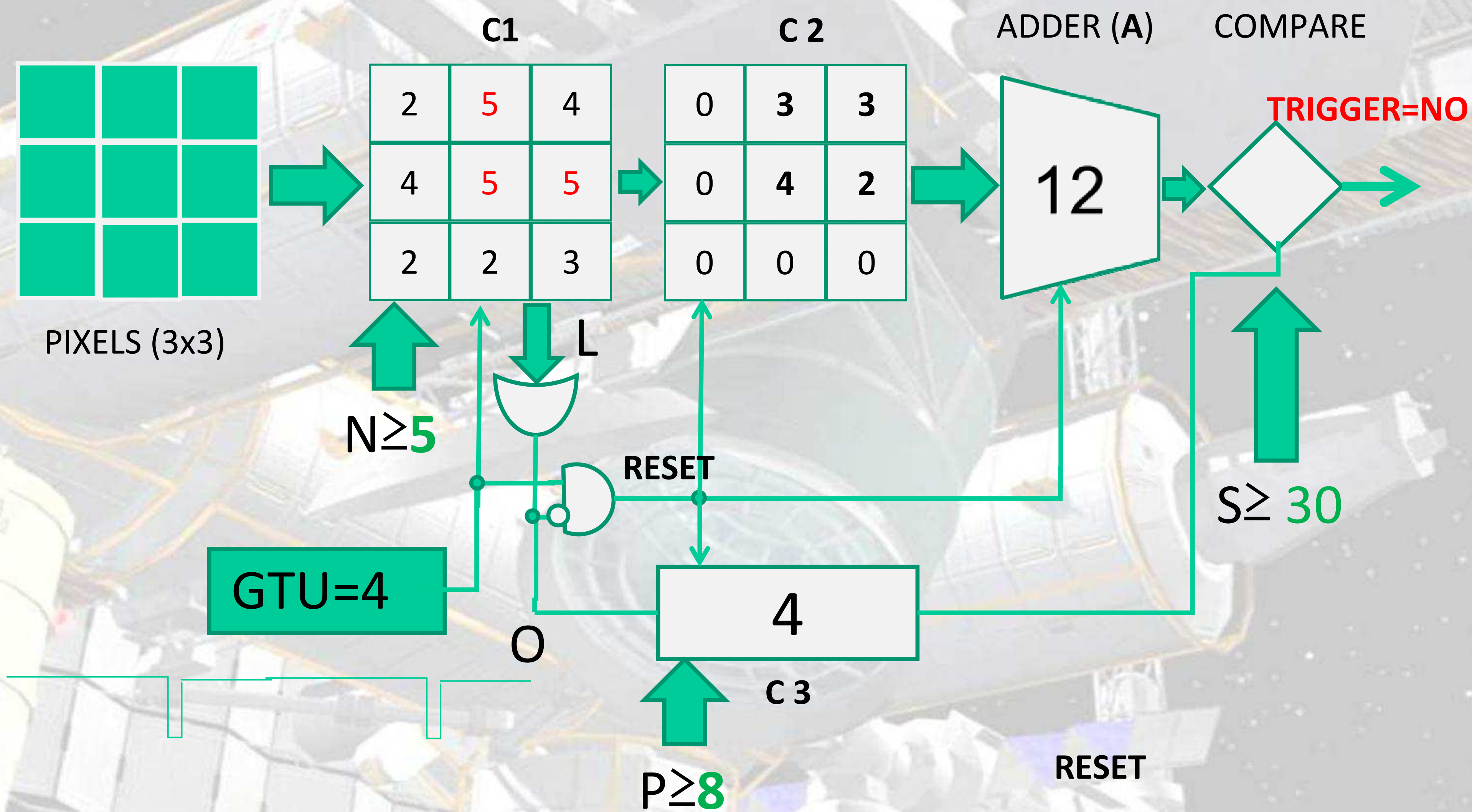


C1 counters are reset every GTU
C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
PIXELS (3x3)
0 0 0
0 0 0
0 0 0
0 1 2
0 0 0
0 0 0
3
L
N≥5
RESET
S≥ 30
GTU=1
1
O
C 3
P≥8
RESET

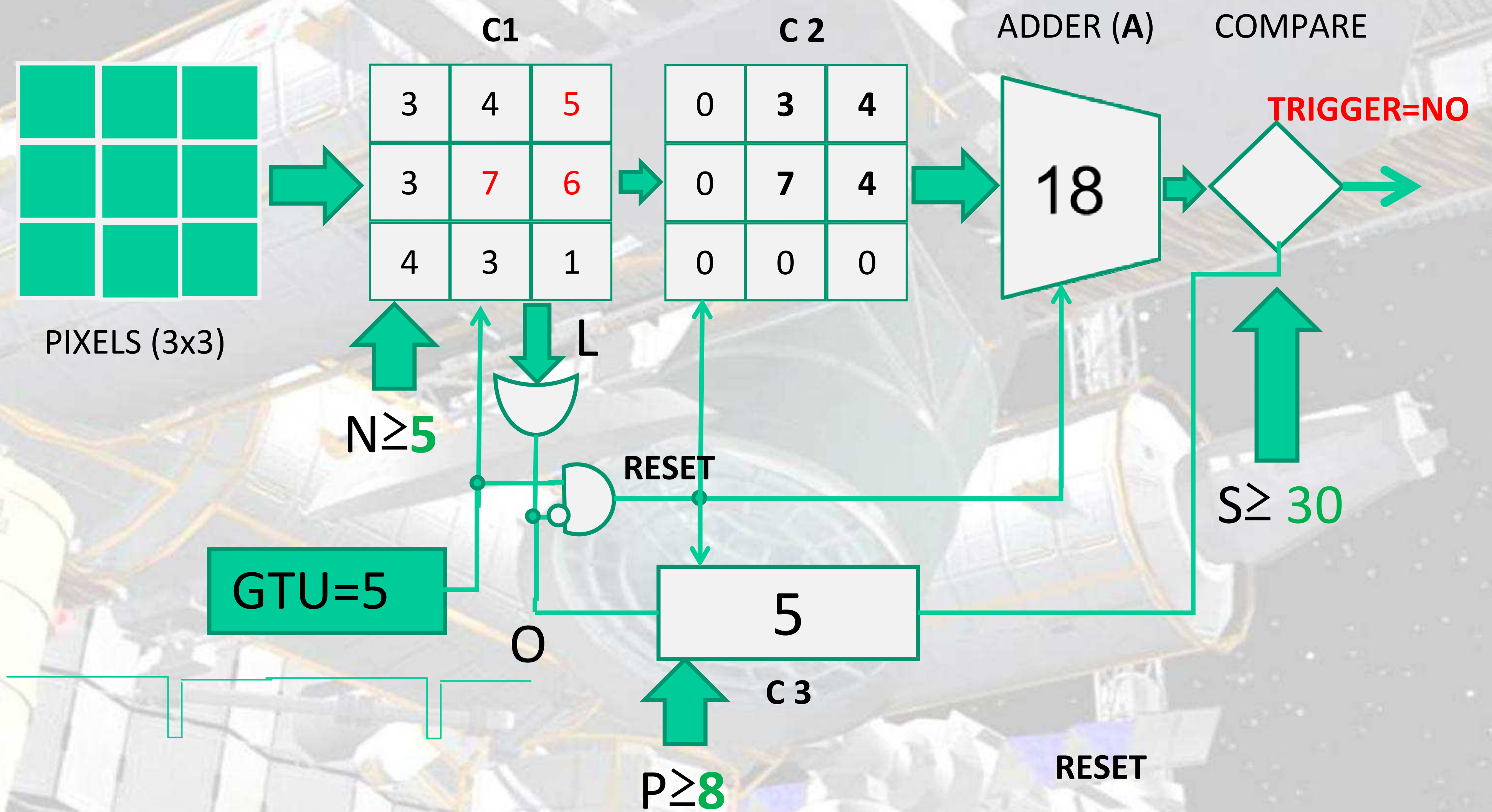

C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
2 5 5
4 6 4
2 2 3
0 2 3
0 2 0
0 0 0
7
PIXELS (3x3)
L
N≥5
RESET
S≥ 30
GTU=2
O
2
C 3
P≥8
RESET

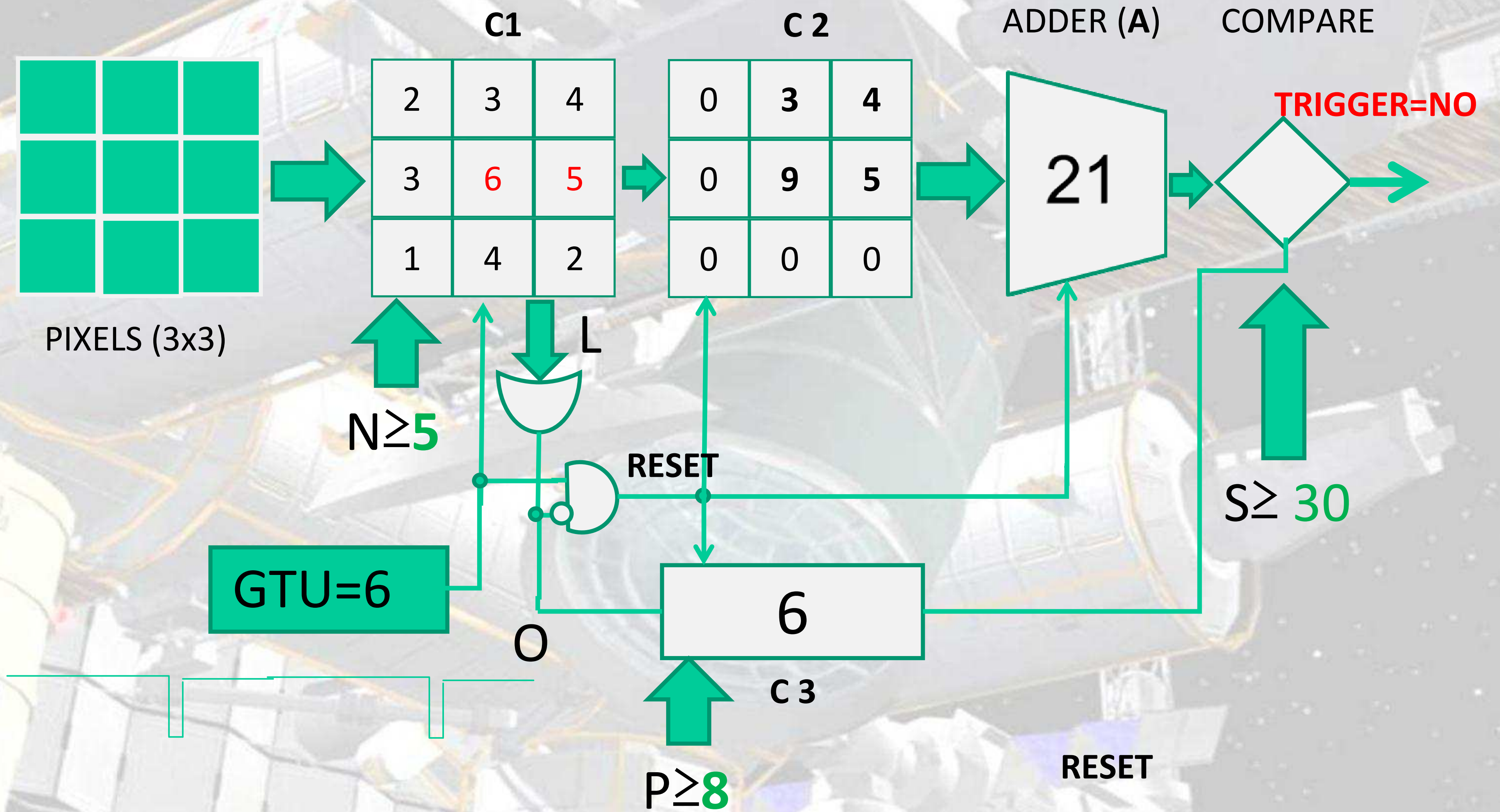


C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
1 3 3
2 5 5
3 4 2
0 2 3
0 3 1
0 0 0
9
PIXELS (3x3)
L
N≥5
RESET
S≥ 30
GTU=3
3
O
C 3
P≥8
RESET

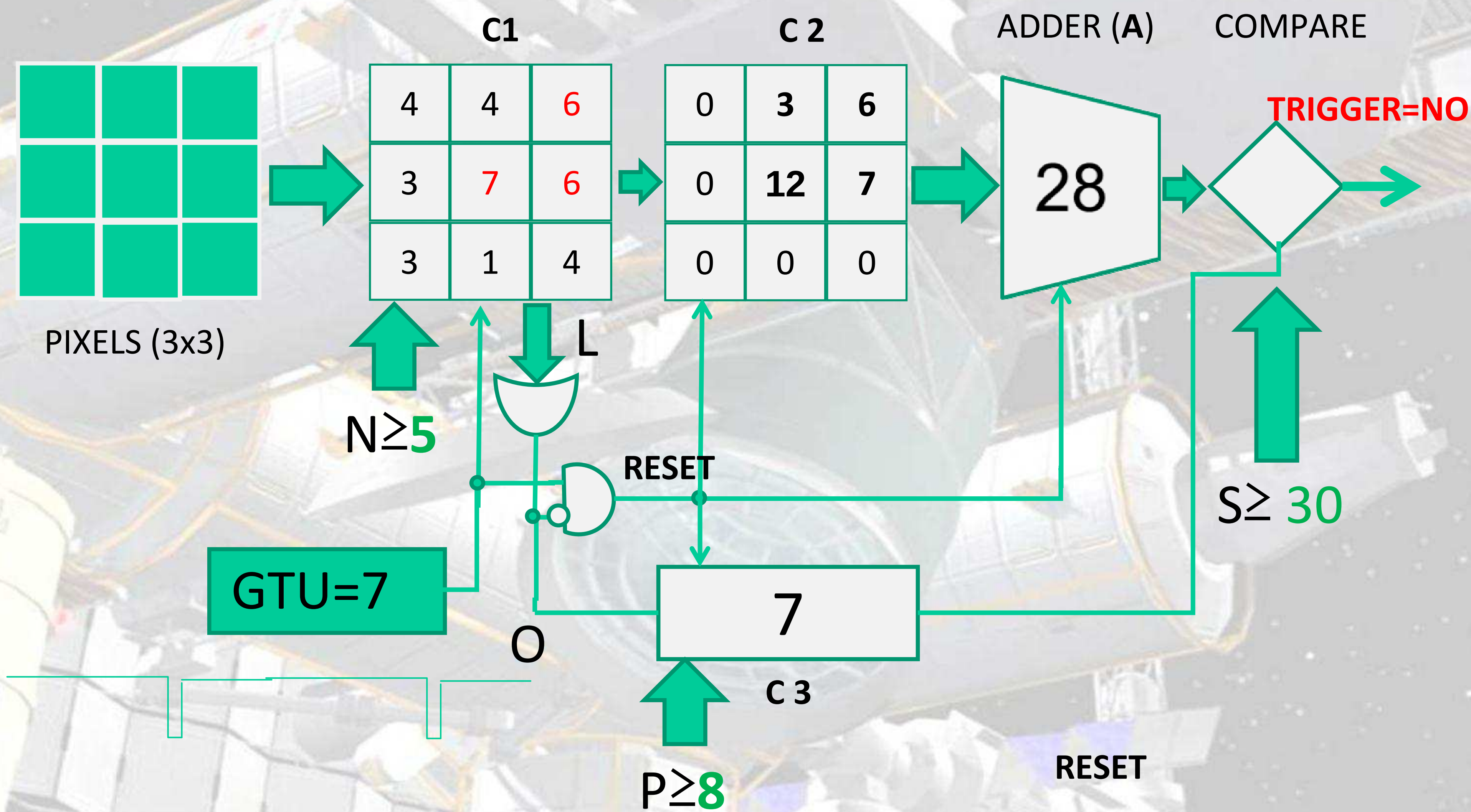


C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
2 5 4
4 5 5
2 2 3
0 3 3
0 4 2
0 0 0
12
PIXELS (3x3)
L
N≥5
RESET
S≥ 30
GTU=4
4
O
C 3
P≥8
RESET

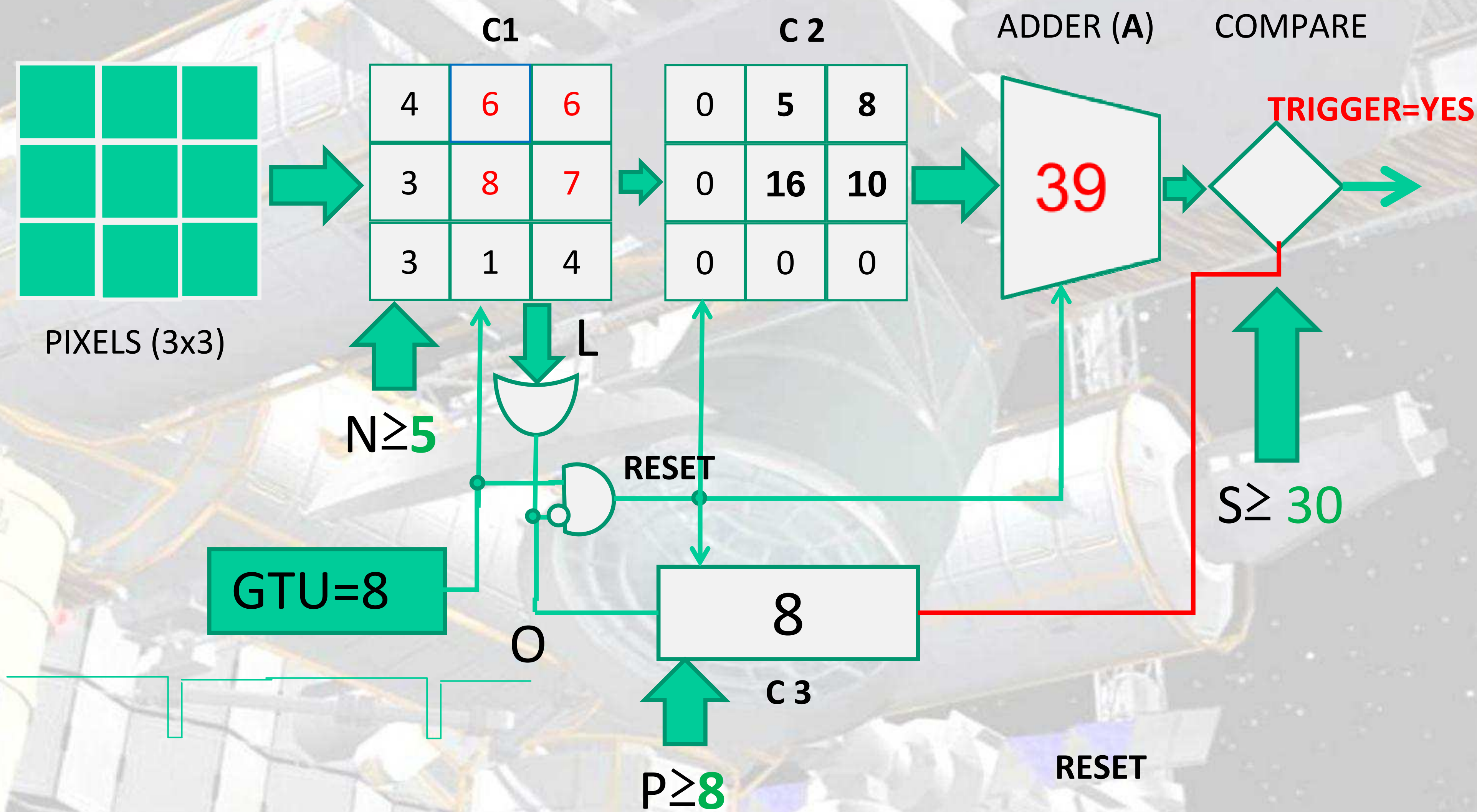

PIXELS (3x3)
C1
3 4 5
3 7 6
4 3 1
C 2
0 3 4
0 7 4
0 0 0
ADDER (A)
18
COMPARE
TRIGGER=NO
L
N≥5
RESET
GTU=5
O
5
C 3
P≥8
S≥ 30
RESET



C1
C 2
ADDER (A)
COMPARE
TRIGGER=NO
2 3 4
3 6 5
1 4 2
0 3 4
0 9 5
0 0 0
21
PIXELS (3x3)
L
N≥5
RESET
S≥ 30
GTU=6
6
O
C 3
P≥8
RESET



PIXELS (3x3)
C1
4 4 6
3 7 6
3 1 4
C 2
0 3 6
0 12 7
0 0 0
ADDER (A)
28
COMPARE
TRIGGER=NO
N≥5
L
RESET
GTU=7
O
7
C 3
P≥8
S≥ 30
RESET


C1
C 2
ADDER (A)
COMPARE
TRIGGER=YES
4 6 6
3 8 7
3 1 4
0 5 8
0 16 10
0 0 0
39
PIXELS (3x3)
L
N≥5
RESET
S≥ 30
GTU=8
8
O
C 3
P≥8
RESET

Tables from studies for the old EUSO experiment (2003)

Identification probability (ESA-Phase A)

Opt. depth	Cloud top altitude [km] <3	3—7	7—10	>10
>2	99%	74%	44%	16%
1—2	85%	60%	35%	38%
0.1—1	59%	43%	35%	60%
<0.1	76%	23%	3%	64%

Ratio of # of phtons (60 degrees 1e20eV; No cloud =1)

Opt. depth	Cloud top altitude [km] 2	5	7.5	10
5	1.07	0.79	0.26	0.03
1.5	0.83	0.65	0.33	0.18
0.15	0.78	0.68	0.54	0.47
0.05	0.77	0.78	0.76	0.76

Convolution

Cloud properties distribution (nighttime)

Opt. depth	Cloud top altitude [km] <3	3—7	7—10	>10
>2	14.1%	4.9%	3.9%	4.5%
1—2	5.8%	2.0%	3.5%	3.1%
0.1—1	6.6%	2.4%	3.9%	17.7%
<0.1	29.5%	0.7%	0.5%	1.8%

Opt. depth	Cloud top altitude [km] <3	3—7	7—10	>10
>2	14%	4%	2%	1%
1—2	5%	1%	1%	1%
0.1—1	4%	1%	1%	11%
<0.1	22%	0%	0%	1%

Average = 69%

Including very fine weather
69% EAS reconstructible

Cloud Coverage X Identification Probability = AverageOf CRsRecontruction

OBJECTIVES:

1) Verify **cloud properties distribution** by:
   a) using same dataset
   b) using different datasets

2) Understand the uncertainties on the **cloud properties distribution**

3) From 1) and 2) derive an uncertainty on the total fraction of detectable events, by assuming the correctness of table **identification probability**

PROGRESSIVE TRACK TRIGGER - PTT

•***PIXELS ABOVE <BACKGROUND>*** . For each Elementary Cell (EC) pixels, digitalized anode pulses (*pe*) are counted within a GTU(2.5 μs) and compared with a pre-set digital threshold **N**. At every GTU the counters **C1**, one for each pixel, are reset. For each **C1,** if the counts are greater than the pre-set threshold , the successive pulses are conveyed to a second counter **C2**, one for each pixel, and a signal **L**, one for each pixel, flags the pixel as active. All the **L** signals are OR-ed.

•***ELEMENTARY CELL ACTIVITY CHECK*** . A counter **C3** (persistency counter), only one per EC, is increased at each GTU if the output signal **O** of the OR-ed **L** signals is active else it is reset.

•***SPACE-TIME CORRELATION OF PIXELS ABOVE THRESHOLD .*** The **C3** counts are compared with a pre-set digital threshold **P**. If the **C3** counts reach the **P** threshold a signal is issued to the adder **A** that holds the **C2** counters 2x2 (or 3x3) grouped. The resulting addition is then compared with the pre-set value **S** corresponding to the total number of *pe* requested in the 2x2 (or 3x3) grouped pixels. If the condition is met, an EC trigger is then generated.

Obviously read-out of data is based on "free running method": pixels counts recorded on memories of suitable depth are reading out at the occurrence of a trigger.

LINEAR TRACK TRIGGER - LTT

- The algorithm looks at the pixel (X_0,Y_0,t_0) that fired trigger level 1 at GTU t_0.
- One of the 9 pixels around (X_0,Y_0,t_0) is used as a starting point for tracks.
- Tracks are 15 GTU long.
- Tracks are free to move in time (Dt<15GTU) around t_0, therefore the pixel (X_0,Y_0,t_0) could be, in principle, even the first or the last pixel of the track.
- Tracks are searched at $0° < f < 360°$ and $5° < q < 85°$ at 10 deg steps for both angles (~315 angles).
- The box is still 4 pixels / GTU and only Yellow pixels inside the
the
- box are used for integration of the signal.
- The threshold on the total photon counts inside the track is set in order to reduce the rate of fake triggers to < 0.1 Hz/FS.

EWHA TRIGGER

1 PDM have 36*36 pixels. And each PDM is independent.

Step 1

Find seed at (i)th GTU.

This seed(pixel) based on over-threshold of n photo-electron per pixel.

Step 2

Find clusters(2x2 pixels) at (i-1)th GTU

2x2 pixels which include seed and satisfy survival condition (mean(cluster) > m photo-electron)

Step 3

Select neighbor clusters (9 clusters per each survived cluster) of survived clusters at (i-1)th GTU

Survival condition again (mean(cluster) > m) at (i-2)th GTU

Step 4

Select neighbor clusters of survived at (i-2)th GTU, consider direction

Survival condition again (mean(cluster) > m) at (i-3)th GTU

Step 5

Do same as (i-2)th frame till (i-4)th frame

Total 5 frames are used to decide trigger

If there is no cluster which satisfy all of these conditions, we cannot trigger at (i)th frame

If there are survived clusters (from (i)th to (i-4)th frame) → triggered at (i)th frame