JEM-EUSO

Extreme Universe Space Observatory on board Japanese Experiment Module

Extensive Air Shower reconstruction in JEM-EUSO mission using ESAF software

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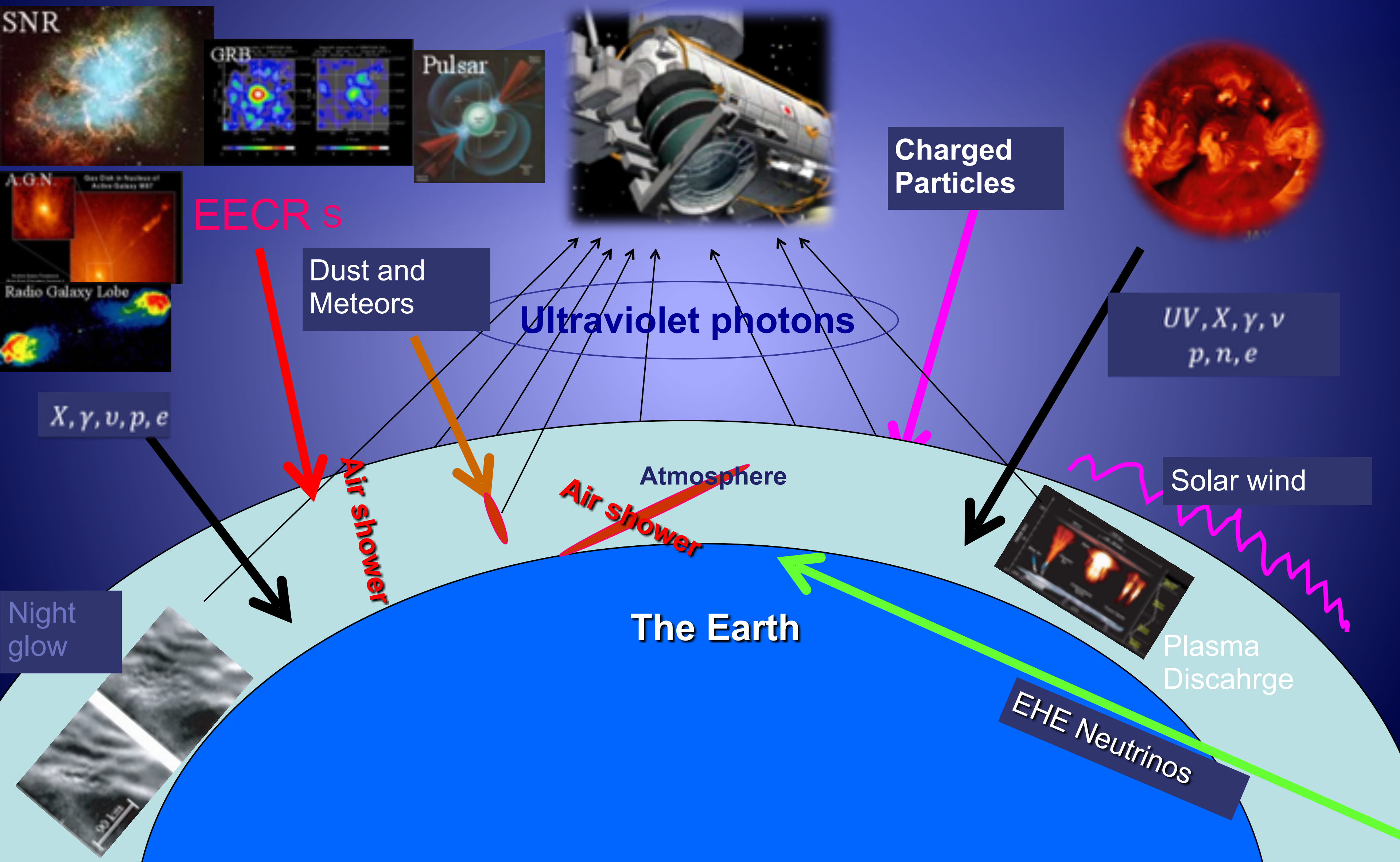
JEM-EUSO is an Astronomical Earth Observatory from Space



Science Objectives

Main Objective: Astronomy and astrophysics through particle channel with extreme energies ($E > 5 \times 10^{19} eV$)

- Identification of **sources** by the high statistics arrival direction analysis
- Measurement of the **energy spectra** from individual sources to constrain acceleration or emission mechanisms

Exploratory objectives:

- Detection of extreme energy **gamma-rays**
- Measurement of extreme energy **neutrinos**
- Study of the Galactic **magnetic field**
- Verification of the **relativity** and the **quantum gravity** effect in extreme energy
- Global observation of **atmospheric** phenomena: nightglows, lightning , plasma discharges and meteors

CR Energy Spectrum

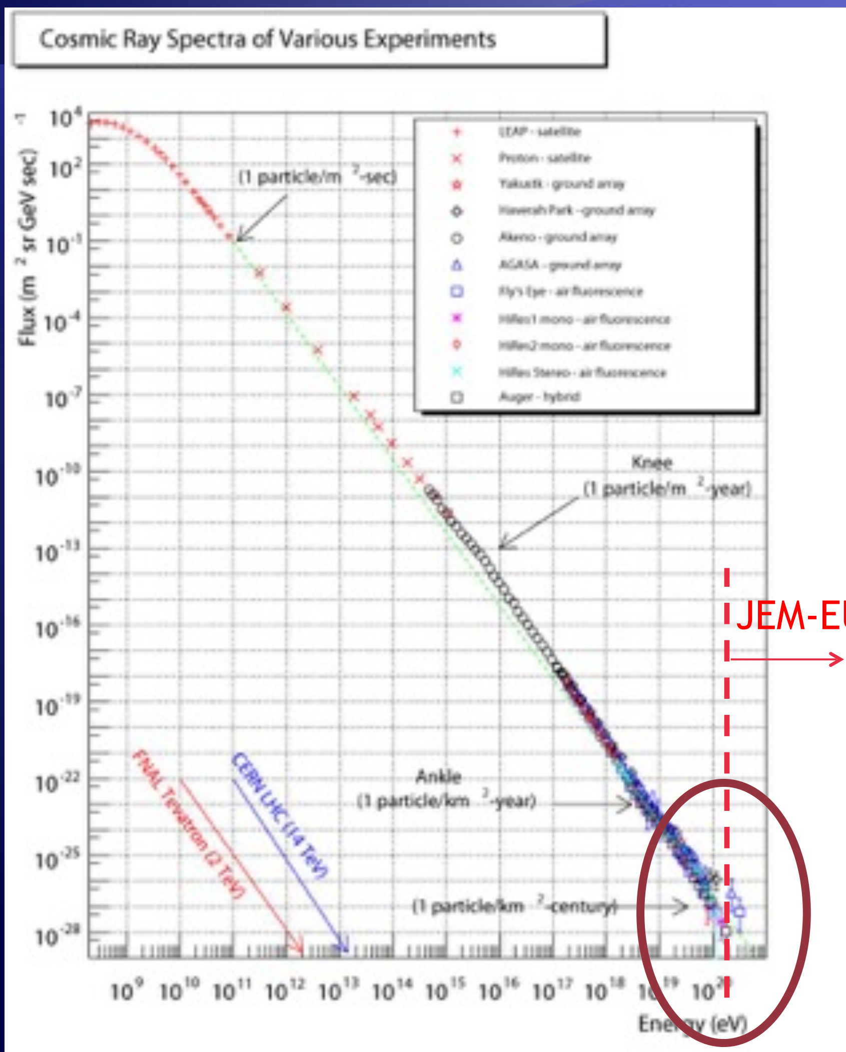
Integral flux:

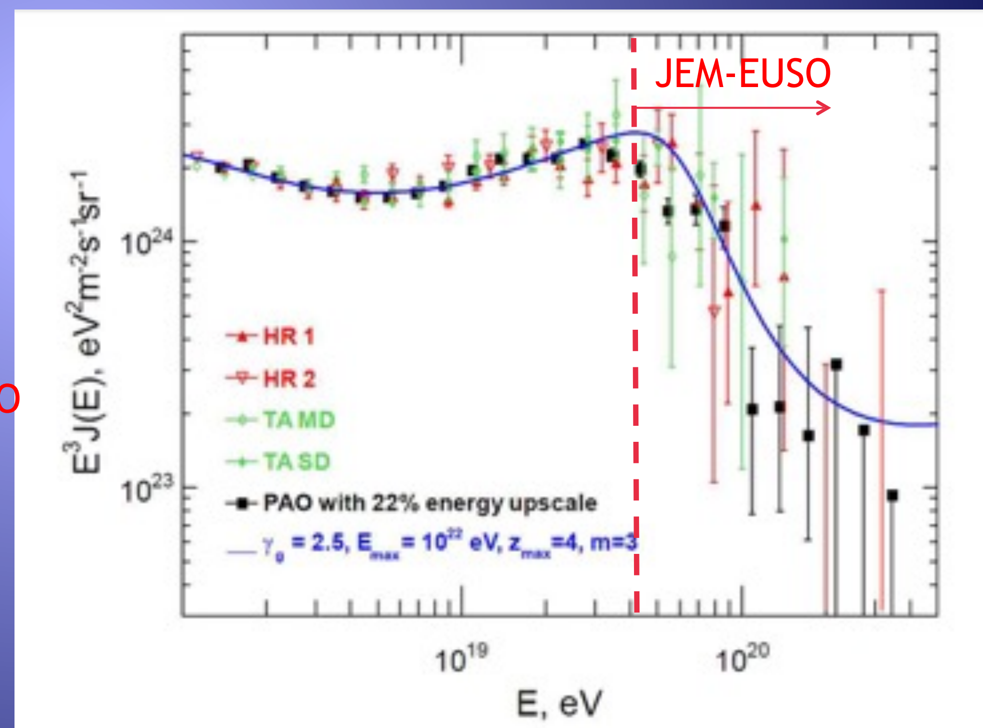
E > 10^{11} eV ~ 1 part./m^2/second

E > $5 \cdot 10^{15}$eV ~ 1 part./m^2/year

E > $5 \cdot 10^{18}$eV ~ 1 part./km^2/year

E > 10^{20} eV ~ 1 part./km^2/millennium



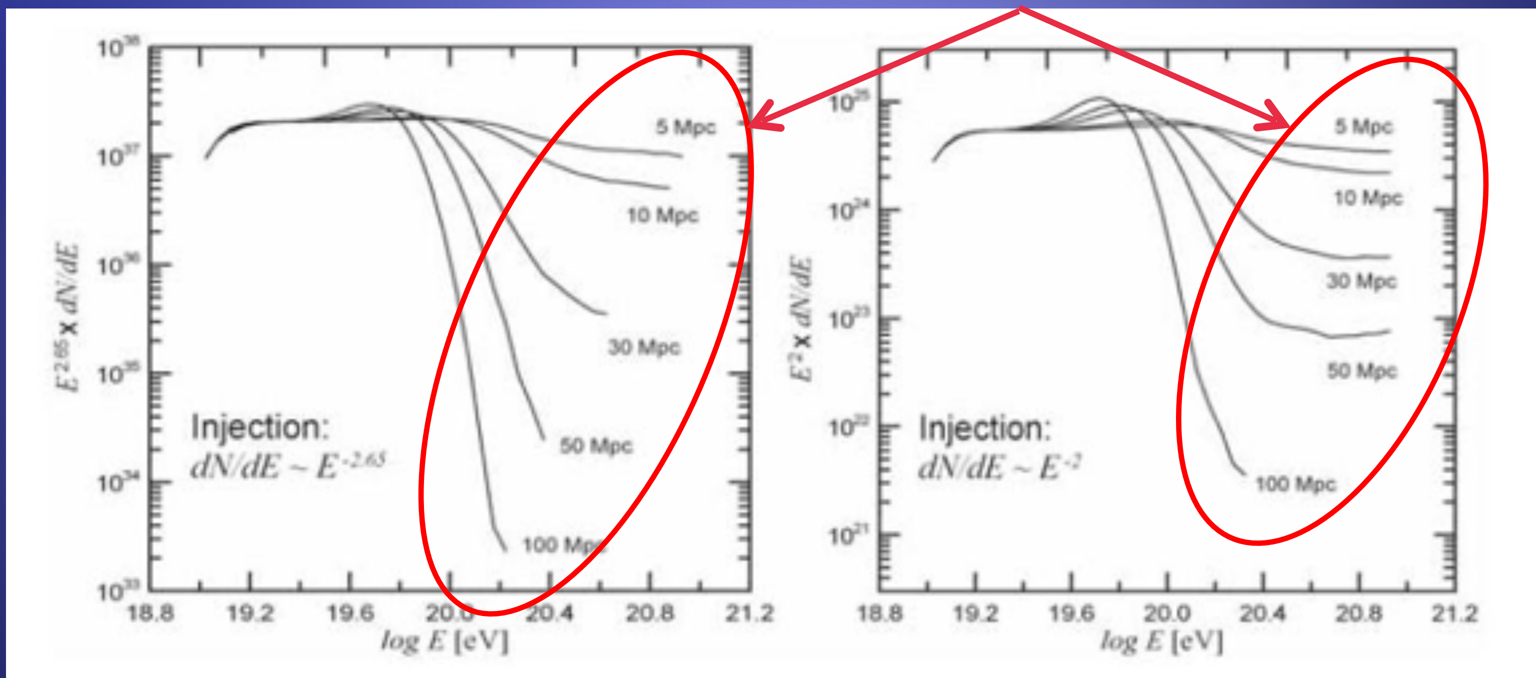


Spectral steepening

$$p + \gamma_{CMB} \rightarrow \Delta^+ \rightarrow n\,\pi^+$$
$$p + \gamma_{CMB} \rightarrow \Delta^+ \rightarrow p\,\pi^0$$

$$E_{GZK} \simeq 5 \times 10^{19}\, eV$$

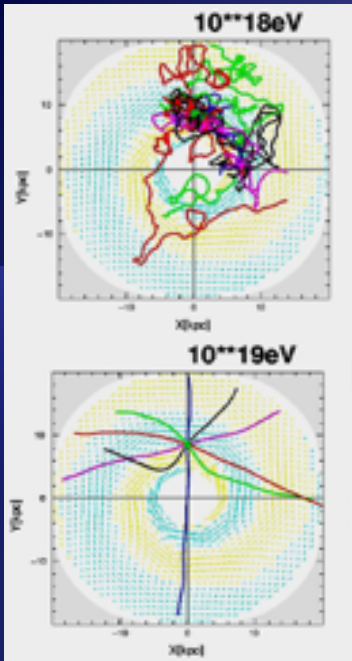
GZK features strongly depend on the distances to the sources

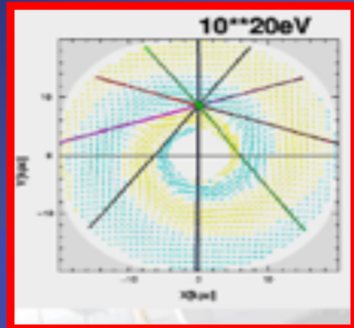


GZK cut-off suppress Energy spectrum in case of isotropic sources

Hillas Plot

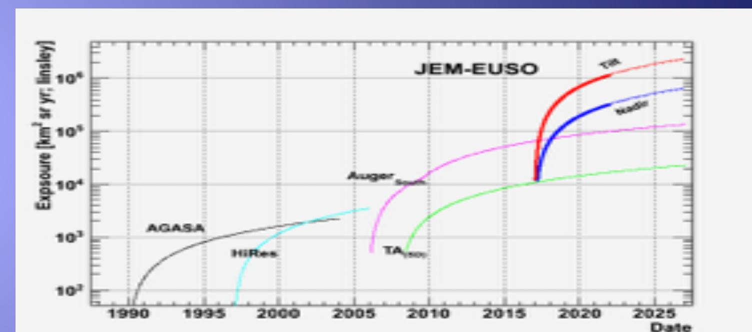
Anisotropy analysis



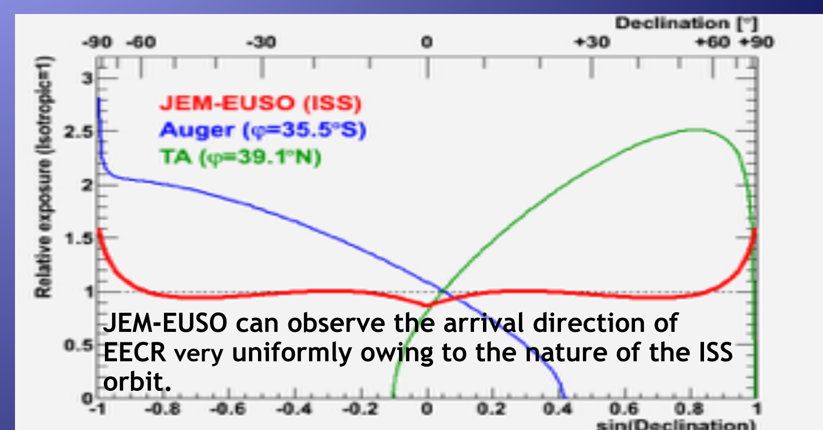


E>10^{20} eV: particles do not bend significantly

- **Point source analysis:** very high statistics (500÷800 events in 3 years) at the highest energies, should identify several dozen individual clusters with tens of events associated to each of them, which will allow correlating the sources with known astronomical objects .

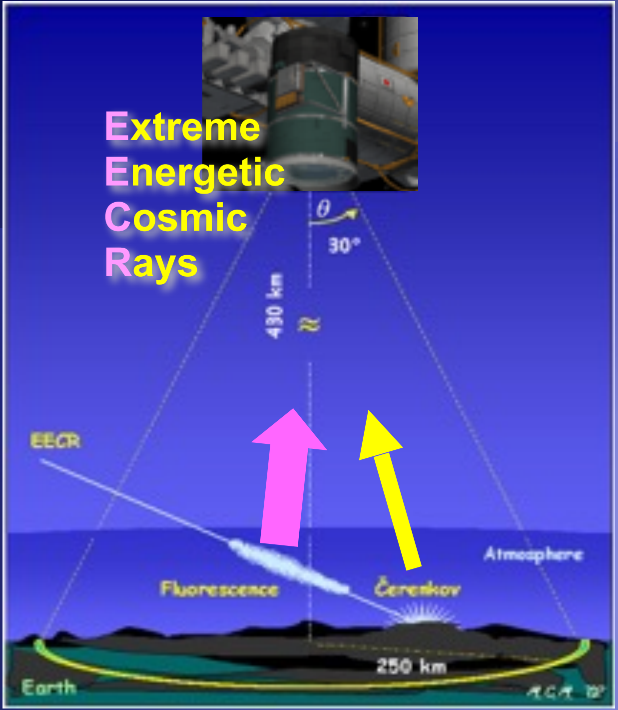


- **Global anisotropy analysis:** very uniform exposure over the whole sky (ISS inclination ≈ 51.6°). If extreme particles come from cosmological distances, as those of GRBs and AGNs, several dozen sources uniformly distributed in the sky will be discovered



Inclination: 51.6°
Height: ~400km

JEM-EUSO Observational Principle

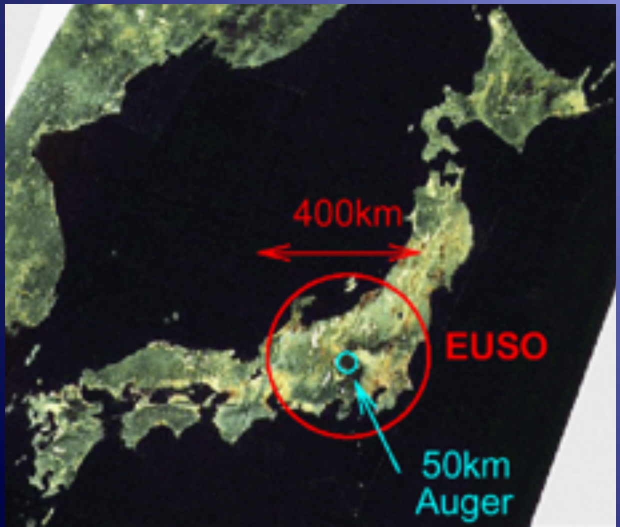


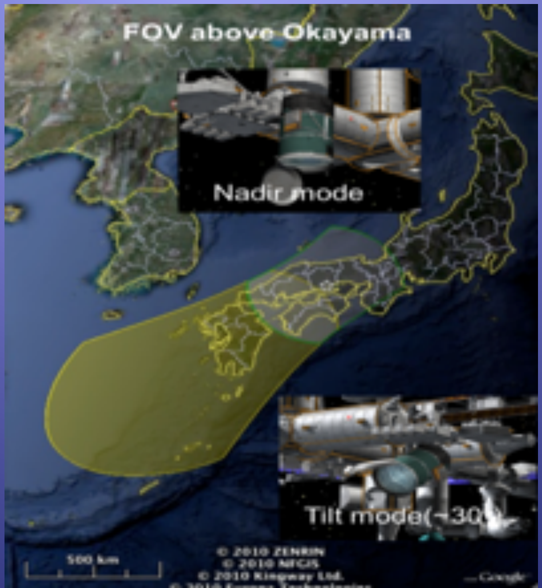
JEM-EUSO is a new type of observatory on board the International Space Station (ISS), which observes transient luminous phenomena occurring in the Earth's atmosphere

- Orbiting at $\sim 8\ km\ s^{-1}$ with inclination of 51.6°, at a nominal altitude of $\sim 400\ km$.
- Super wide FoV (60°) and a large diameter (2.5 m).
- Covers both northern and southern hemisphere.
- 1 orbit every 90 minutes.

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

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





Requirements

Science requirements:

- SR1: Specification of EECR origin by arrival direction analysis with determination accuracy better than a few degrees
- SR2: Determination of trans-GZK structure in cosmic ray energy spectrum
- SR3: EECR primary identification capability: discriminating among nucleus, gamma ray and neutrino
- SR4: Observation capability of TLEs

To detect 500-800 events in 3 years mission:

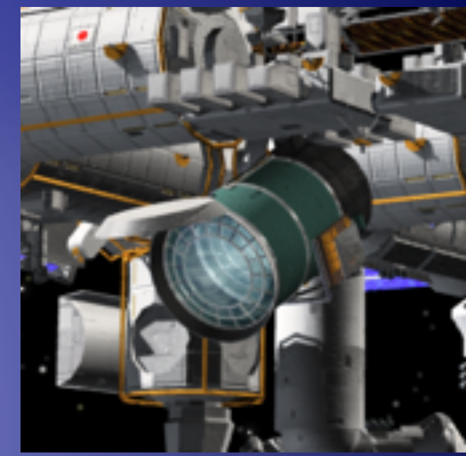
Observation requirements:

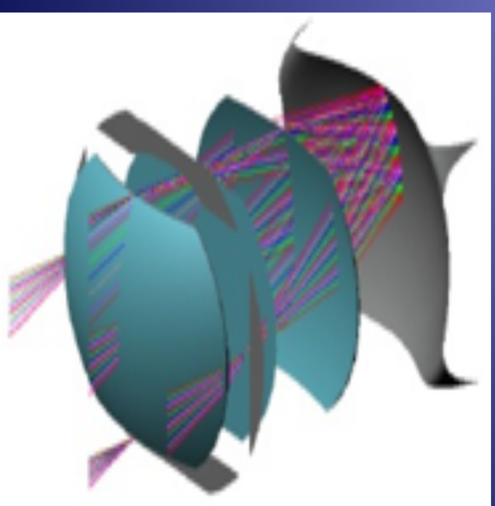
- OR1: Observation area: ≥ 1.3×10^5 (Horbit/400[km])^2 [km^2] [SR1]
- OR2: Arrival direction determination precision: ≤ 2.5° (E=10^{20} [eV] and 60° zenith angle) [SR2]
- OR3: Energy determination precision: ≤ 30% (E=10^{20} [eV] and 60° zenith angle) [SR3]
- OR4: X_{max} determination precision: ≤ 120[g/cm2] (E=10^{20} [eV] and 60° zenith angle) [SR4]
- OR5: Energy threshold: ≤ 5.5×10^{19} [eV] [SR1]
- OR6: Monitoring the average signal rate for all pixel every 3.5 s [SR4]
- OR7: Capability of observing TLE with time scales short than 1 s [SR4]

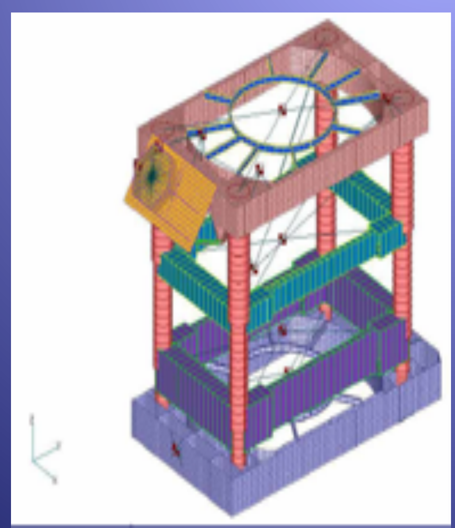
The JEM-EUSO System

MISSION PARAMETERS

- Time of launch: year 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



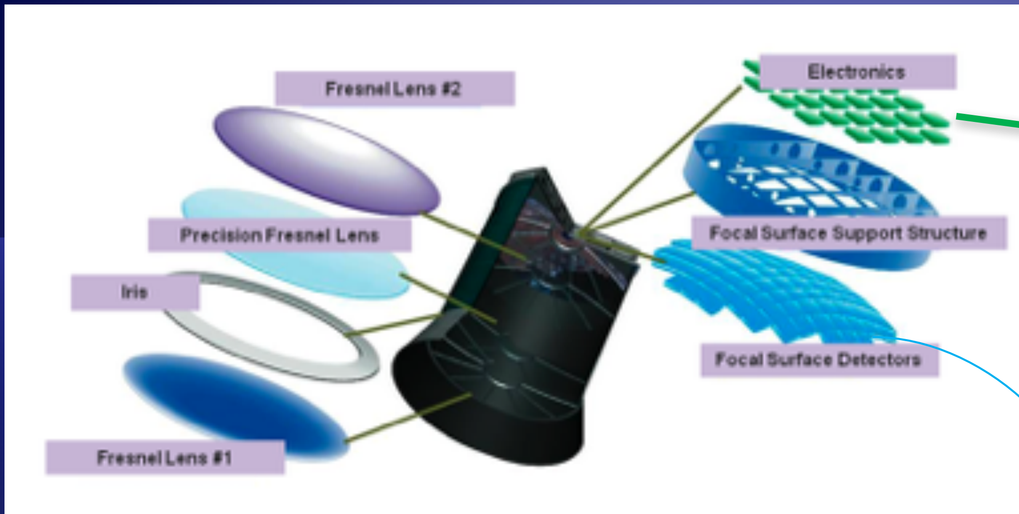


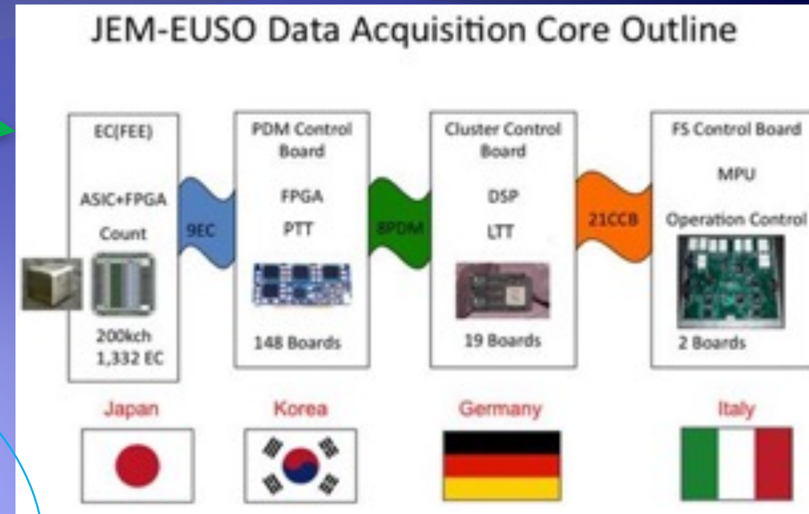


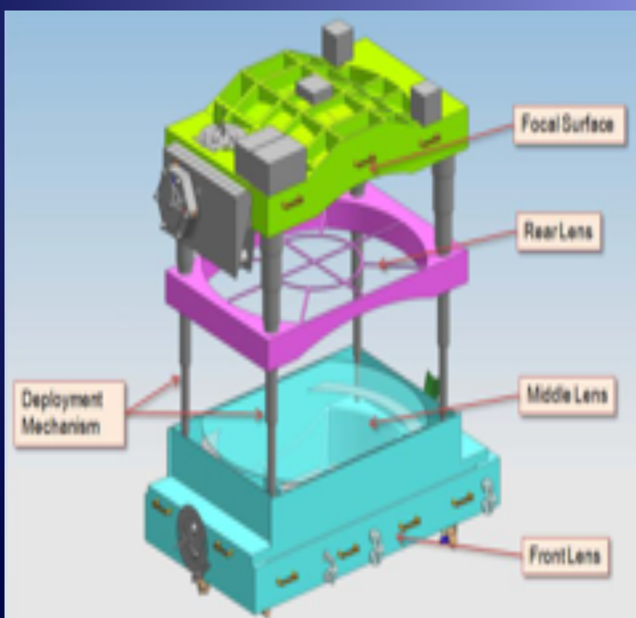
INSTRUMENTS PARAMETERS

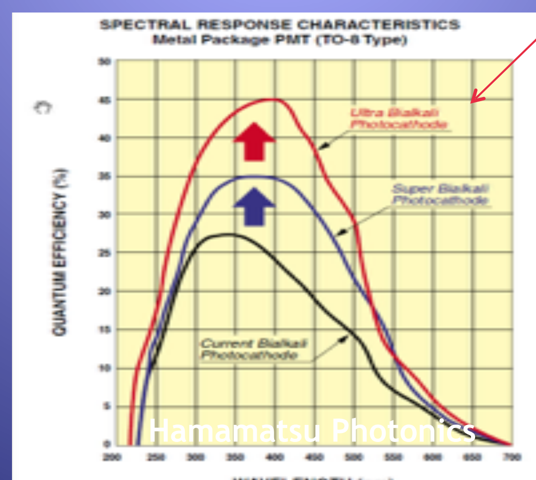
- Field of view: ±30°
- Aperture diameter: 2.5 m
- Optical bandwidth: 330 – 400 nm
- Angular resolution: 0,074°
- Pixel size: 2,9 mm
- Number of pixels: $\sim 3.2\times 10^5$
- Pixel size at ground: ~510 m
- Duty cycle: ~20%
- Observational area: $> 1.3\times 10^5$ km^2

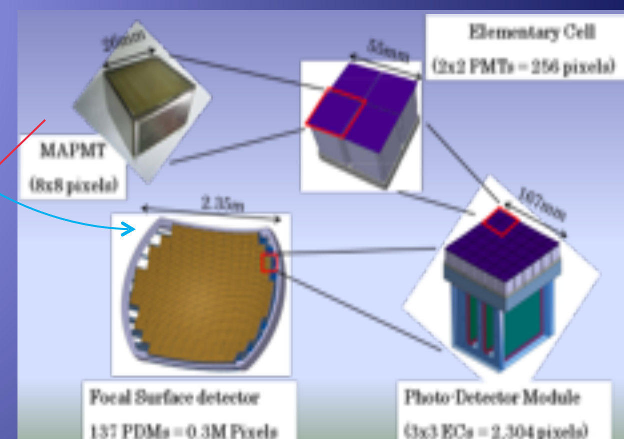
The JEM-EUSO Telescope





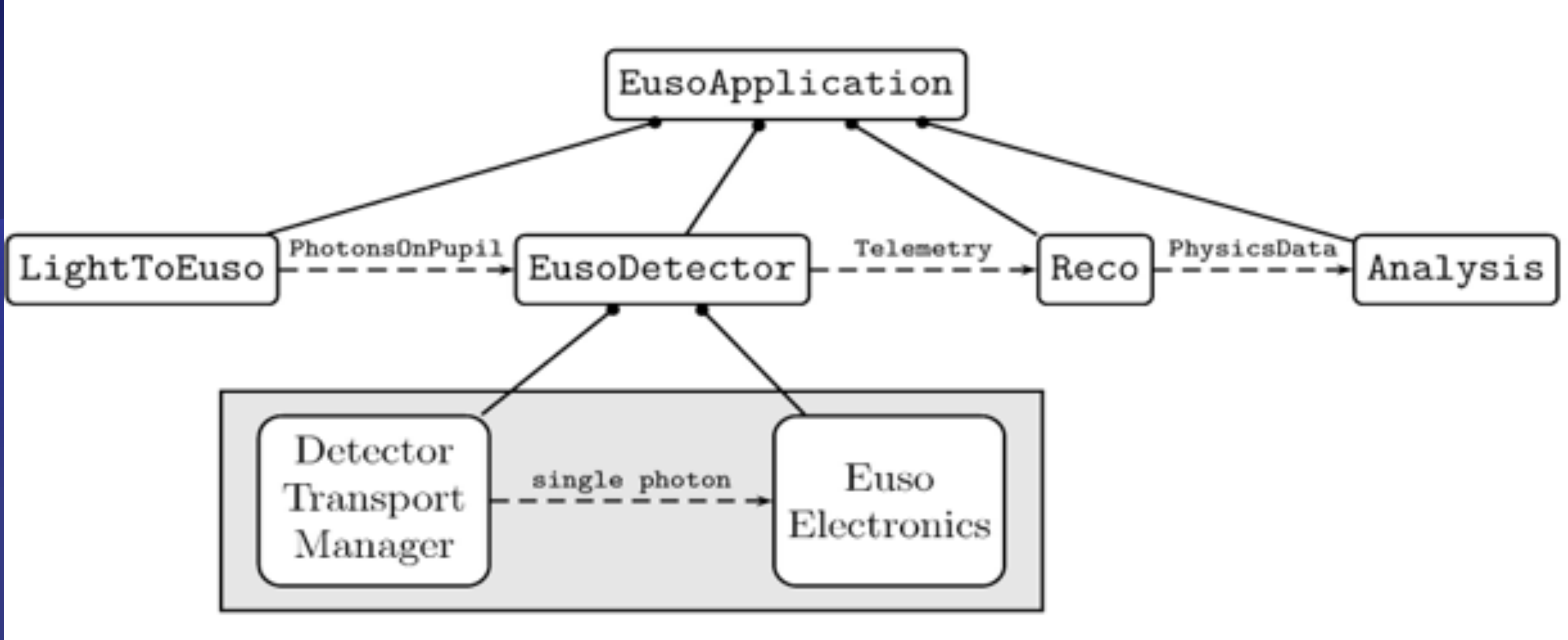






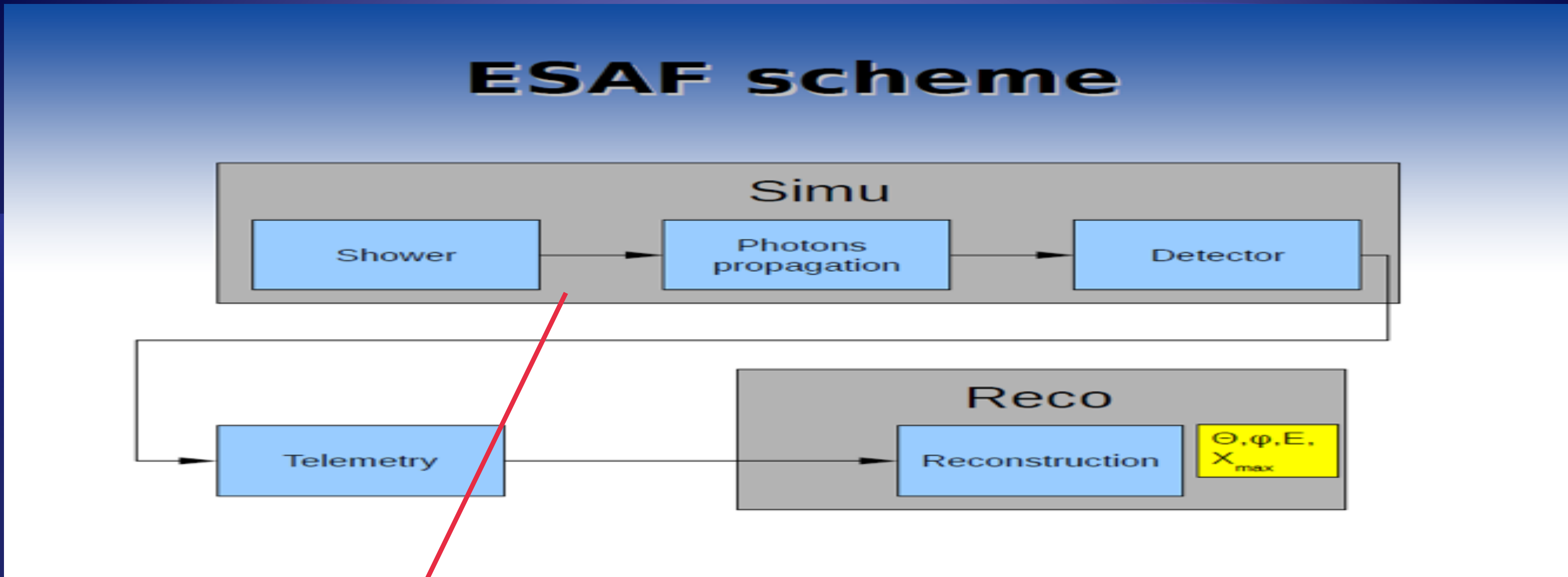
JEM-EUSO
UBA M64 Q.E. ~ 38%
pixel size 2.9 mm

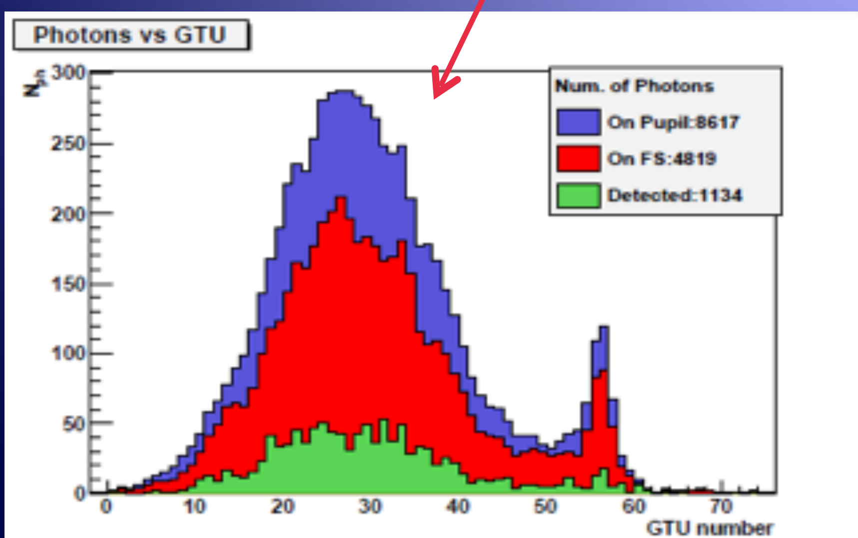
ESAF (Euso Simulation & Analysis Framework)



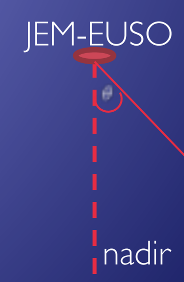
- **LightToEuso**: simulation of the shower development and the light transport through the atmosphere to the detector.
- **EusoDetector**: simulation of all the detector components from Optics to the Electronics of the JEM-EUSO telescope.
  Once trigger alghoritms issued a trigger signal, the event is sent through telemetry to Earth for the event reconstruction.
- **Reco**: reconstruction of the arrival direction, energy and type of primary particle.
- **Analysis**: UNDER COSTRUCTION

ESAF: Simu and Reco files



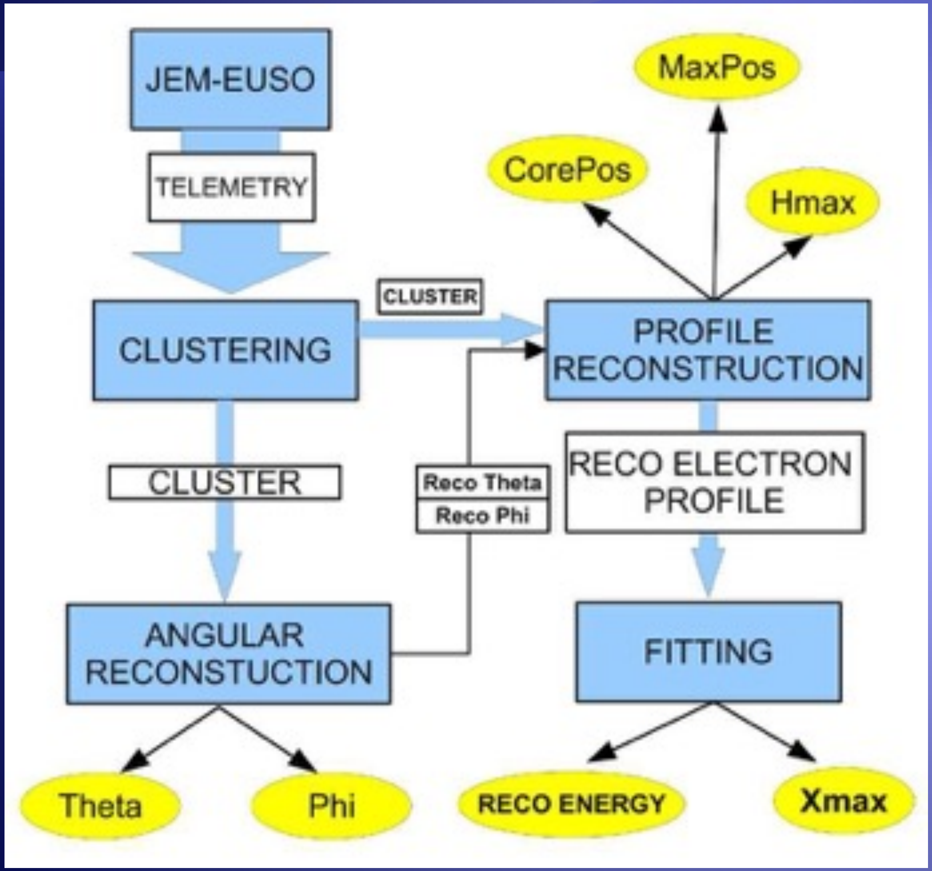


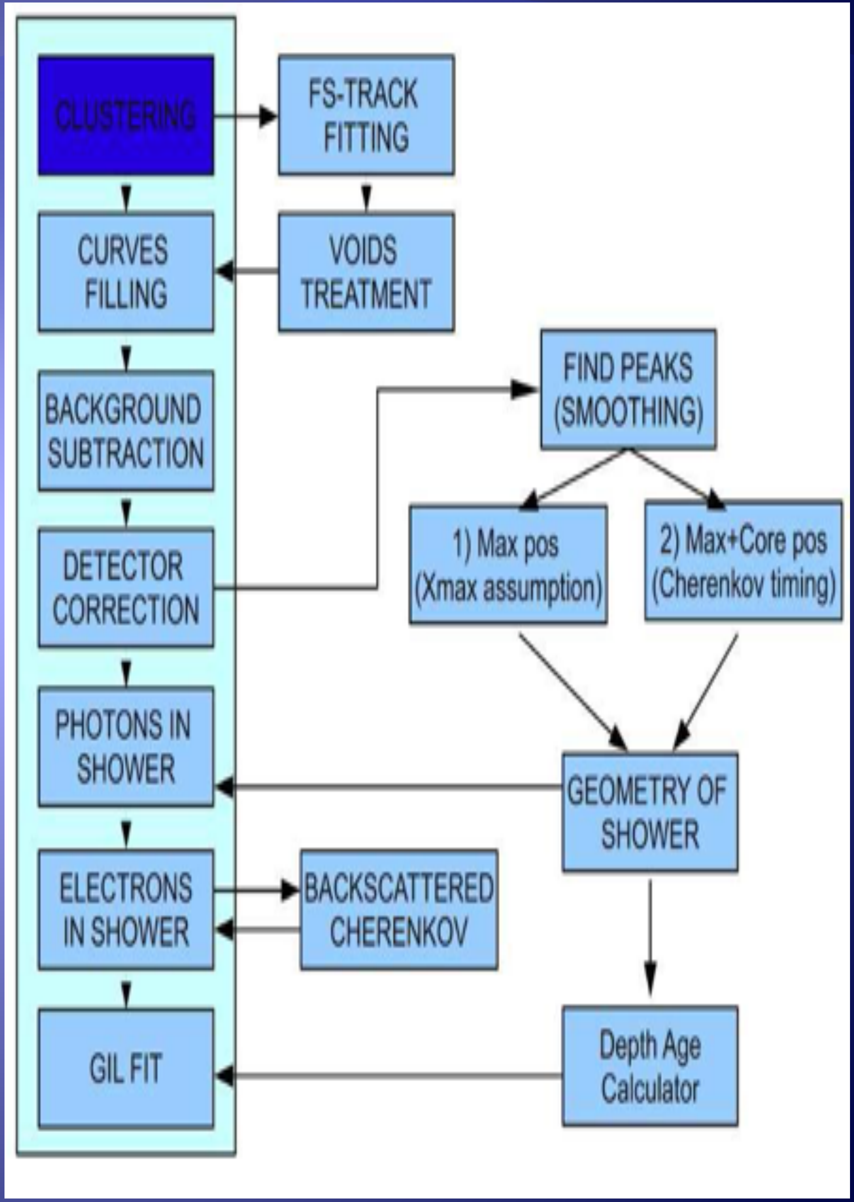
PUPIL = telescope surface
FS (Focal Surface) = PMT surface (behind optics)
Detected = after electronics
GTU = Gate Time Unit (2,5 μs)



The event as seen through the detector. (10^{20} eV 60 deg) as simulated by ESAF with the GIL parameterization.

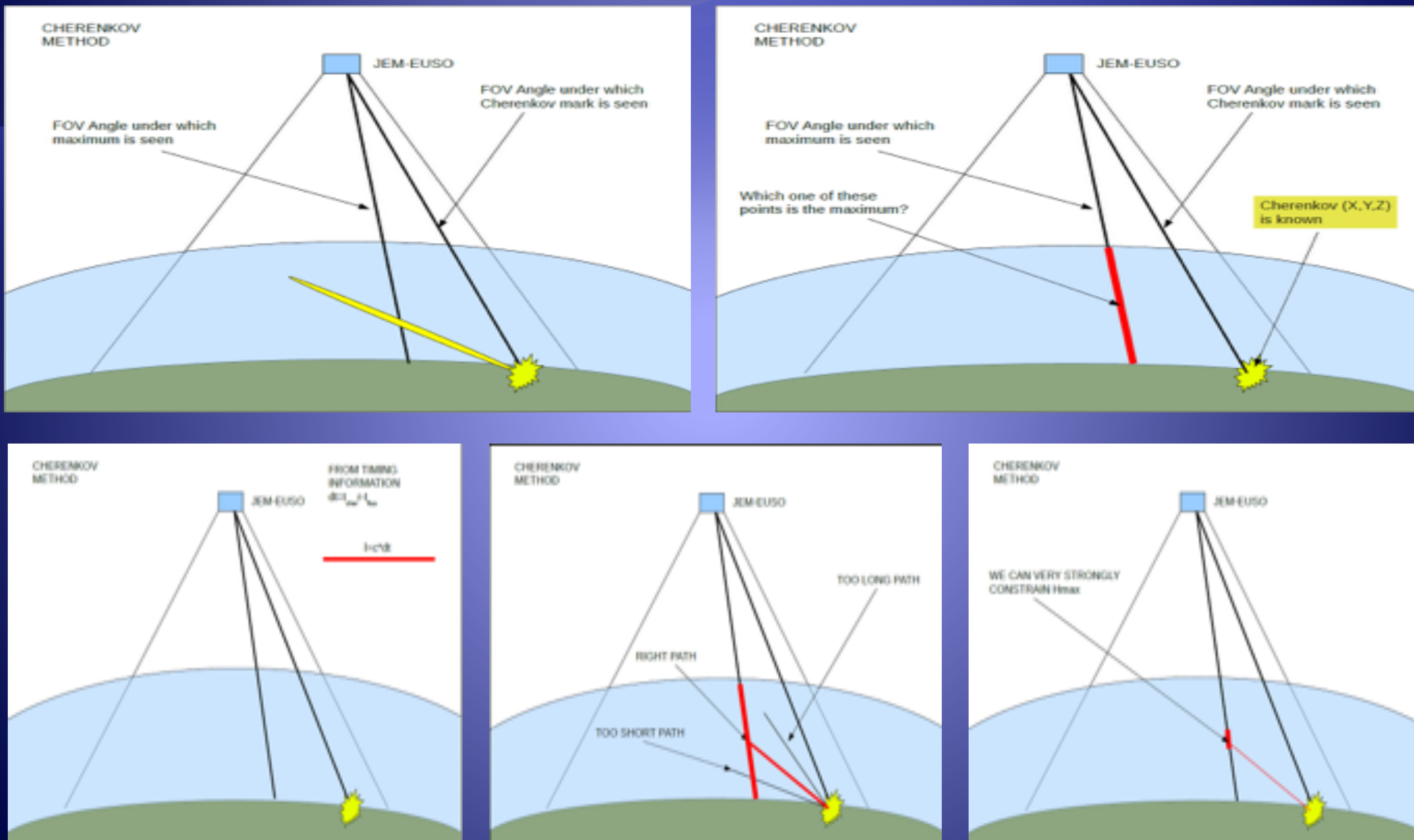
The Reconstruction framework





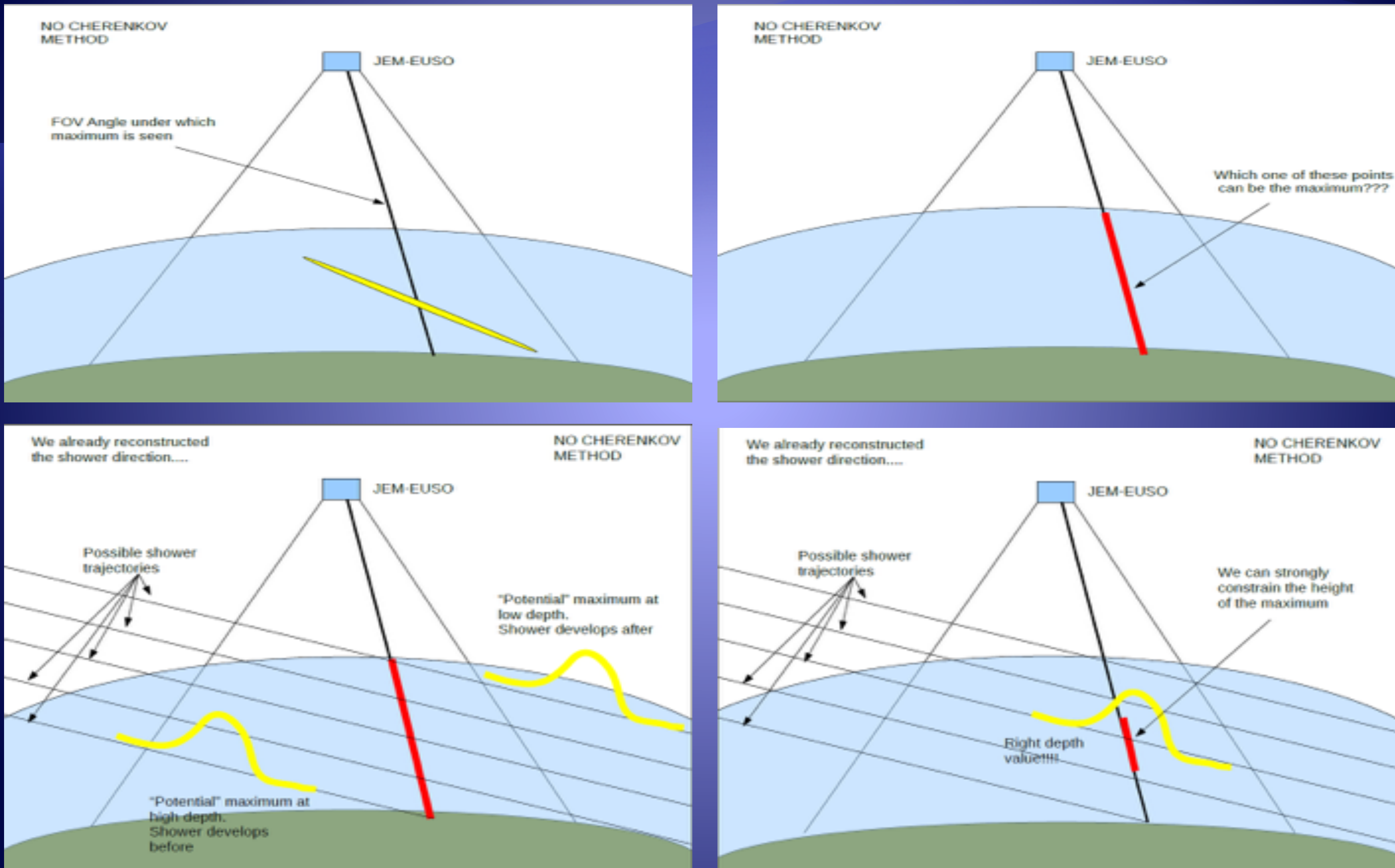
The Reconstruction method

CHERENKOV METHOD



The Reconstruction method

NO CHERENKOV METHOD



Objectives of my thesis work

Study on detection capability dependency

- Energy vs angle dependency
- Primary nature dependency (protons or heavier nuclei)
- ISS orbit altitude

Energy reconstruction

- Reconstruction in "*Debug mode*"
- Implementation of new method as a first attempt to discard the "*Debug mode*"

EUSO-Balloon simulation

- Roughly attempt to assess the chance to observe at least one EAS in the time flight mission

JEM-EUSO detetion capability dependency

Studying the energy vs. angle dependency

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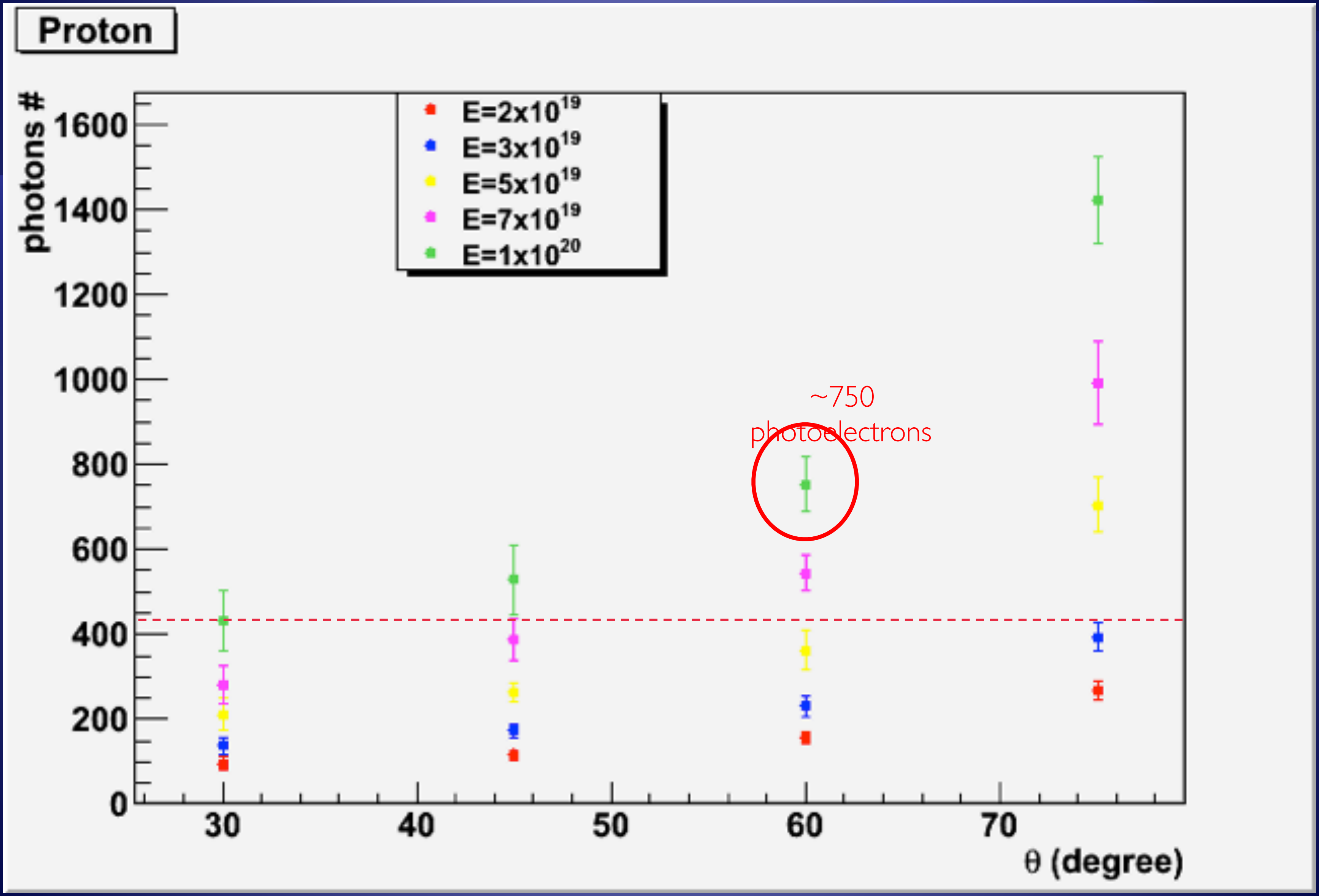
Modifying the nature of the EECR

- Protons (p)
- Iron Nuclei (Fe)

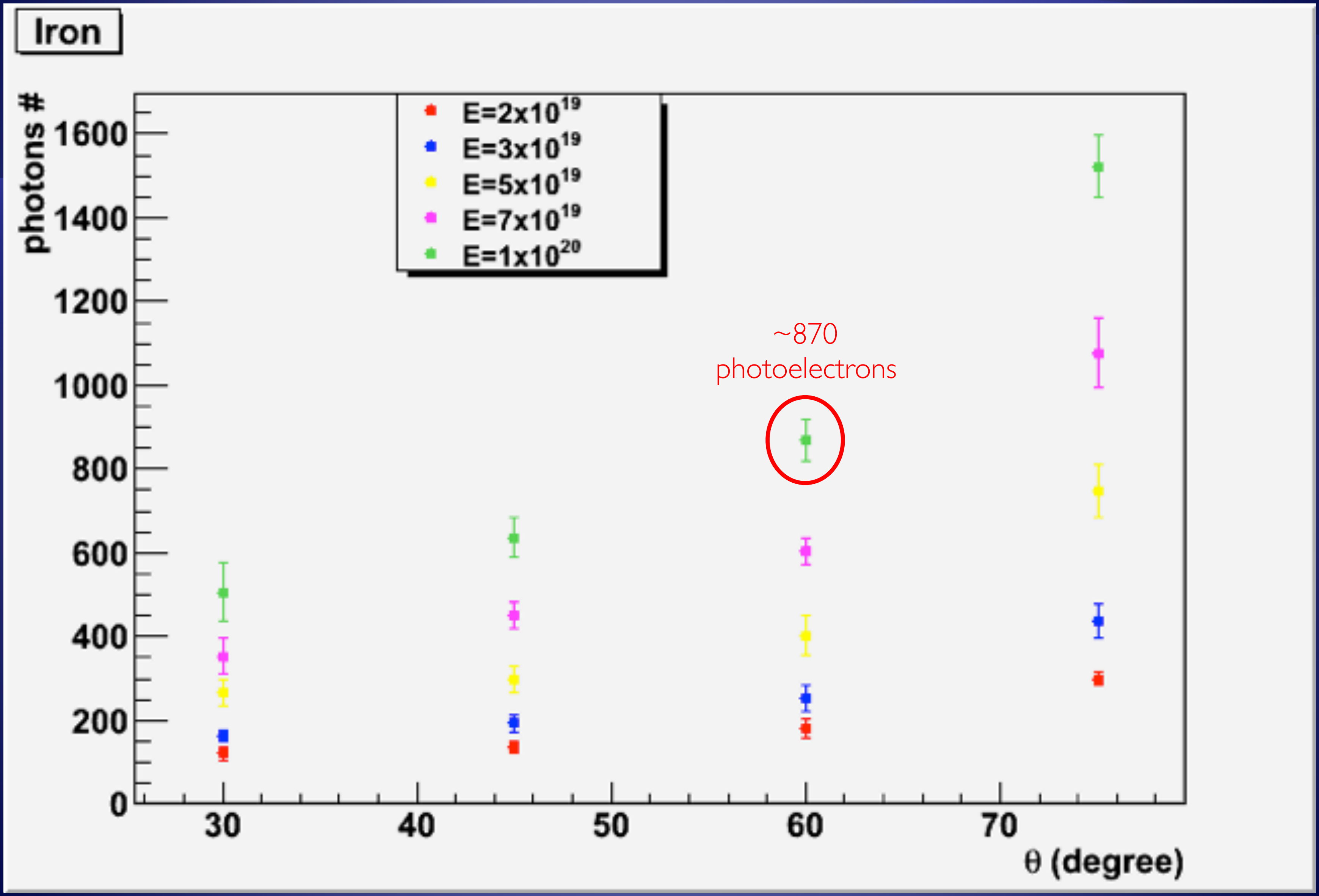
Modifying ISS altitude

- 430 km
- 350 km

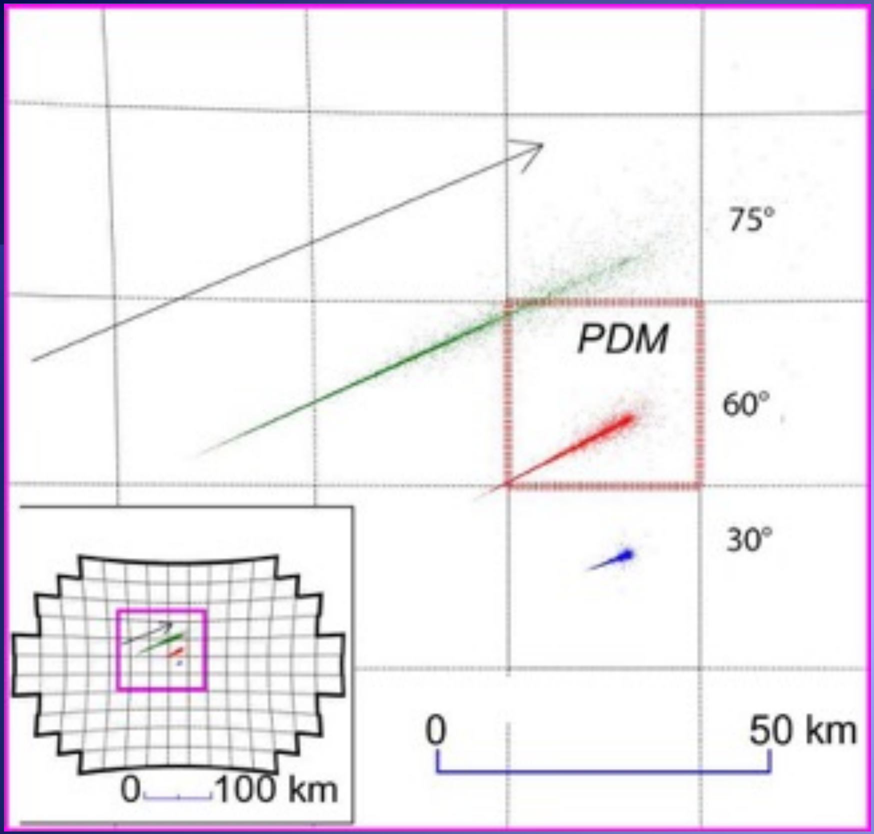
Energy vs. angle dependency

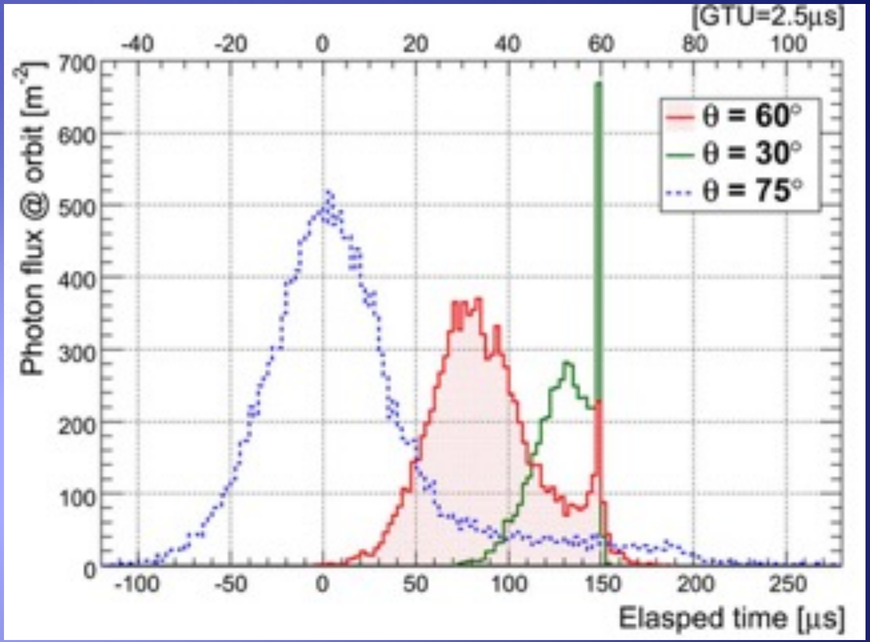


Changing EECR nature



Angle dependency





A standard event (E = 10^{20} eV) projected on FS

A standard event (E = 10^{20} eV) development time

Protons vs Iron Nuclei

energy (eV)	*photon-count average*							
	30°		45°		60°		75°	
	p	Fe	p	Fe	p	Fe	p	Fe
2×10^{19}	96	121	116	136	157	182	268	300
3×10^{19}	137	163	173	193	232	253	394	437
5×10^{19}	212	266	262	298	362	403	704	748
7×10^{19}	280	353	387	450	545	605	991	1077
1×10^{20}	431	506	528	637	754	869	1423	1523

(a) Gain as a function of the incident angle.

angle	gain
30°	22.8 %
45°	15.9 %
60°	12.5 %
75°	9.0 %
	15.0 %

(b) Gain as a function of the energy.

energy (eV)	gain
2×10^{19}	17.8 %
3×10^{19}	12.6 %
5×10^{19}	14.2 %
7×10^{19}	15.5 %
1×10^{20}	15.1 %
	15.0 %

Changing ISS altitude

(a) Photon count average for different ISS altitude.

ISS altitude (km)	*photon-count* 3°	*photon-count* 23°
350	803 ± 27	406 ± 10
430	521 ± 12	275 ± 6

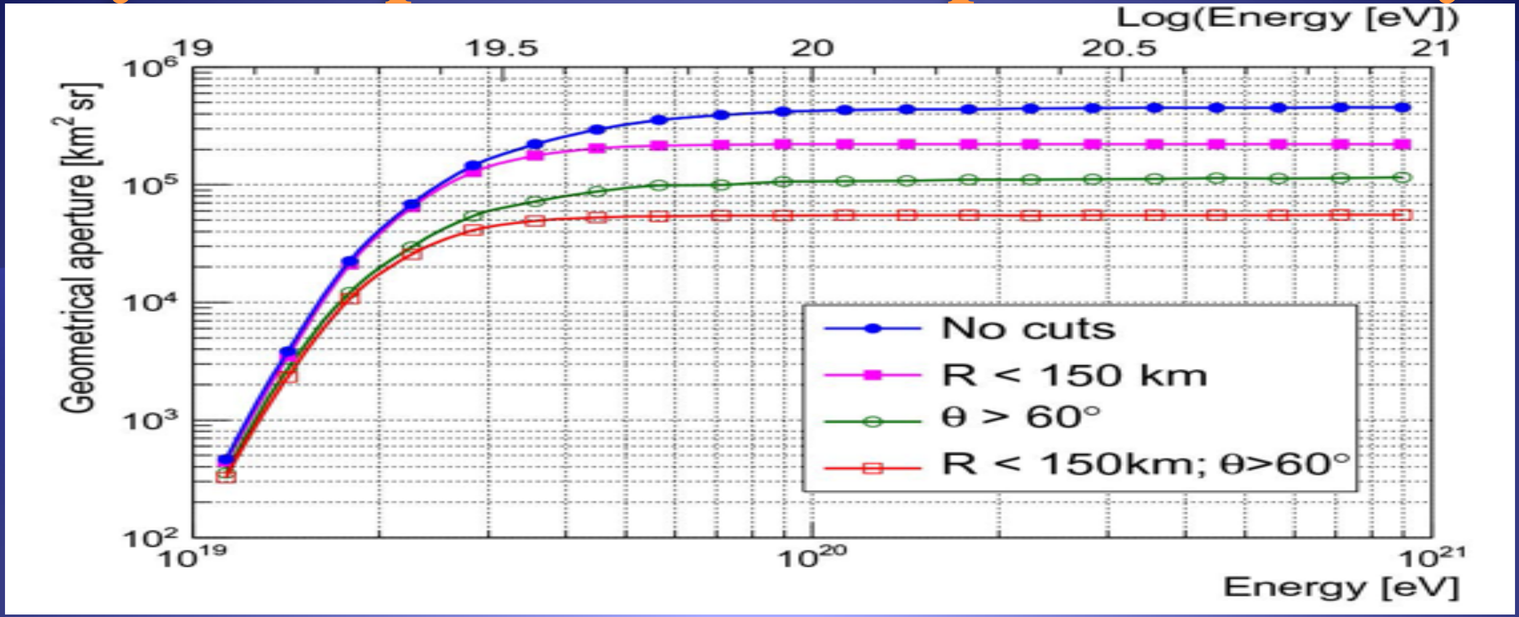
(b) Gain in lowering ISS

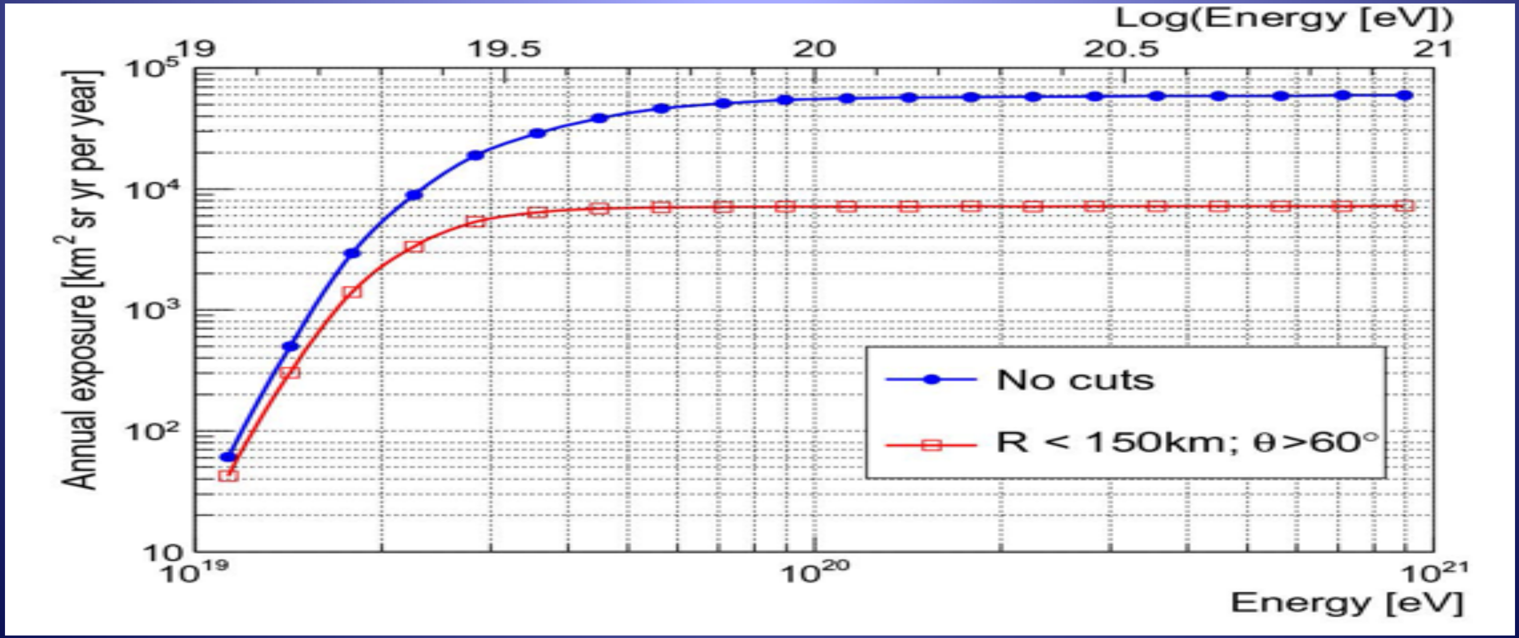
h_{350}/h_{430} **ratio** 3°	h_{350}/h_{430} **ratio** 23°
1.54 ± 0.03	1.48 ± 0.03
1.51 ± 0.03	

$$\frac{(R_{h_{350}})^{-2}}{(R_{h_{430}})^{-2}} = \frac{1/_{350^2}}{1/_{430^2}} = 1.51$$

About 1.5 times better from 430 to 350 km ISS altitude ($E = 2 \times 10^{20}$, $\theta = 60°$)

1 year Aperture & Exposure study





JEM-EUSO energy reconstruction

"Debug mode"

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LTT Pre Clustering + Pmt To Shower Reco

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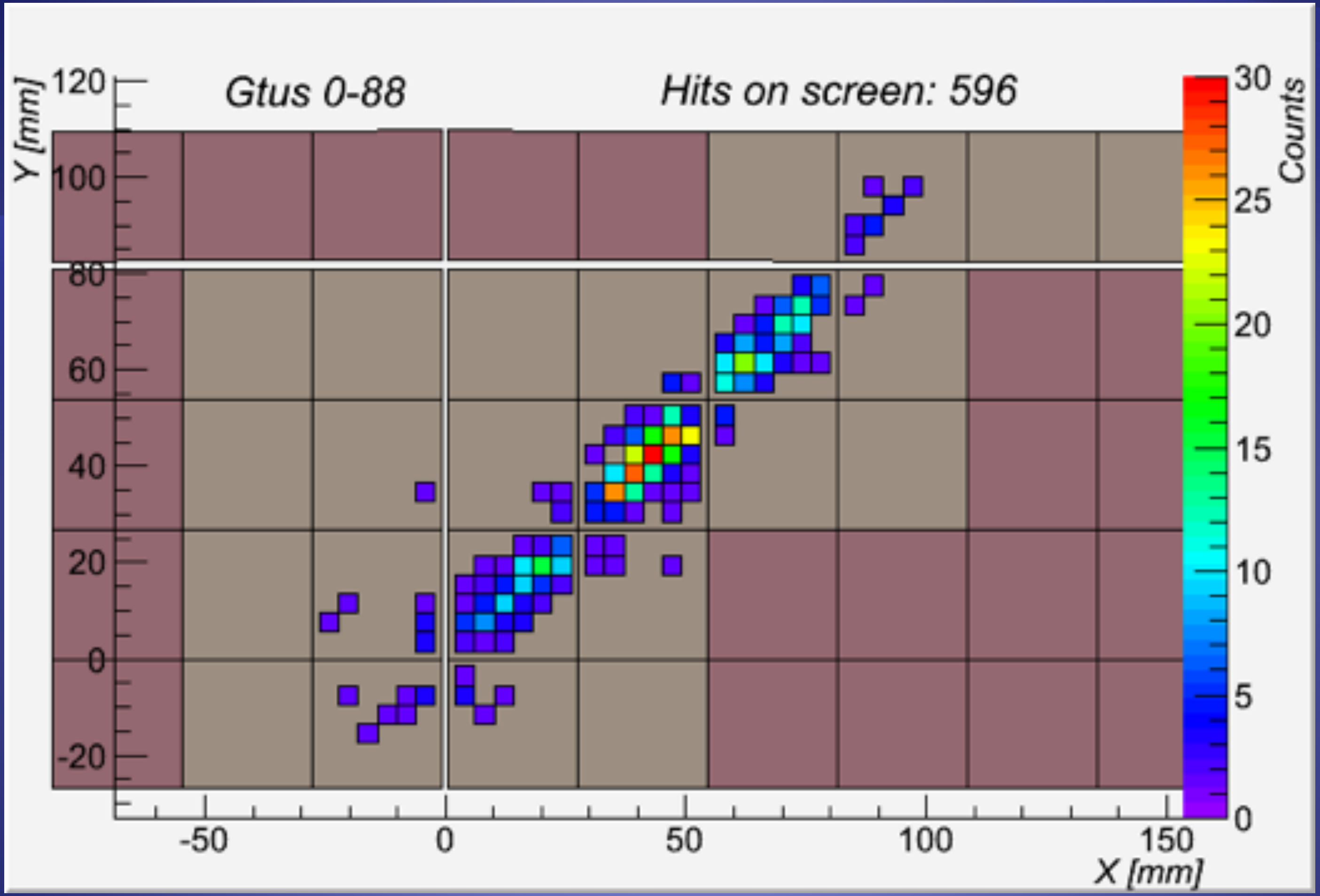
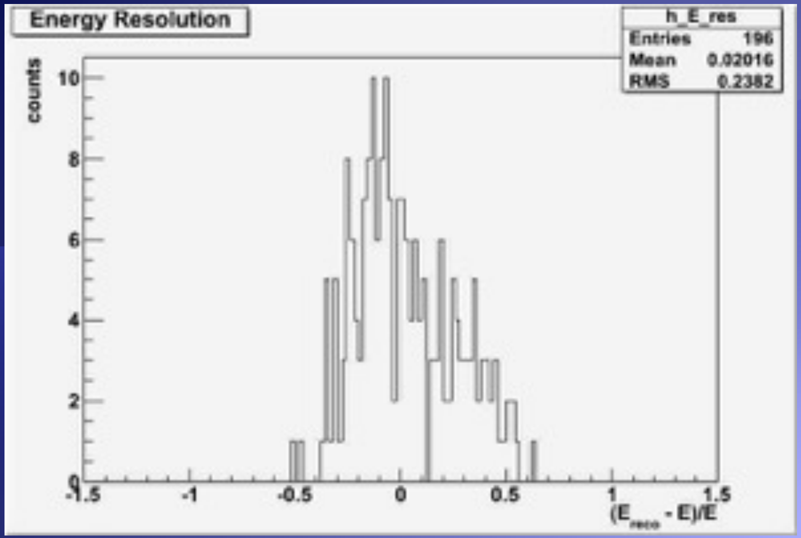
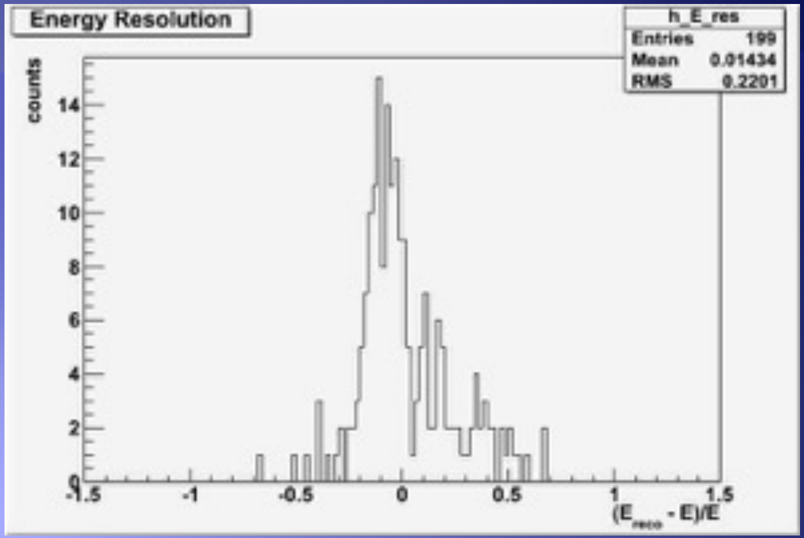
"*Debug* mode": the signal on Focal Surface



The standard event arrival direction is here reconstructed.
The event is seen after the clustering procedure while a fit is performed in order to find the arrival direction

Energy Resolution *("Debug mode")*





$E = 2 \times 10^{19}\ eV, \theta = 75°$

$$\frac{E_{reco} - E_{real}}{E_{real}} = 0{,}02$$

$RMS = 24\%$

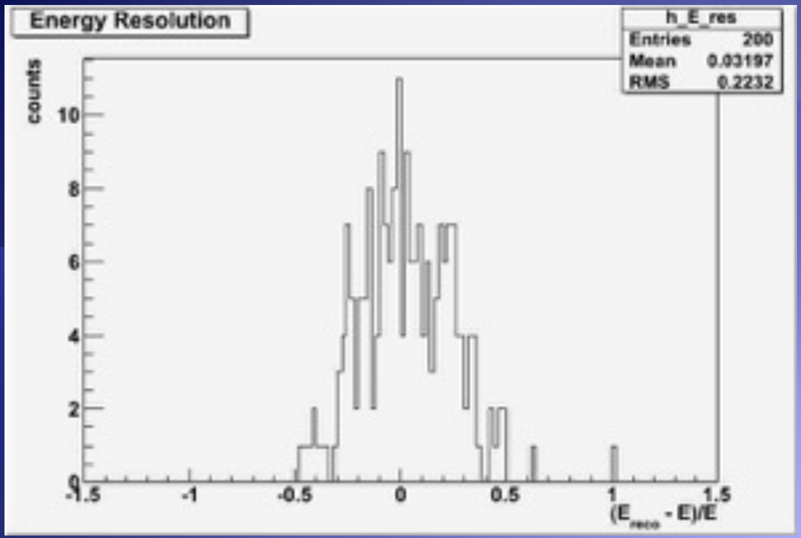
$E = 3 \times 10^{19}\ eV, \theta = 75°$

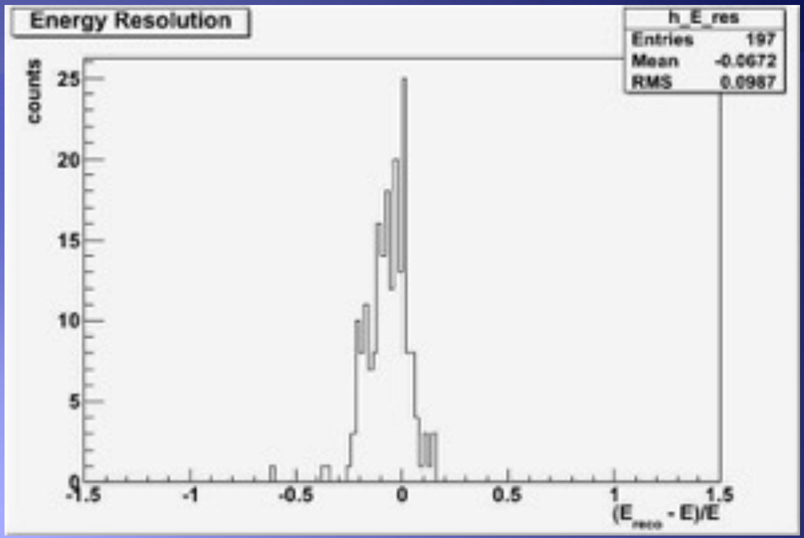
$$\frac{E_{reco} - E_{real}}{E_{real}} = 0{,}01$$

$RMS = 22\%$

Impact point coordinates: $\begin{cases} X = 10\ km \\ Y = 20\ km \end{cases}$

Energy Resolution





$E = 1 \times 10^{20}\ eV, \theta = 30°$

$$\frac{E_{reco} - E_{real}}{E_{real}} = 0{,}03$$

$RMS = 22\%$

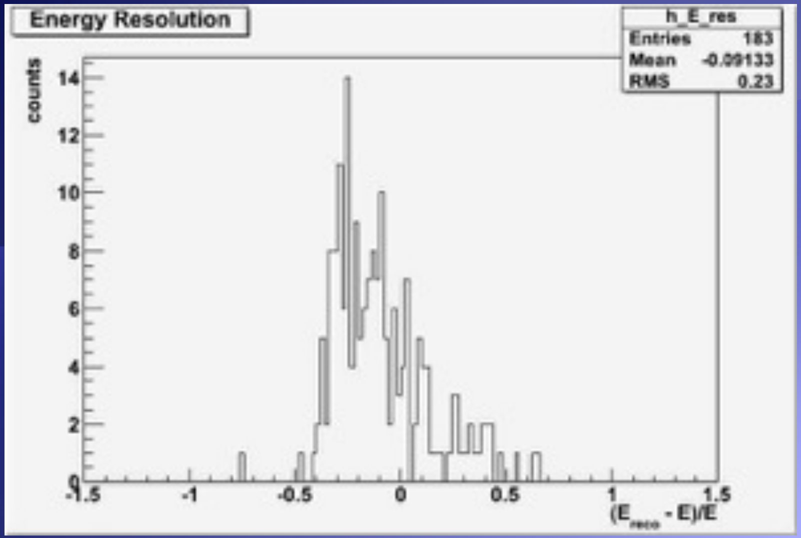
$E = 1 \times 10^{20}\ eV, \theta = 60°$

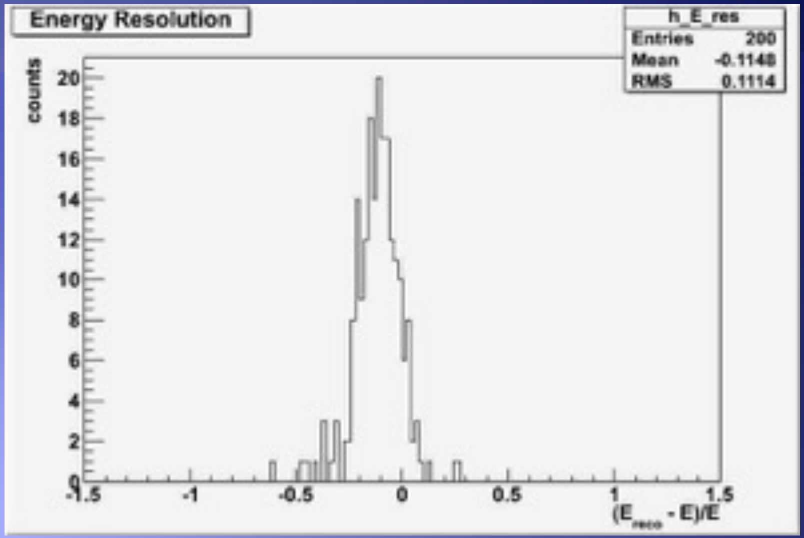
$$\frac{E_{reco} - E_{real}}{E_{real}} = -0{,}07$$

$RMS = 10\%$

Impact point coordinates: $\begin{cases} X = 10\ km \\ Y = 20\ km \end{cases}$

Energy Resolution





$$E = 2 \times 10^{19}\ eV, \theta = 75°$$

$$\frac{E_{reco} - E_{real}}{E_{real}} = -0{,}09$$

$$RMS = 23\%$$

$$E = 1 \times 10^{20}\ eV, \theta = 60°$$

$$\frac{E_{reco} - E_{real}}{E_{real}} = -0{,}11$$

$$RMS = 11\%$$

Impact point coordinates: $\begin{cases} X = 90\ km \\ Y = 45\ km \end{cases}$

Energy Resolution – Summary Table

Impact point coordinates: $\begin{cases} X = 10\ km \\ Y = 20\ km \end{cases}$

E (eV)	ϑ	Energy accuracy $\left(\frac{E_{RECO}-E_{real}}{E_{real}}\right)$	Energy accuracy RMS
2×10^{19}	75°	0.020	0.24
3×10^{19}	75°	0.014	0.22
5×10^{19}	60°	-0.069	0.12
7×10^{19}	45°	-0.008	0.13
1×10^{20}	30°	0.032	0.22
1×10^{20}	60°	-0.067	0.10

E (eV)	ϑ	Energy resolution $\left(\frac{RMS}{1+\text{Mean}}\right)$
2×10^{19}	75°	23.3%
3×10^{19}	75°	21.7%
5×10^{19}	60°	12.6%
7×10^{19}	45°	13.1%
1×10^{20}	30°	21.6%
1×10^{20}	60°	10.6%

Impact point coordinates: $\begin{cases} X = 90\ km \\ Y = 45\ km \end{cases}$

E (eV)	ϑ	Energy accuracy $\left(\frac{E_{RECO}-E_{real}}{E_{real}}\right)$	Energy accuracy RMS
2×10^{19}	75°	-0.091	0.23
1×10^{20}	60°	-0.115	0.11

E (eV)	ϑ	Energy resolution $\left(\frac{RMS}{1+\text{Mean}}\right)$
2×10^{19}	75°	25.3%
1×10^{20}	60°	12.6%

LTT Pre Clustering module

Select the pixel on the FS containing the highest number of counts

↓

Search for the track that maximize counts by moving an integration "box" along a predifined set of directions intersecting this point

↓

The size of the "box" can selected in a range of 1-8 pixel from the center

↓

Pixels inside are "flagged" and handed over to angular and energy reconstruction

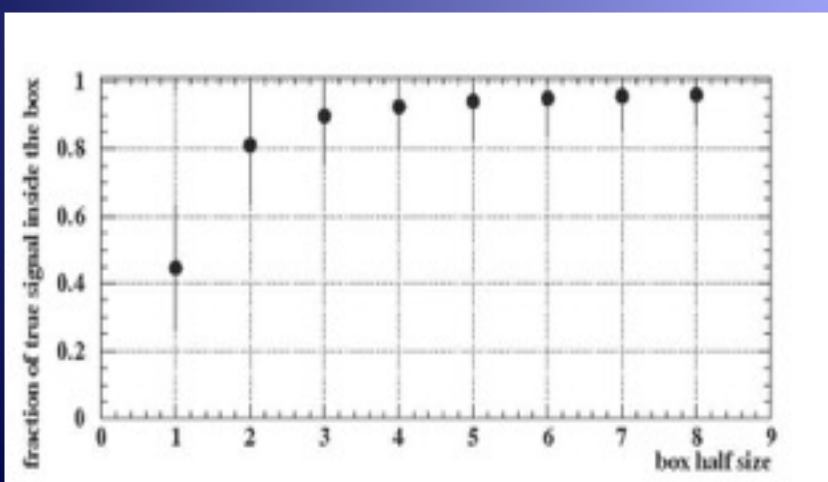
LTT Pre Clustering module

$$6\times10^{19}\,\mathrm{eV} < E < 3\times10^{20}\,\mathrm{eV},\quad 60^\circ < \vartheta < 90^\circ,\quad \begin{cases} -270\,\mathrm{km} < X < 270\,\mathrm{km} \\ -190\,\mathrm{km} < Y < 190\,\mathrm{km} \end{cases}$$

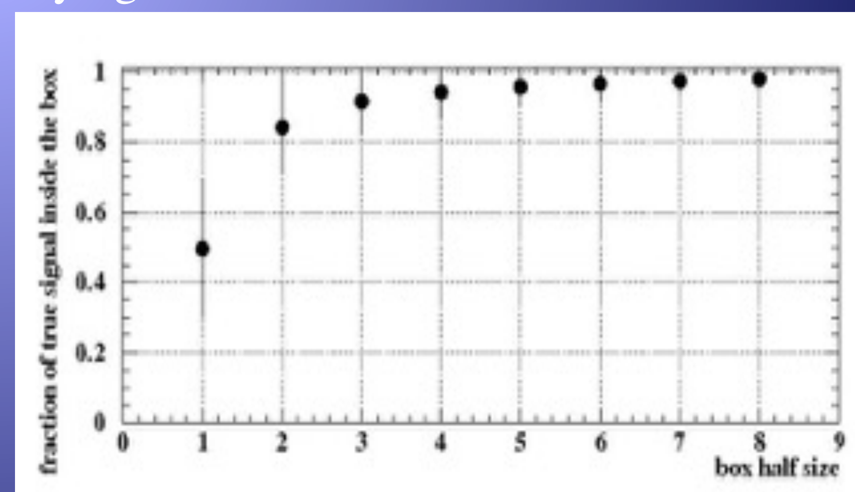
$$1\times10^{20}\,\mathrm{eV} < E < 3\times10^{20}\,\mathrm{eV},\quad 30^\circ < \vartheta < 60^\circ,\quad \begin{cases} -270\,\mathrm{km} < X < 270\,\mathrm{km} \\ -190\,\mathrm{km} < Y < 190\,\mathrm{km} \end{cases}$$

$$3\times10^{19}\,\mathrm{eV} < E < 6\times10^{19}\,\mathrm{eV},\quad 60^\circ < \vartheta < 90^\circ,\quad \begin{cases} -100\,\mathrm{km} < X < 100\,\mathrm{km} \\ -100\,\mathrm{km} < Y < 100\,\mathrm{km} \end{cases}$$

Amount of signal collected, varying the "box" size

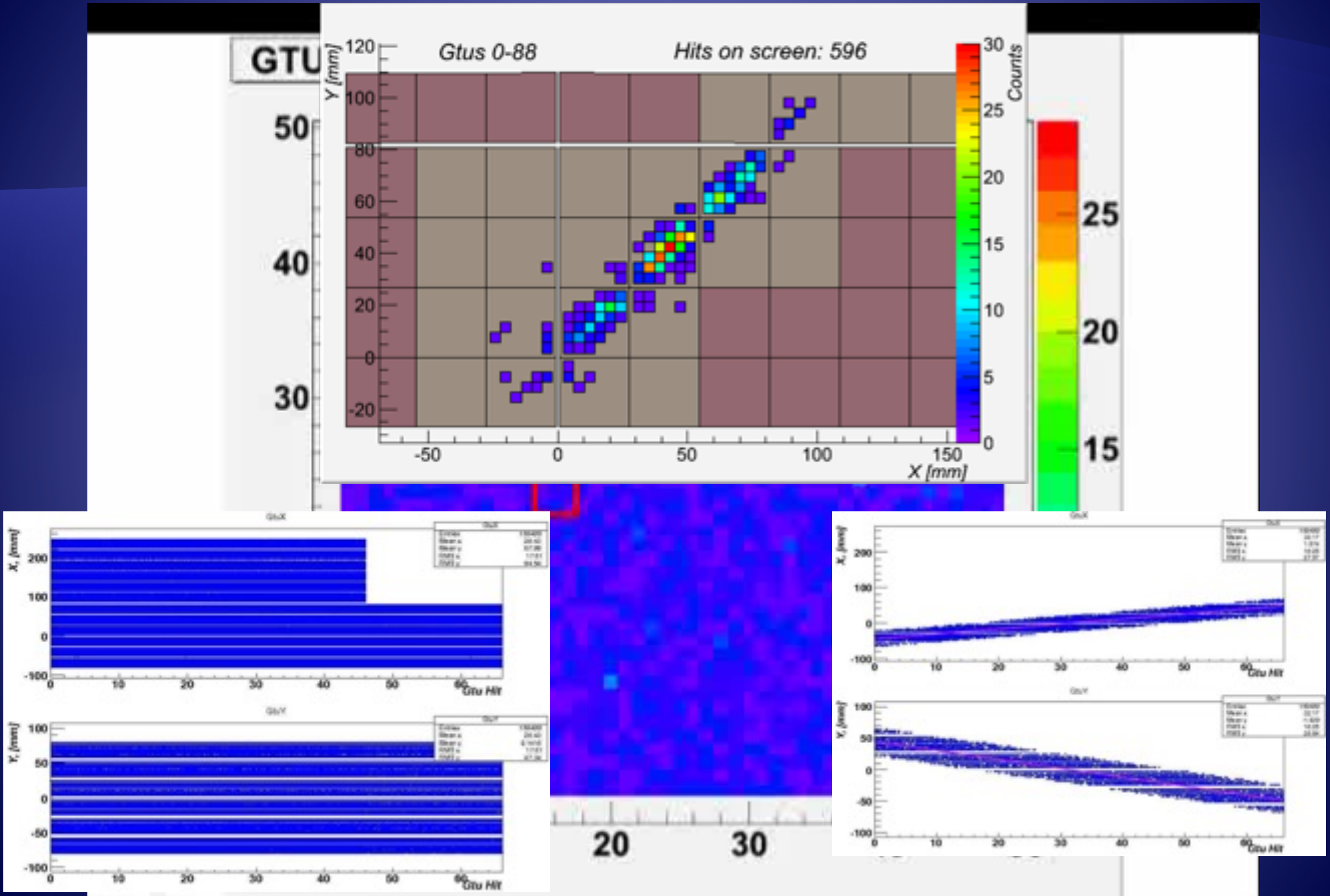


Entire FoV considered



Center of FoV considered

LTTPreClustering operational principle



Signal track before and after *LTTPreClustering* application

Energy reconstruction with "*LTTPreClustering*" and "*PmtToShowerReco*" together

Two new parameters introduced

- fFlag (select the reconstruction method)
- fBox (select the "box" size)

3 primary energy simulated

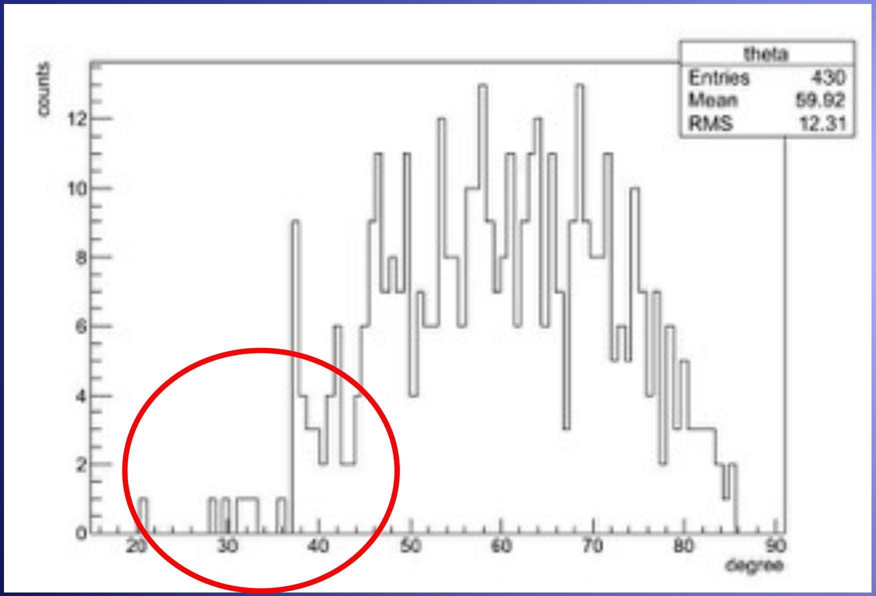
-
-
-

For each energy the events have been reconstructed with three method

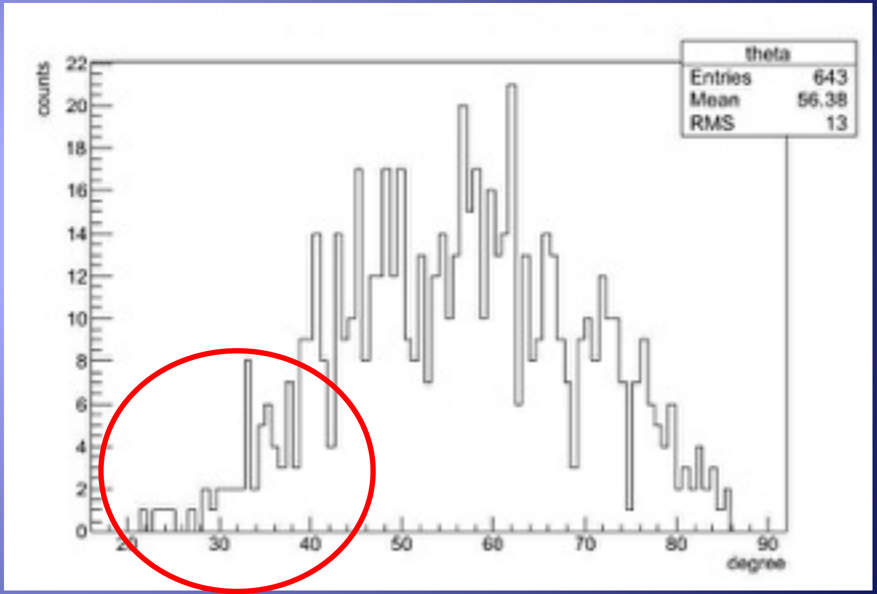
- "PmtToShowerReco" in pure "Debug mode" (fFlag = 0)
- Combined application of "LTTPreClustering" and "PmtToShowerReco" with a box of 8 pixels side (fFlag = 0

Energy reconstruction with "*LTTPreClustering*" and "*PmtToShowerReco*" together

$5 \times 10^{19}\ eV$



$1 \times 10^{20}\ eV$



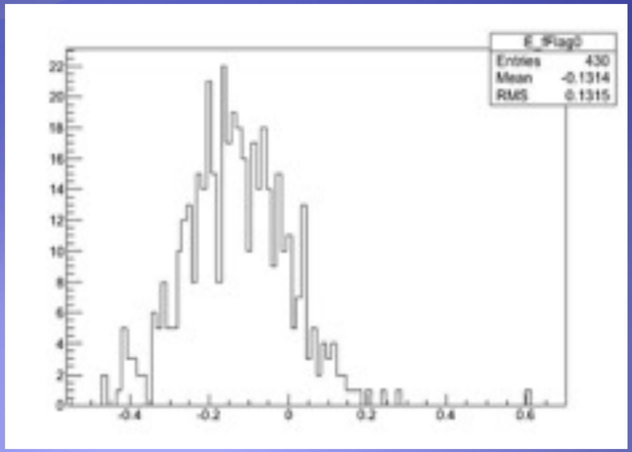
θ distribution

Energy reconstruction with "*LTTPreClustering*" and "*PmtToShowerReco*" togheter

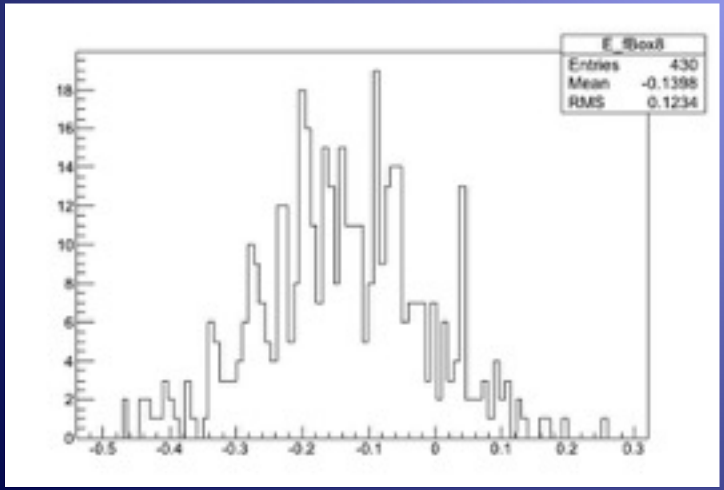
$$5 \times 10^{19}\ eV$$

$$\frac{E_{RECO} - E_{real}}{E_{real}}$$

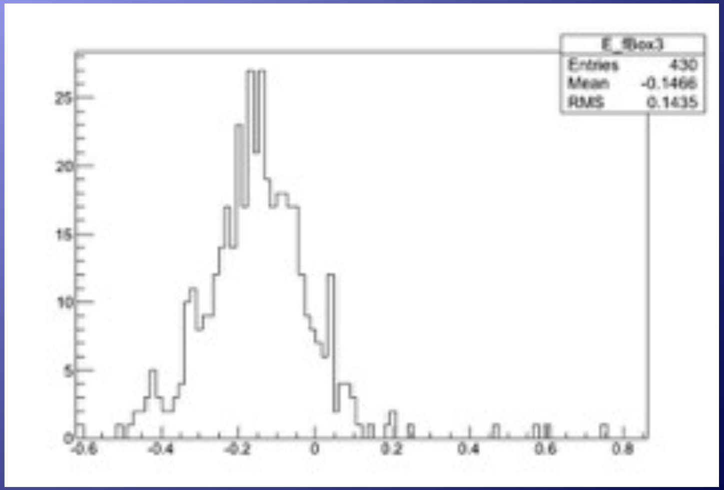
Pure *"Debug mode"*



"LTTPreClustering"
with 8 pixels box size



"LTTPreClustering"
with 3 pixels box size



Energy reconstruction with "*LTTPreClustering*" and "*PmtToShowerReco*" togheter

	Energy Accuracy	RMS	Energy Resolution
	$E = 1 \times 10^{20}$ eV		
Debug mode	−0.189	0.165	20.3 %
fBox = 8	−0.198	0.149	18.6 %
fBox = 3	−0.212	0.149	18.9 %
	$E = 5 \times 10^{19}$ eV		
Debug mode	−0.131	0.132	15.1 %
fBox = 8	−0.140	0.123	14.3 %
fBox = 3	−0.147	0.144	16.8 %
	$E = 3 \times 10^{19}$ eV, $60° < \vartheta < 90°$ and $R < 100$ km (anomaly discarded)		
Debug mode	−0.061	0.126	13.5 %
fBox = 8	−0.069	0.121	13.0 %
fBox = 3	−0.078	0.134	14.5 %

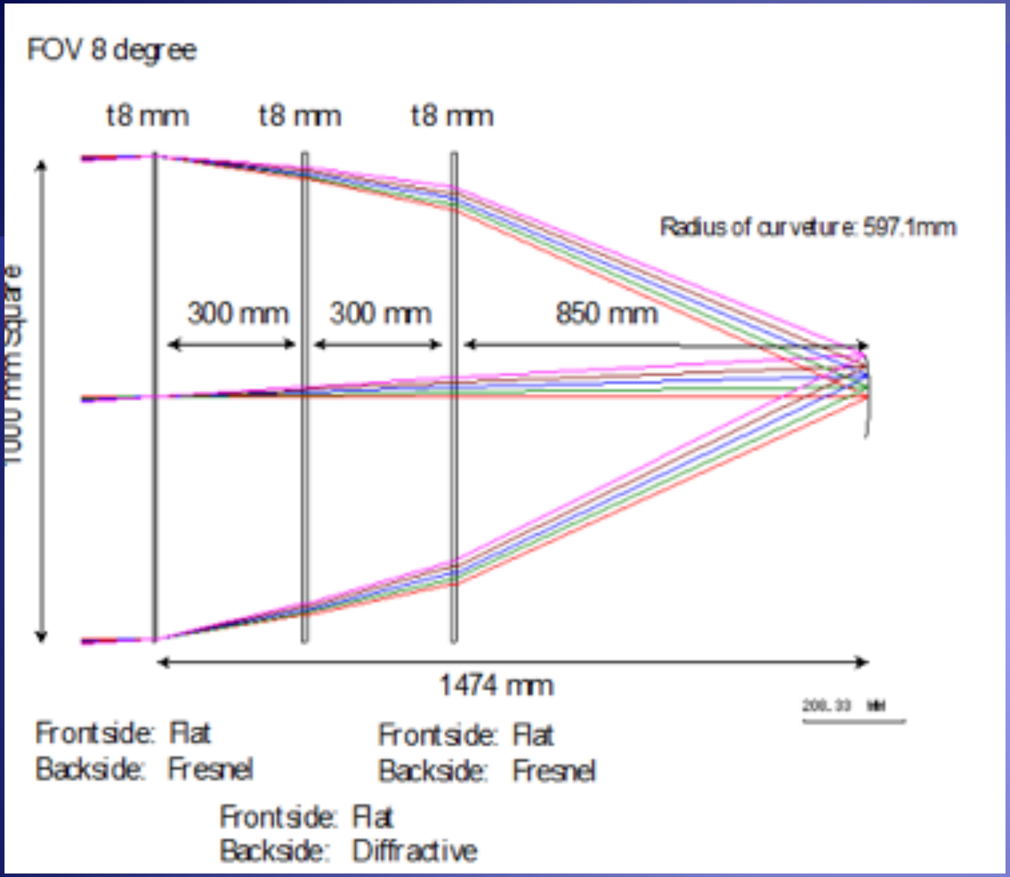
Objectives of the 1th EUSO Balloon mission

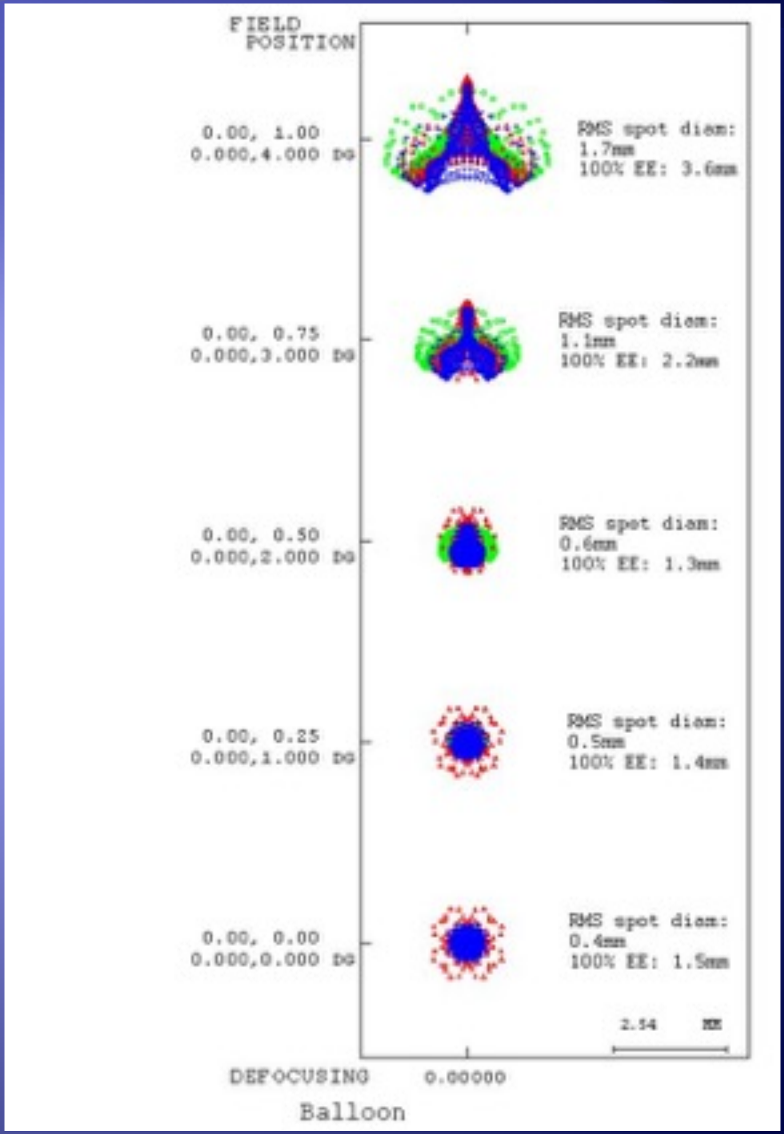
Main: test the trigger scheme

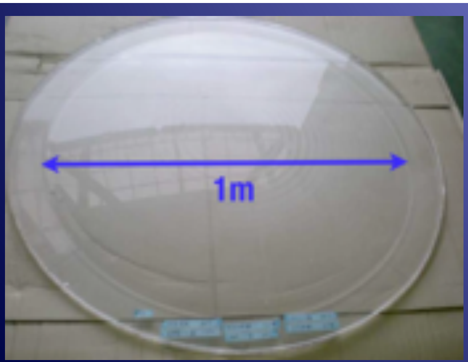
- The goal of the trigger system is to detect the occurrence of a scientifically valuable signal among the background noise detected by the JEM-EUSO telescope.

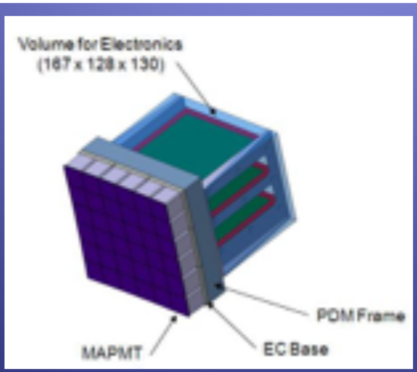
Secondary: observe a cosmic ray event if feasible

EUSO Balloon









Parameters of EUSO-Balloon compared to JEM-EUSO

Even though it is not guaranteed to observe such events, we might be prepared as the probability to see one event is not extremely low.

	JEM-EUSO	EUSO-Balloon	EUSO-Balloon (FoV x2)
Height (km)	420	40	40
Diameter (m)	2.5	1	1
FoV/pix (deg)	0.08	0.17	0.34
Ground/pix (km)	0.586	0.119	0.238
FoV/PDM (deg)	3.84	8.16	16.32
GroundPDM (km)	28.191	5.736	11.71
Signal ratio	1	17.64	17.64
BG ratio	1	0.723	2.892
[illegible]	1	20.753	10.37
E_{th}	[illegible]	[illegible]	[illegible]
# of PDM	143	1	1
Event ratio (h^{-1})	0.560	0.070	0.070

The triggering Philisophy

The JEM-EUSO trigger philosophy is at the core of the concept of the instrument.

The goal of the trigger system is to detect the occurrence of a scientifically valuable signal among the background noise detected by the JEM-EUSO telescope.

Since the total number of pixels in the array is very large (~ 2×10^5), a multi-level trigger scheme was developed.

This trigger scheme relies on the partitioning of the Focal Surface in subsections, named PDM (Photo Detector Module), which are large enough to contain a substantial part of the imaged track under investigation (this depends on the energy of air shower and the zenith angle).

The general JEM-EUSO trigger philosophy asks for a System Trigger organized into two main trigger-levels.

The two levels of trigger work on the statistical properties of the incoming photon flux in order to detect the physical events hindered in the background, basing on their position and time correlation.

The trigger is issued in accordance with two different stages:

Outline of noise reduction capability.

Level		**Rate of signals/ triggers at PDM level**	**Rate of signals/ triggers at FS level**
1st level trigger (PDM)	Photon trigger	~9.2×10^{8} Hz	~1.4×10^{11} Hz
	Counting trigger	~7.1×10^{5} Hz	~1.1×10^{8} Hz
	Persistency trigger	~7 Hz	~10^{3} Hz
2nd level trigger (PDM cluster)		~6.7×10^{-4} Hz	~0.1 Hz
Expected rate of cosmic ray events		~6.7×10^{-6} Hz	~10^{-3} Hz

Comments

A) The nightglow background is variable during the night.
B) The effect of man-made lights is extremely important and has to be taken into account.

These two effects require:

A) Capability of self adjusting thresholds to keep the trigger rate at constant level.
B) Avoid triggers in presence of man-made sources.

Solutions:

A) Rate-meters on board to monitor the background variability.
B) Persistency checks. If the signal excess is lasting too long (ms or s) compared to the typical time span of an air showers (100-300 μs) , the trigger system should be inhibited.

The Balloon flight could give us very useful hints and checks on how to deal with these situations.

My work concept

First simulations to evaluate the capability of the EUSO Balloon to observe air showers have been performed by simply moving a JEM-EUSO like detector to the altitude of 40 km.

The performance of the Balloon can be derived by rescaling the number of photons reaching the pupil by its aperture, 1 m vs 2.5 m, that implies a factor of ~6 less photons at pupil level.

The detector global efficiency can be assumed 12%, in accordance to JEM-EUSO efficiency as the main parts of the detector are similar.

Expected number of events

Based on the experimental results of other experiments it has been calculated that the expected number of events with energy $E > 5 \times 10^{17}$ eV would be ~ 20 in 10 hours data taking inside the FoV of the EUSO Balloon (5.7x5.7 km^2).

By means of the standard JEM-EUSO software simulation code (ESAF), 100 events following a cosmic ray spectrum with differential slope E^{-3} have been simulated in the energy range $5 \times 10^{17} < E < 10^{19}$ eV.
The following slides show the 5 brightest simulated events.
We, therefore, expect that one of the following events could be the brightest event that would occur in the FoV of EUSO Balloon during 10 h measurement.

Zenith angular dependence of the residence time of EAS signal in 1 pixel

(assuming ~40km distance between shower maximum and detector)

θ = zenith angle of the shower
T = time needed to cross the pixel size AC= 119 m in 1 GTU (shower flies 750 m in 2.5μs).

Since the EAS travels at the speed of light, the photons reaching EUSO from any point on the EAS lags behind the passing EAS front by a time:

$$\Delta t = \frac{\overline{AB}+\overline{BC}}{c} = \frac{\overline{AC}}{c\tan\frac{\vartheta}{2}}$$

as can be deduced from Figure 5.1.1-1.

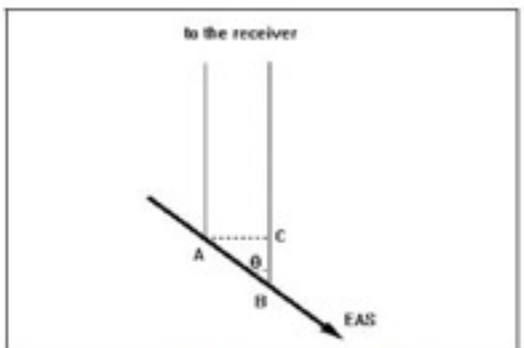
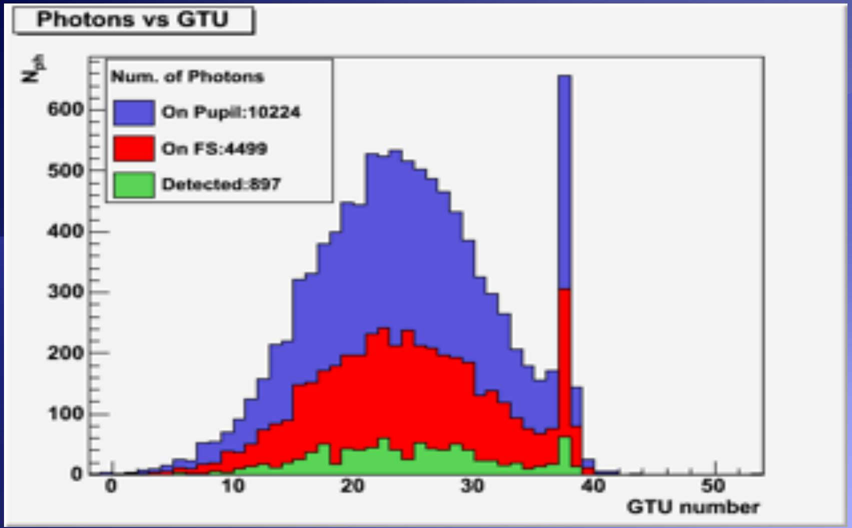
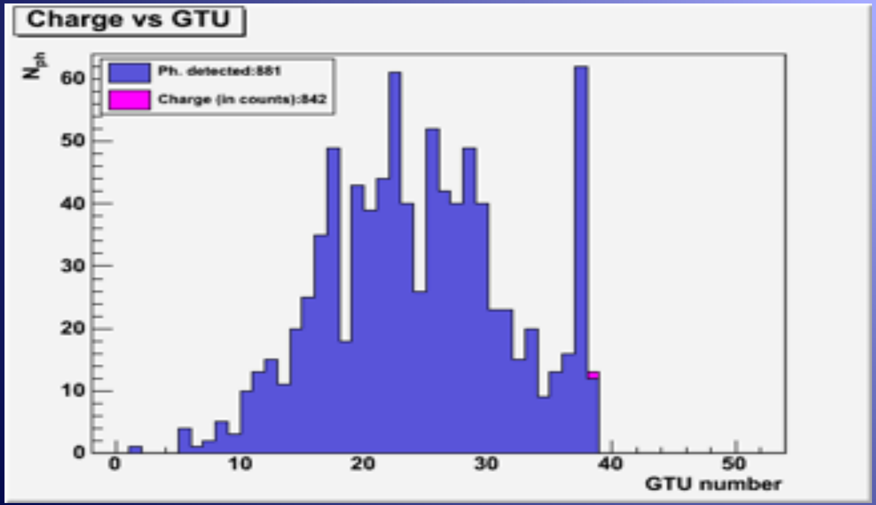


Figure 5.1.1-1 *Kinematics of the EAS*

θ	T (ns)	T (FoV x2) (μs)
5	9.091	18.183
10	4.537	9.074
15	3.015	6.030
30	1.481	2.963
45	0.958	1.917
60	0.688	1.375
75	0.517	1.035
90	0.397	0.794

Bright event #1





Event energy: 1.11e+18 eV
θ: 38.0°

φ: 18.8°

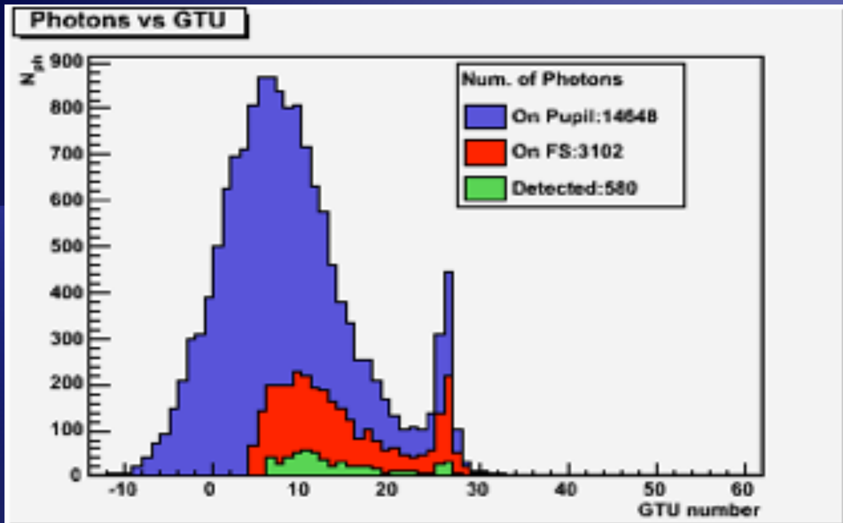
Impact on Earth (X): 1.45 km
Impact on Earth (Y): -3.27 km

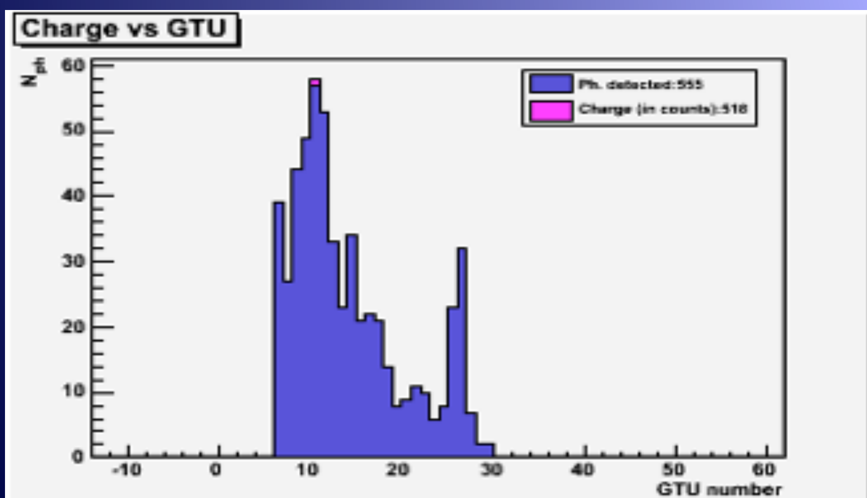
Photons @ max. : ~ 540
Phe B-EUSO: 540/6*0.12 =10.8
Crossing time/pixel = 2.306 μs

N. phe/pix=10.8x2.306/2.5=10.0

10 phe/pix is at the limit of the observational capabilities assuming that the average bckg is around 4 phe/pix/GTU. To be observed it would require very low nightglow background conditions.

Bright event #2





Event energy: 1.46e+18 eV
θ: 52.6°

φ: 97.4°

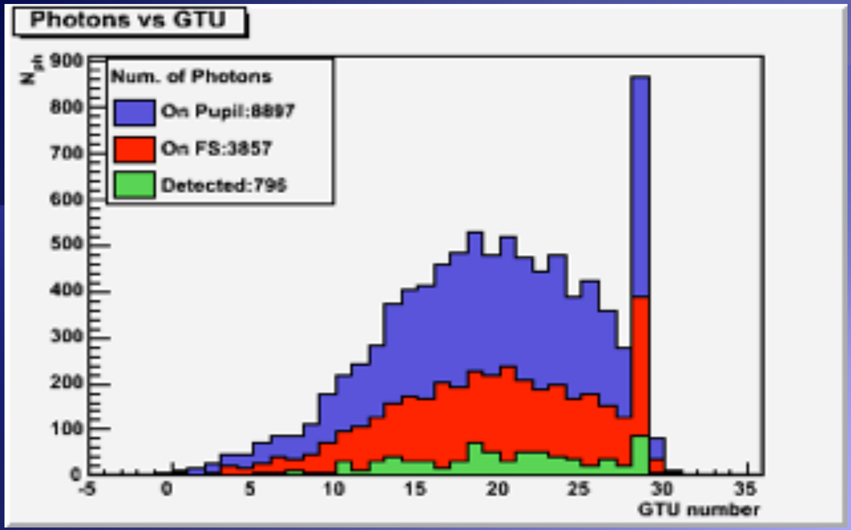
Impact on Earth (X): -2.44 km
Impact on Earth (Y): 5.32 km

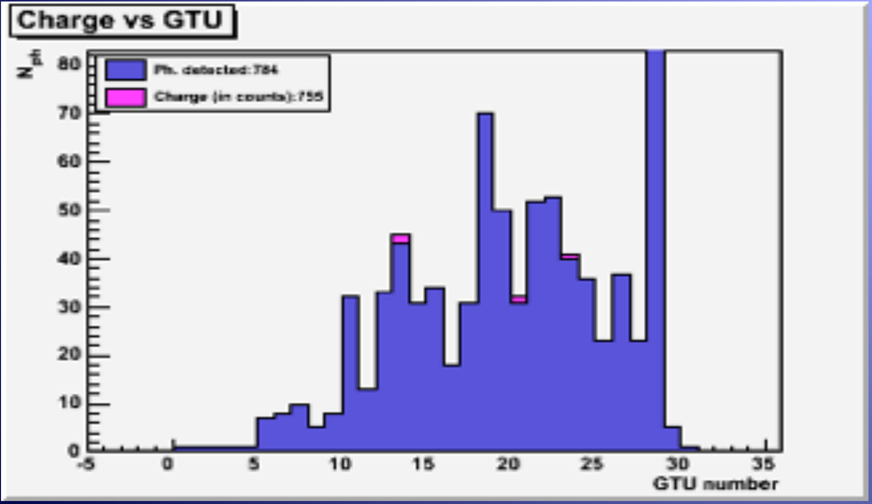
Photons @ max. : ~ 860
Phe B-EUSO: 860/6*0.12 =17.2
Crossing time/pixel = 0.803 μs

N. phe/pix=17.2x1.61/2.5=11.0

11.0 phe/pix is at the limit of the observational capabilities assuming bckg of ~4 phe/pix/GTU. It would require very low nightglow background conditions.

Bright event #3





Event energy: 1.32e+18 eV

θ: 25.6°

φ: 39.4°

Impact on Earth (X): 0.32 km

Impact on Earth (Y): -6.91 km

Photons @ max. : ~ 520

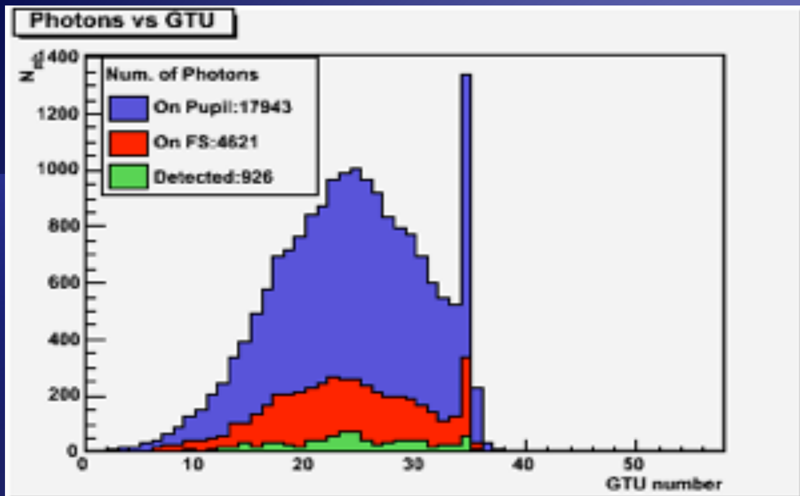
Phe B-EUSO: 520/6*0.12 =10.4

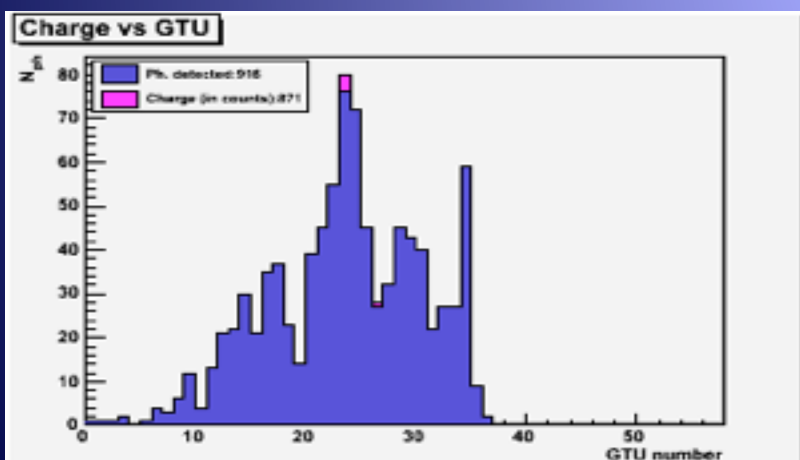
Crossing time/pixel = 1.746 μs

N. phe/pix=10.4x3.49/2.5=14.5

14.5 phe/pix is a reasonable number to detect the event. It depends mainly on the average nightglow background.

Bright event #4





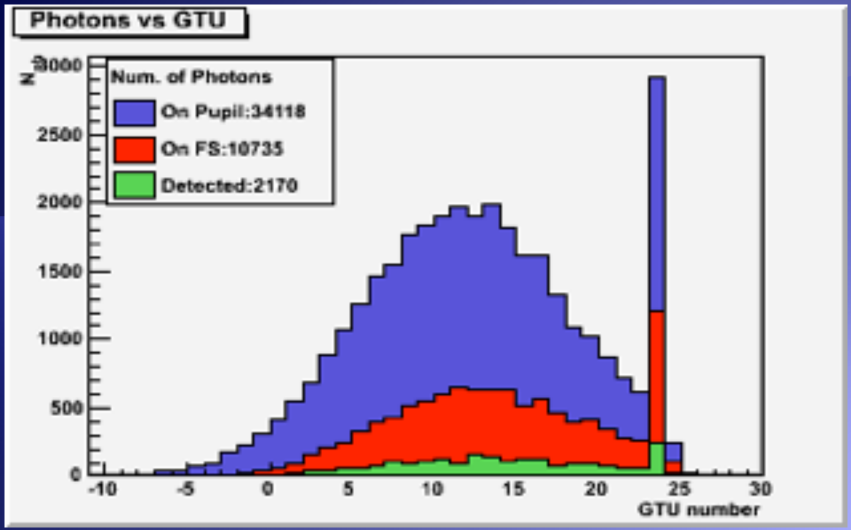
Event energy: 3.42e+18 eV
θ: 34.7°
φ: 266.3°
Impact on Earth (X): 9.91 km
Impact on Earth (Y): 15.65 km

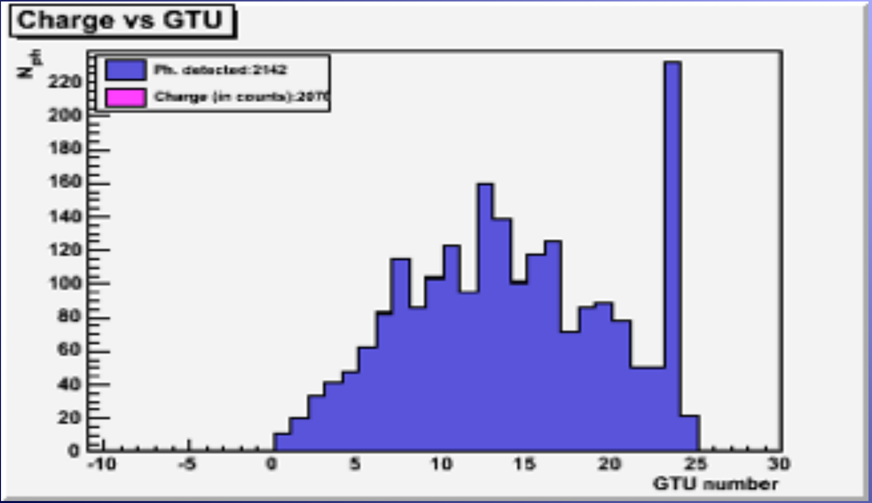
Photons @ max. : ~ 1000
Phe B-EUSO: 1000/6*0.12 =20.0
Crossing time/pixel = 1.270 μs

N. phe/pix=20.0x2.54/2.5=20.3

Most probably OK unless high nighglow background

Bright event #5





Event energy: 4.92e+18 eV
θ: 36.8°

φ: 152.2°

Impact on Earth (X): -12.3 km
Impact on Earth (Y): 0.2 km

Photons @ max. : ~ 2000
Phe B-EUSO: 760/6*0.12 =40.0
Crossing time/pixel = 1.192 μs

N. phe/pix=40.0x2.38/2.5=38.1

Definitively observable

EUSO Balloon – preliminary Coclusions

A first estimation of detecting air showers with EUSO Balloon has been performed by means of the standard ESAF code employed for JEM-EUSO.
Some simplified assumptions have been made.
The result seem to indicate that among the 5 brightest events:

- 2 events seem to be detectable without problems
- 1 event could be detected unless the background is high
- 2 events are at the limit and their detection is quite dependent on the average nightglow background.

In conclusion, the EUSO Balloon flight might be able to observe one EAS candidate in one night flight, however, it is not guaranteed due to the low flux and the unknown background conditions.

Conclusions