Università degli Studi di Torino
Tesi di Laurea Triennale in Fisica

"AN OFFLINE ANALYSIS OF THE MINI-EUSO TRIGGER RESPONSE AND SEARCH FOR ANITONS-LIKE EVENTS"

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L'argomento di tesi è stato oggetto di stage presso l'Istituto Nazionale di Fisica Nucleare (INFN), per cui è stata svolta una verifica della performance offline di Mini-Euso.

SUMMARY

- Mini-EUSO mission and EECRs
- The ANITONS events
- Mini-EUSO and ANITONS research
- The trigger software (thresholds estimation offline)
- ANITONS research through the data: the candidates
- Conclusions
- Bibliography

THE MINI-EUSO MISSION

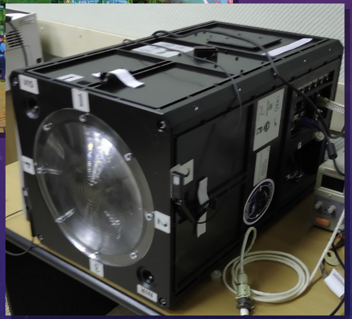
Working time: Mini-EUSO is online every two weeks for 12 hours; every orbit is about 45 minutes(before sunrise).

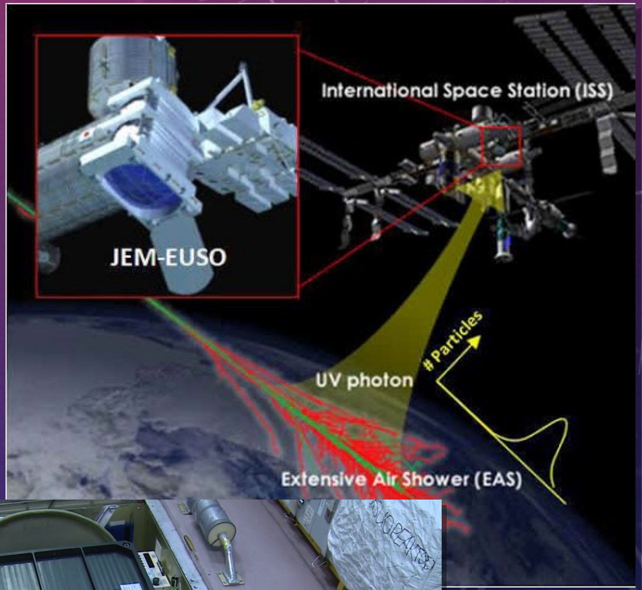
Mini-EUSO telescope is observing Earth in the UV band from the International Space Station (ISS)

Part of the JEM-EUSO program for EECRs observation!

Observational band: 300-400 nm
Time resolution: 2.5 µs
Space resolution: 6km

	Mini-EUSO
mirror size	$0.05\ m^2$
FoV	44 x 44 deg^2/PDM
Ang. resolution	0.8 deg/pixel
Pixel size	3x3 mm^2
Camera size	2304 pixel/PDM
EAS distance	400 km
light intensity (@40km=1)	0.01
time resolution	2.5 µs
signal acquisition	photon counting





Mini-EUSO on the ISS module

What Mini-EUSO can see?

EVENTS ABOUT ms to s

UV Earth emission

Airglow

Meteors

Space debris

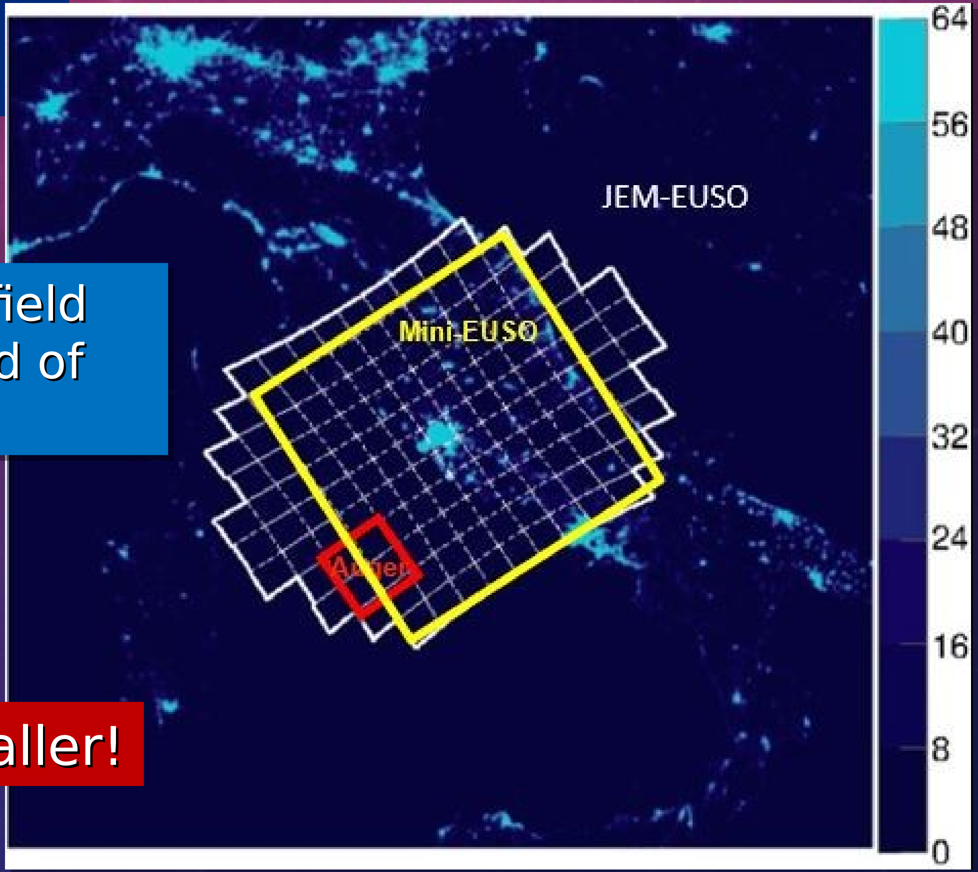
Energetic TLEs(Transient Luminous Events), as

EVENTS ABOUT 10-100 µs

EECRs(Extreme Energy Cosmic Rays)

«In astroparticle physics, cosmic rays with energy higher than are EECRs (extreme energy cosmic rays)»

JEM-EUSO/Mini-EUSO field of view and Auger field of view.

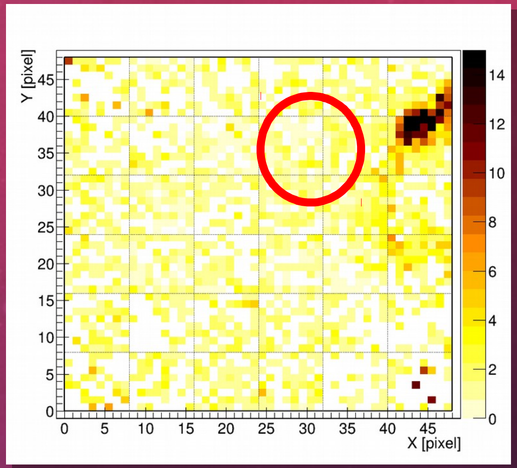


Mini-EUSO was made to study issues in UHECRs observation from space

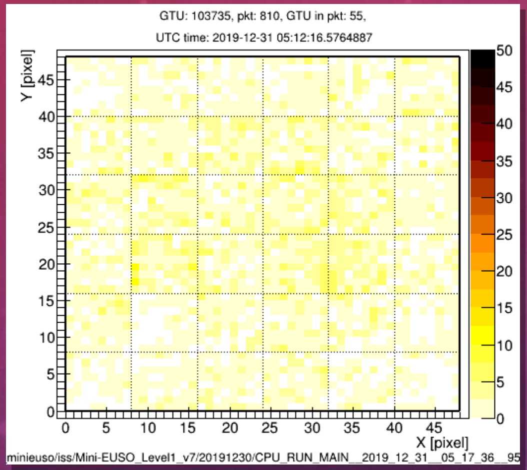
Made as JEM-EUSO, but smaller!

Here some examples of events detected by Mini-EUSO:

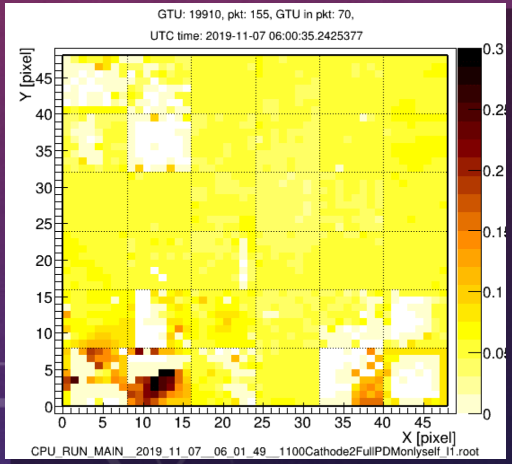
(all the animations developed in ETOS software)



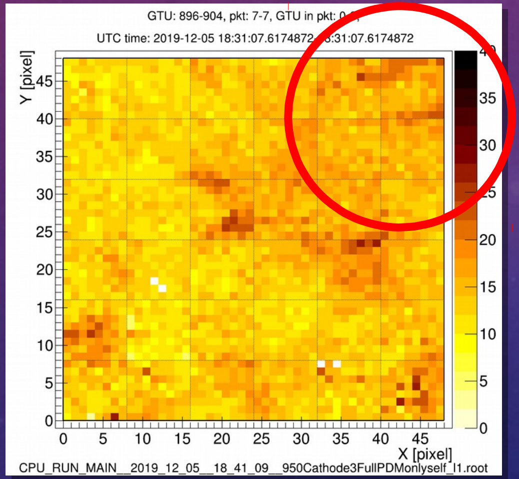
Flasher



Direct cosmic ray



Lightning

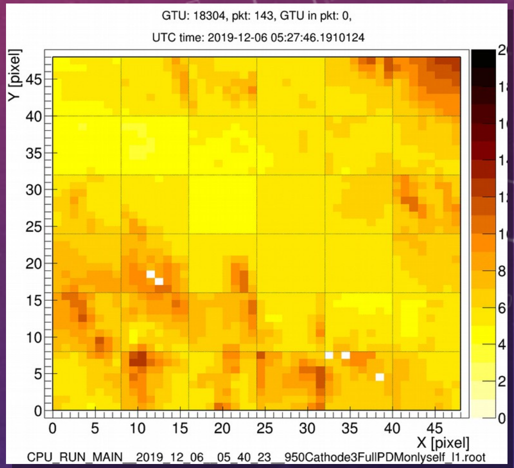


Elve

Time resolution 2.5 µs

We see EECRs, TLEs and anthropogenic phenomena as flashers

Time resolution 40.96 ms



Clouds

THE ANITONS: ANOMALOUS EVENTS

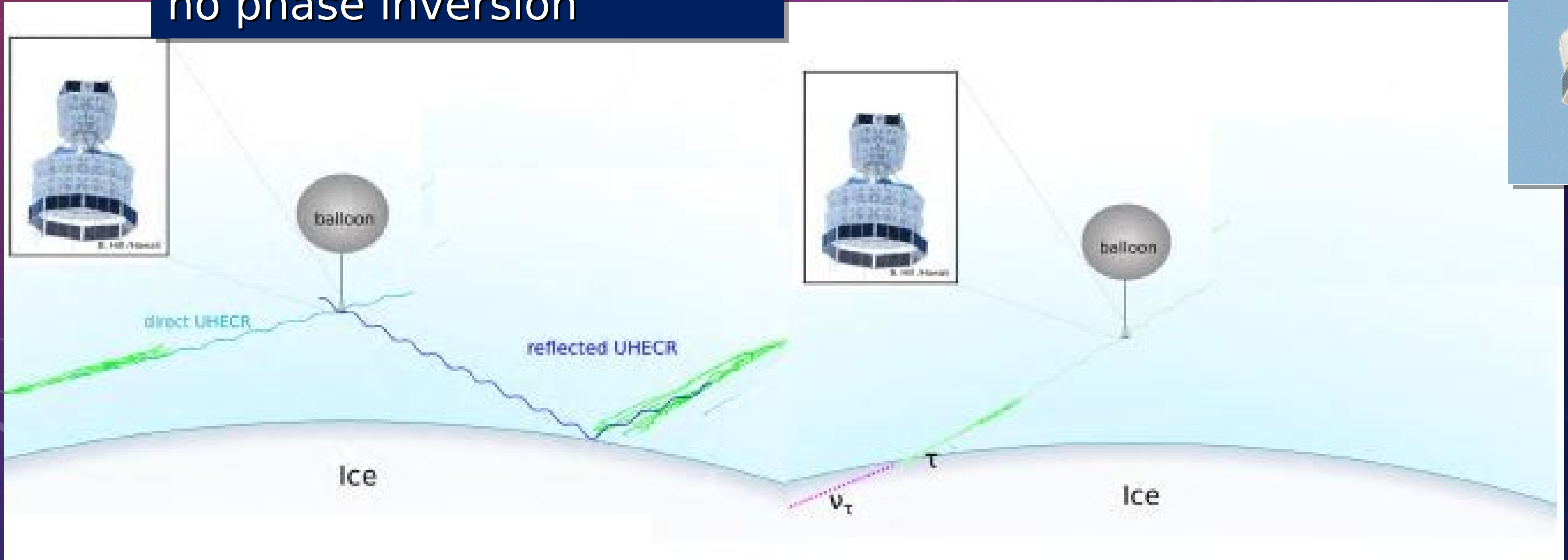
ANITA(Antarctic Impulsive Transient Antenna) : stratospheric balloon launched in 2006 from Antartica. Equipped with impulsive antennas, it flew four times between 2006-2016.

Two anomalous events:
- E1=600 ± 400PeV
- E2=560 ± 300 PeV

Nadir angle about 62°-55°, no phase inversion

The origin of these events is unknown.

ANITA concept



ANITA balloon

The ANITONS origin

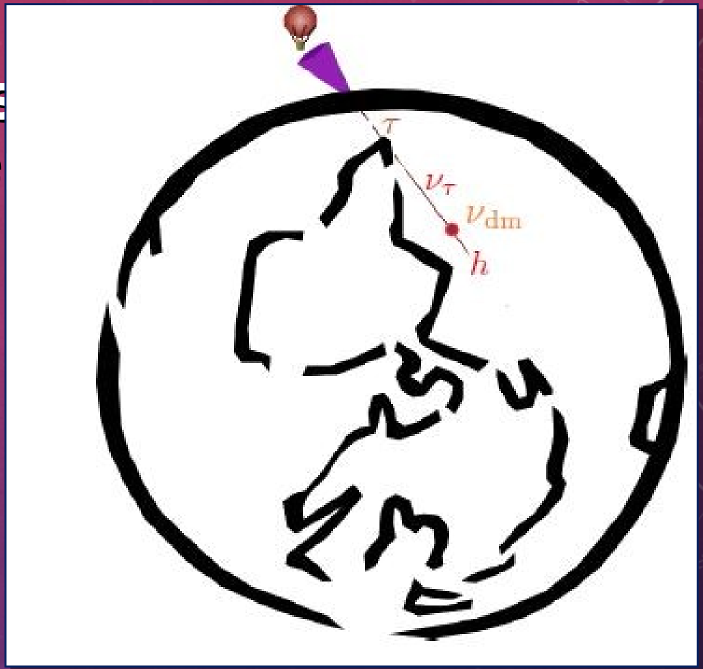
First ipothesis

Decay of τ-neutrino skimming through Earth in τ-le

CONS

Standard Model says a particle of 500 PeV can skim through the Earth for 600 km (10-12 SM interaction lenghts)

Highly disfavored!



Scheme of a dark matter neutrino decay inside the Earth

AN INNOVATIVE THEORY

Decay of a dark matter quasi stable neutrino inside the Earth into a x-boson and a τ-neutrino; the products will decay in τ-leptons, producing the EAS.

Dark matter density value today:

For this density, mass of a dark matter particle should be:

$$M_{\nu_{dm}} = 4.8 \times 10^8 \text{ GeV} = 480 \text{ PeV}$$

which is similar to anitons value!

Sakarhov theory of CPT symmetric universe predict dark matter particles density at the centre of the

Concept of Sakarhov CPT symmetric universe

What kind of signal can be associated to an AN

ANITONS-like events detected thanks to the Cherenkov light, not fluorescence

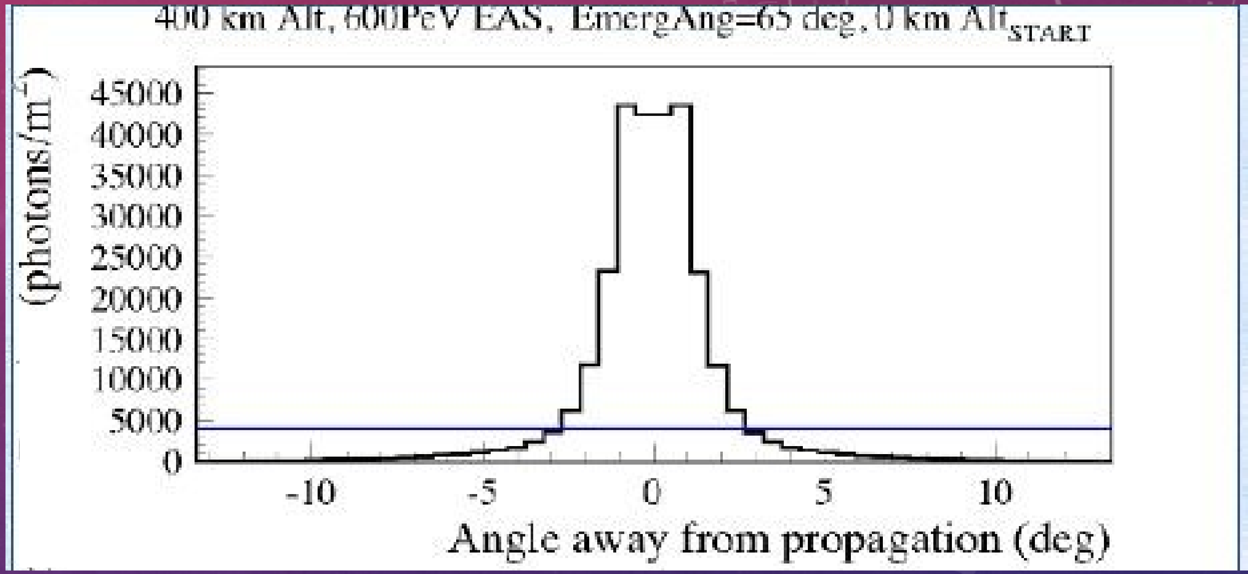
brighter

Cherenkov angle ≈ 1°
Energy ≈ 600 PeV

Mini-EUSO has a field of view of 300x300

A space telescope with wider visual area could have more chance to see these events.

Simulation of an aniton event on Mini-EUSO



10 times ANITA!

(per orbit)

These are speculations: the reality could be a systematic error of ANITA, or an anomalous reflection through ice. Last ANITA flight did not observe these events.

MY WORK: MINI-EUSO DATA AND TRIGGER SYSTEM

Two main stages:

- An offline analysis of the trigger system of Mini-EUSO, in particular of the thresholds of every triggered event. **This was part of the internship at INFN.**
- A research through the data we collected until today looking for events similar to anitons.

Main Mini-EUSO components

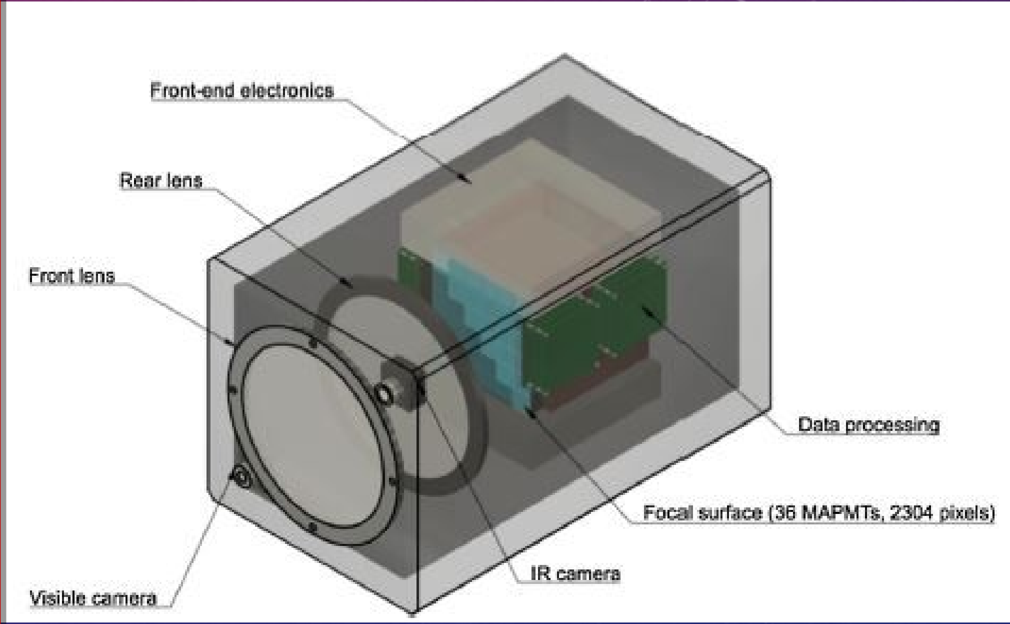
Electronic system(Trigger system)

Fresnel lens system (2 lens, 25 cm diameter)

PDM(Photon Detector Module, 36 photomultiplier for 64x64 pixels)

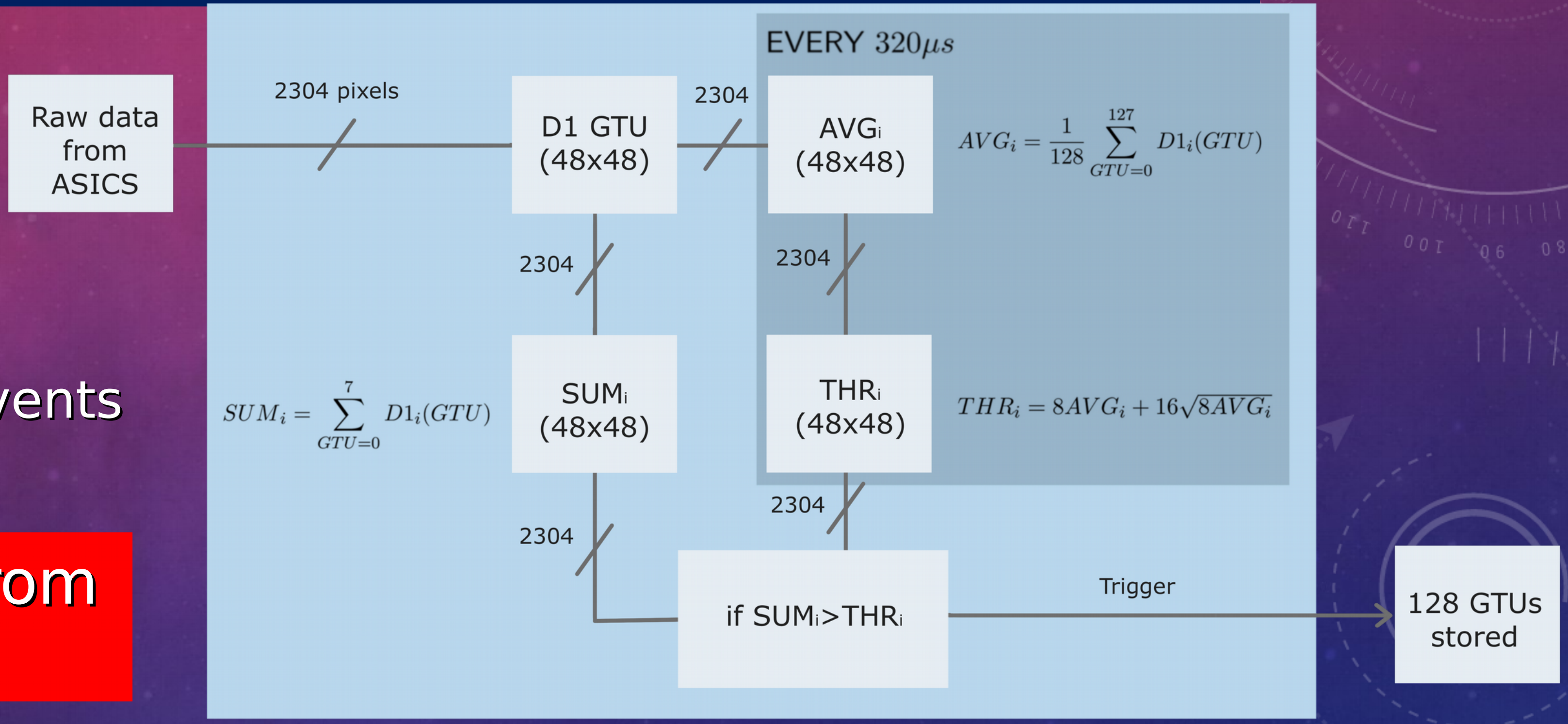
CHARACTERISTICS

- Analysing and collecting the data
- Three levels with three time resolutions
- Each pixel is indipendent
- The system restarts the trigger every



The trigger system of Mini-EUSO

Mini-EUSO trigger works on a 48x48 pixels matrix from the PMD. Each pixel has a field of view about 6 km, and it takes nearly 20 µs for light to cross a pixel: the system integrated over 8 GTU (time unit), and it compares the result with the background over 128 GTU.



L1 trigger scheme

The levels:

L1 [GTU= 2.5 µs] Shorter events scale(EECRs,ELVES)

I worked mostly on data from L1 level!

L2 [GTU=320µs] Longer events(TLEs, lightning,etc..)

L3 [GTU=40.96ms]The third level stores a continuous readout of 40.96 ms

The main problem:

Mini-EUSO data are photon counts and relative timestamps. It does not store the threshold used by the system to detect the event: the thresholds are changed every 128 GTU.

Part of my internship was to estimate the value of these thresholds with two different methods:

- Average photon counts over the first 32 GTU of each L1 packet (128 GTU).
- Average photon counts over 40.96 ms (a L3 cycle).

That because the event is usually placed at the 64 GTU by the system.

The average was used to calculate the threshold as:

We calculated the threshold in both ways for each L1 packet.
The data have been developed through Python coding.

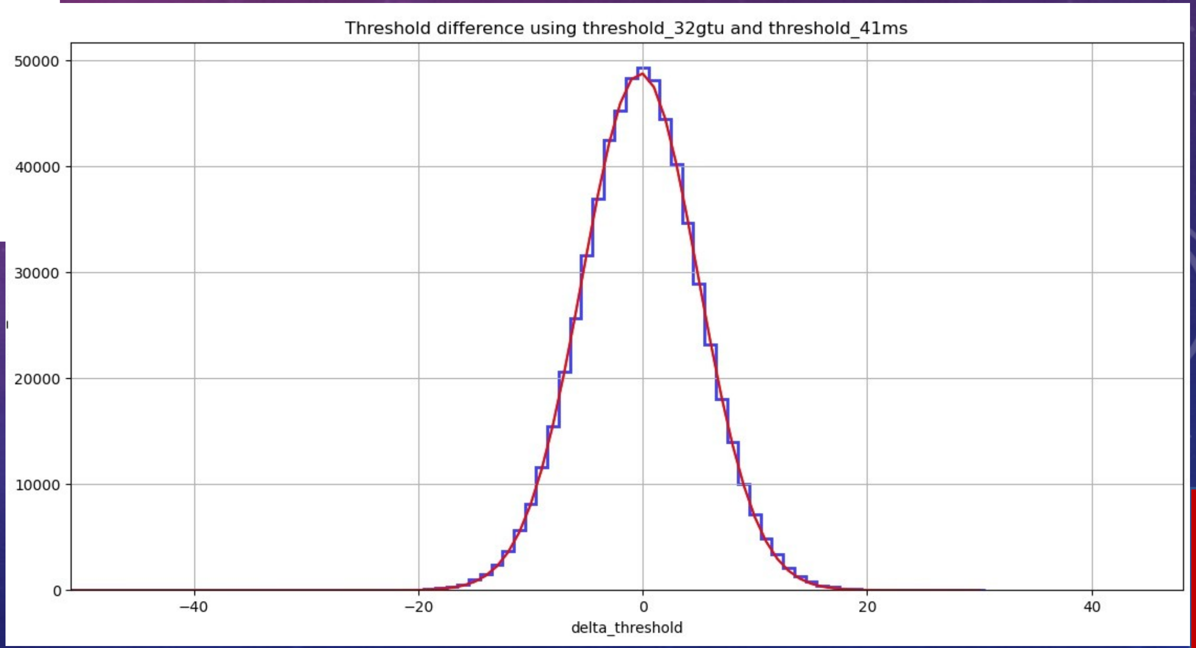
Which threshold is higher?

We analysed how the difference value between the two thresholds changed through the session.

To do this, we made an hystogram of differences for each session(on each packet/GTU/pixel):

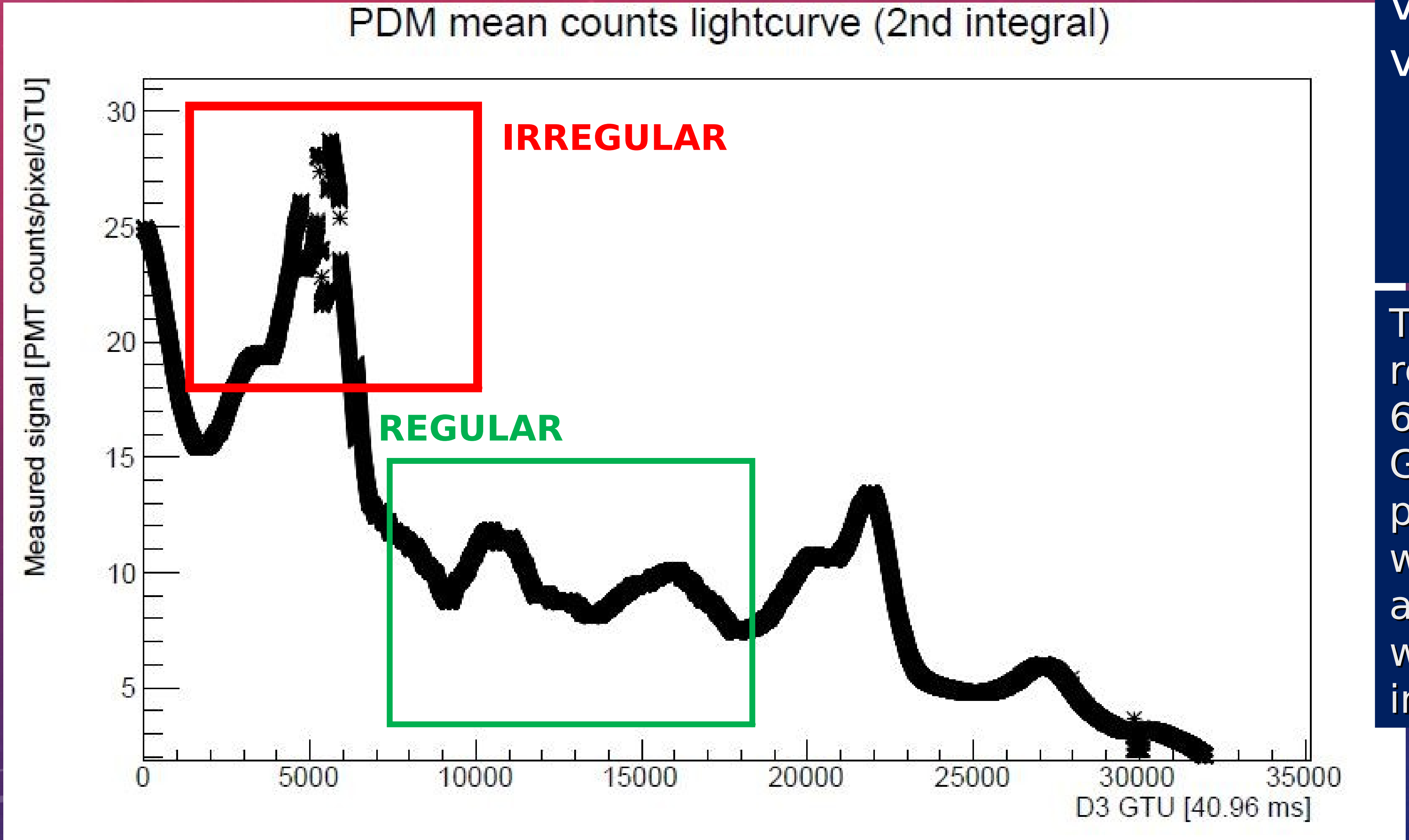
The hystogram was compared with a gaussian fit:

Example of a differences hystogram on a sing



We wanted the differences to be symmetric with no evidence of a higher threshold between the two methods!

Photon counts curve respect to L3 GTU of 40.96ms

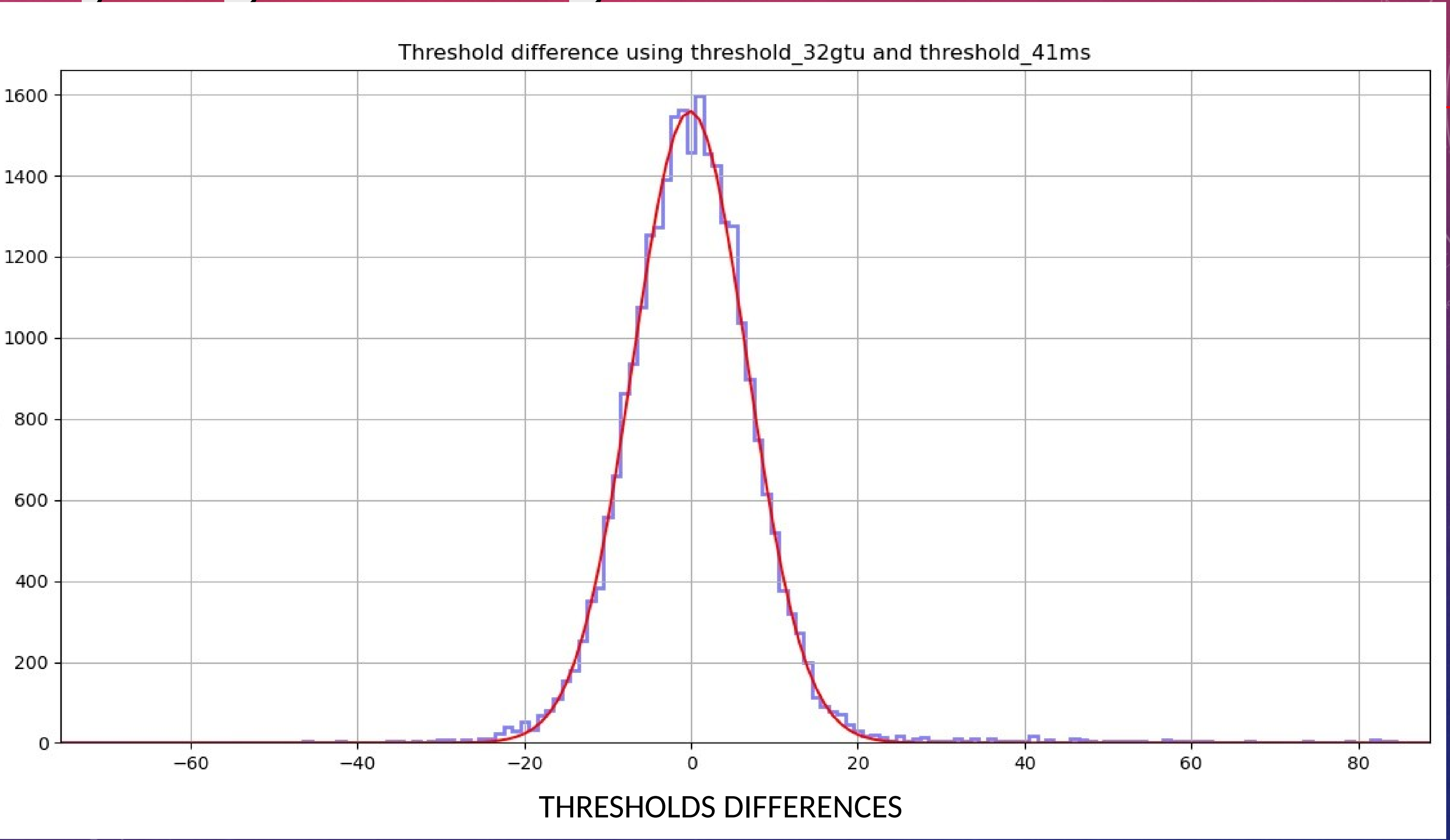


- Regular
- Irregular (lots of peaks and drops in photon counts)

The light curve is regular between 6’000 and 18’000 GTU. In the first part(<6’000 GTU) we can see mostly an irregular pattern, with lots of changes in photon counts.

SESSION 19 ORBIT 1

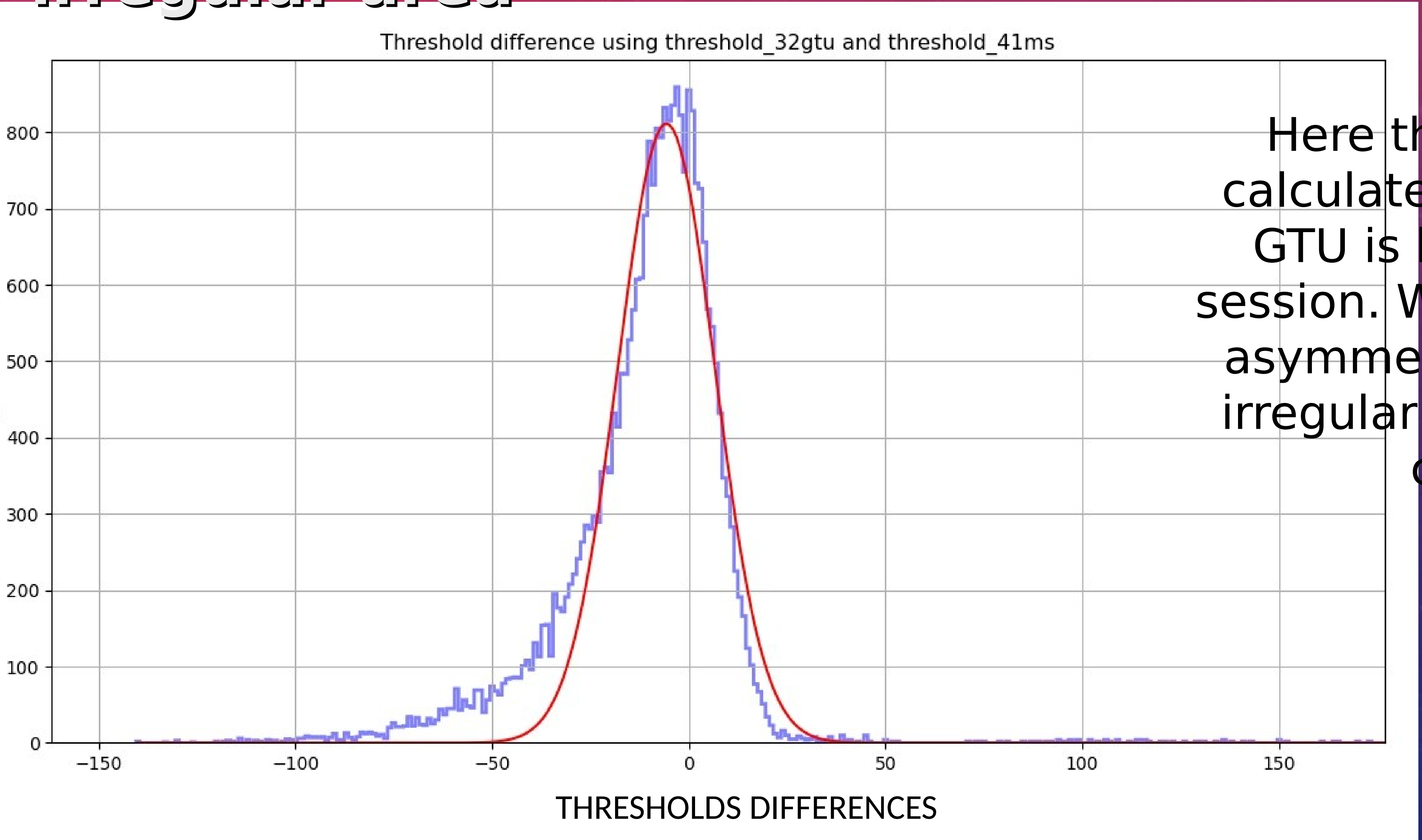
Hystogram in regular area



fit

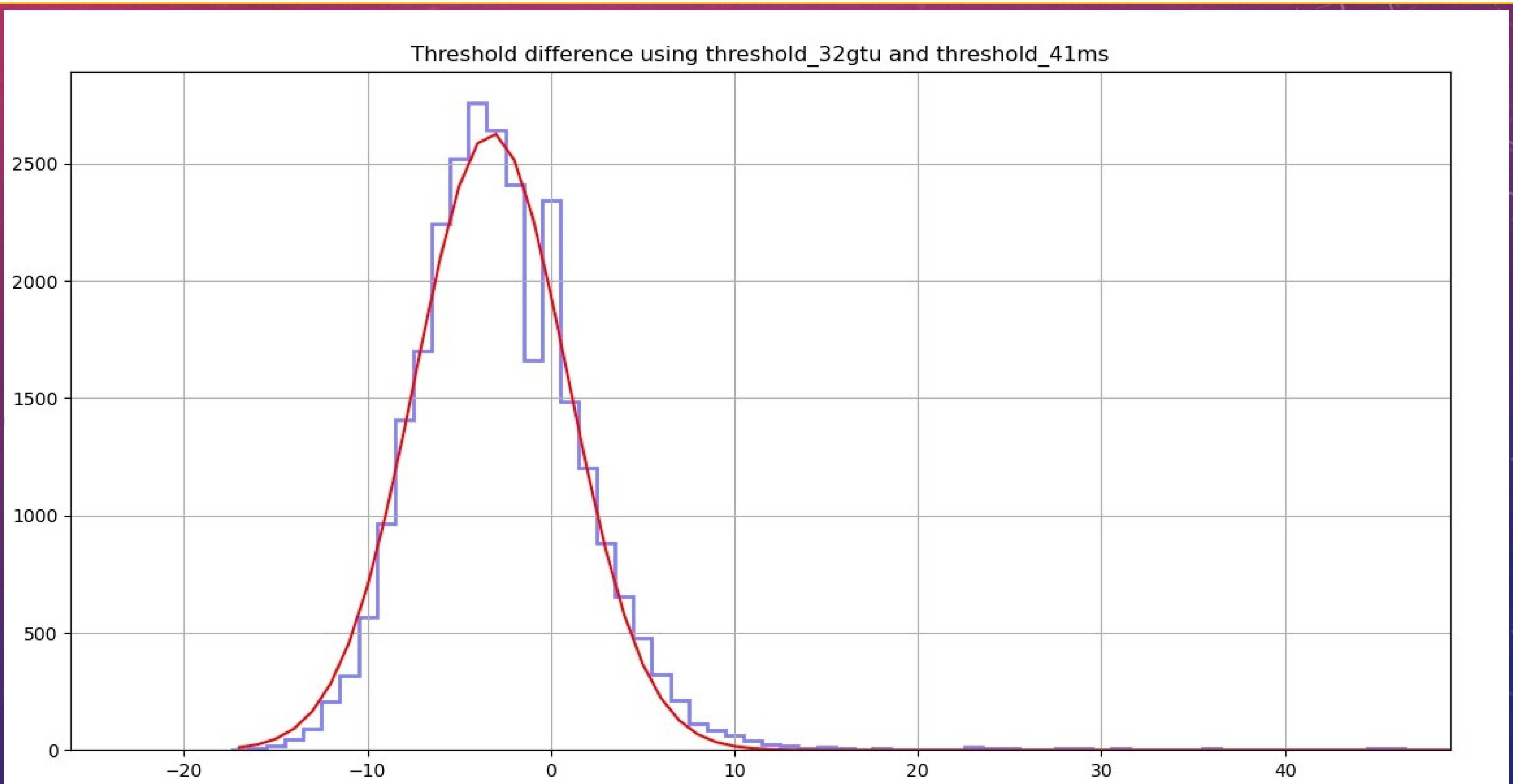
The differences distribute symmetrically around

Hystogram in irregular area



Here the threshold calculated over the 32 GTU is higher in the session. We expected an asymmetry due to the irregularity of the light curve.

We used absolute values, but in this way we did not consider systematic decrease or increase in photon counts (as the approaching of sunrise). Plotting the percent relative differences, we obtained a better fit:



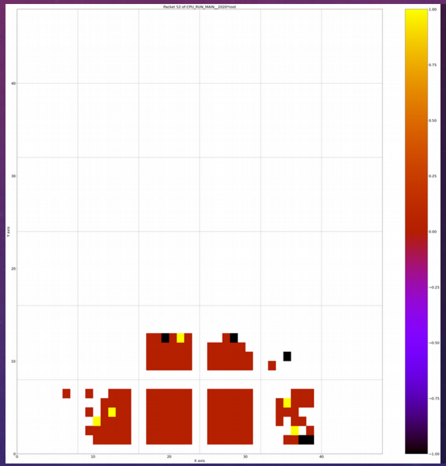
RELATIVE DIFFERENCES [%]

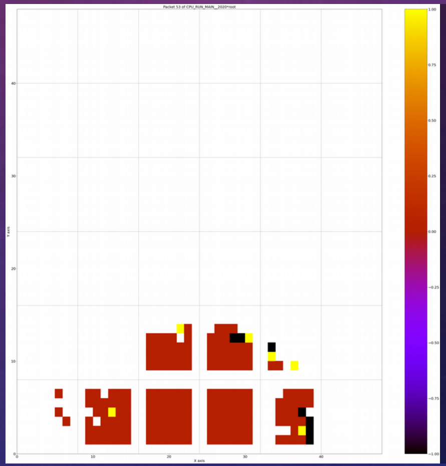
Which threshold detects more events?

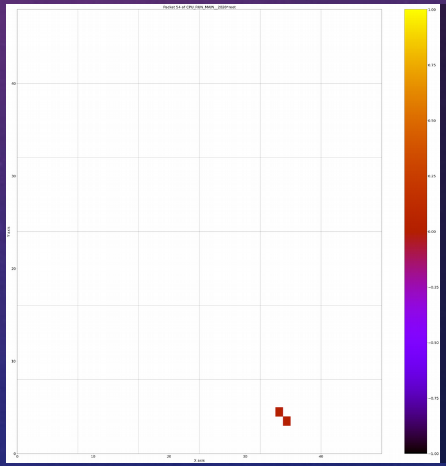
We made a series of 48x48 pixels plot for each packet. We applied both thresholds, with different colors if the photons were triggered with a method or the other.

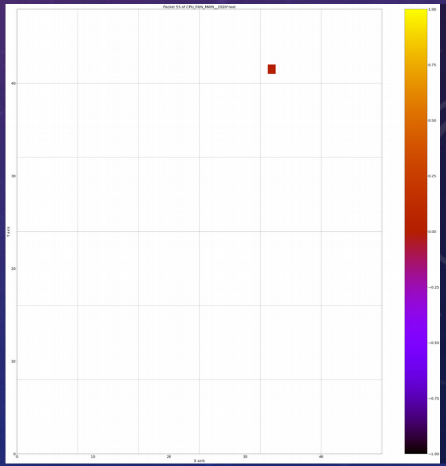
The main goal was to observe if a method has higher chance to detect incoming events.

Some examples of the 48x48 pixel plots







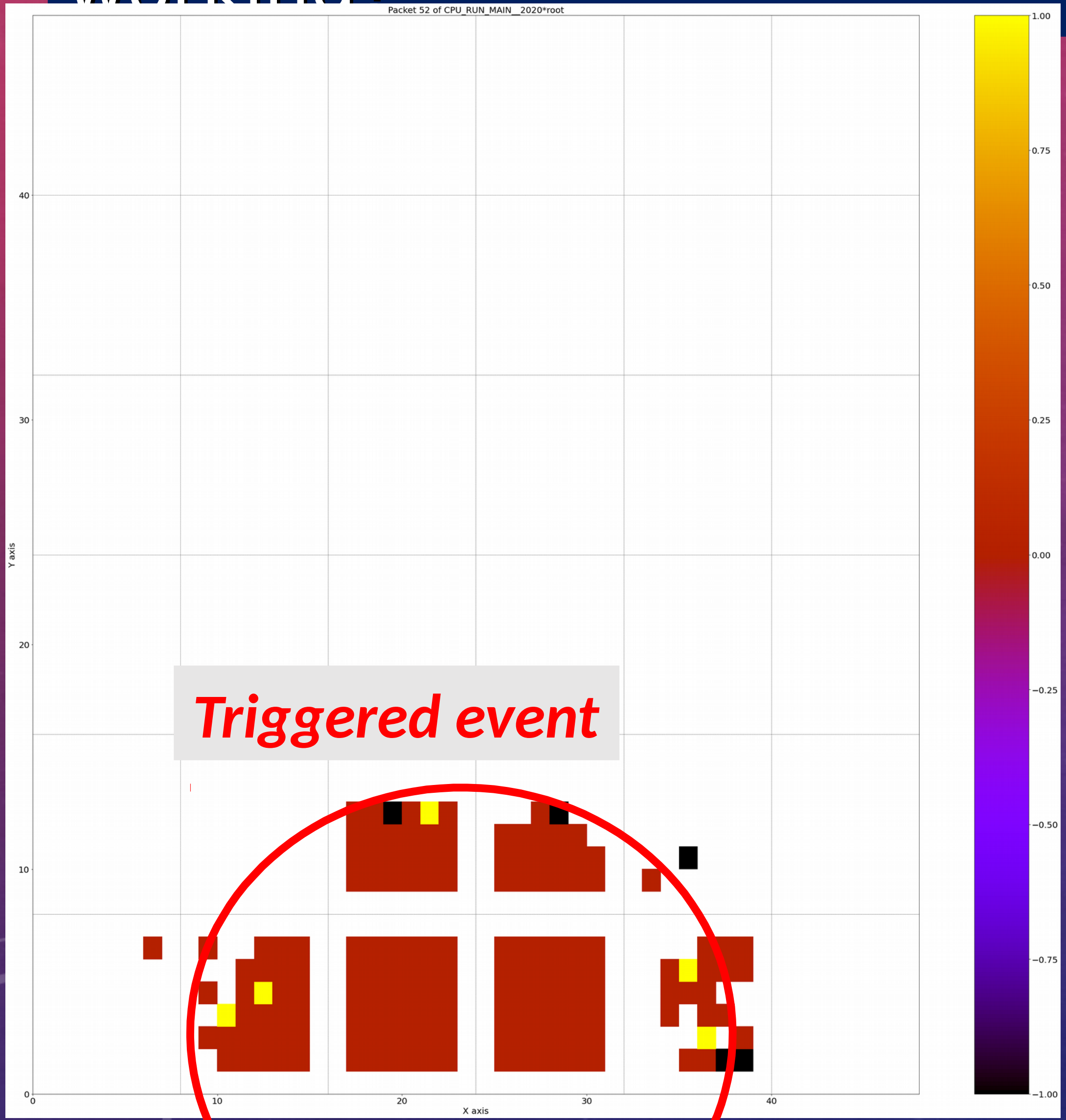


What happen in a packet where the trigger is working?

RED= both thresholds triggered

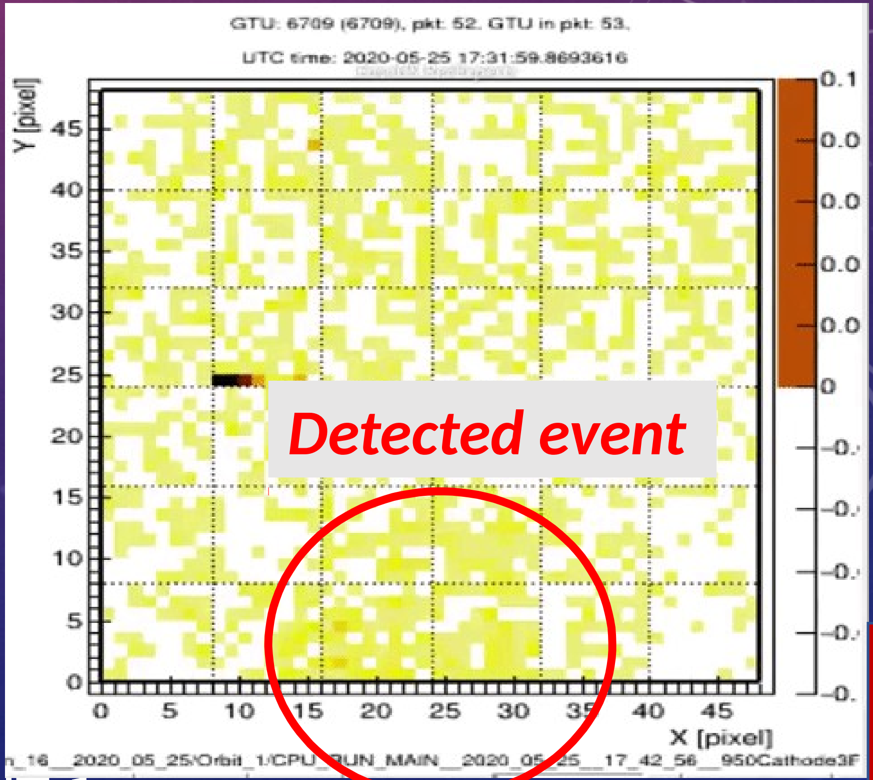
BLACK= threshold over 32GTU

YELLOW=threshold over 40.96 ms



What the PDM is observing

What the trigger is detecting



SESSION 16 ORBIT 1

Results of the thresholds a

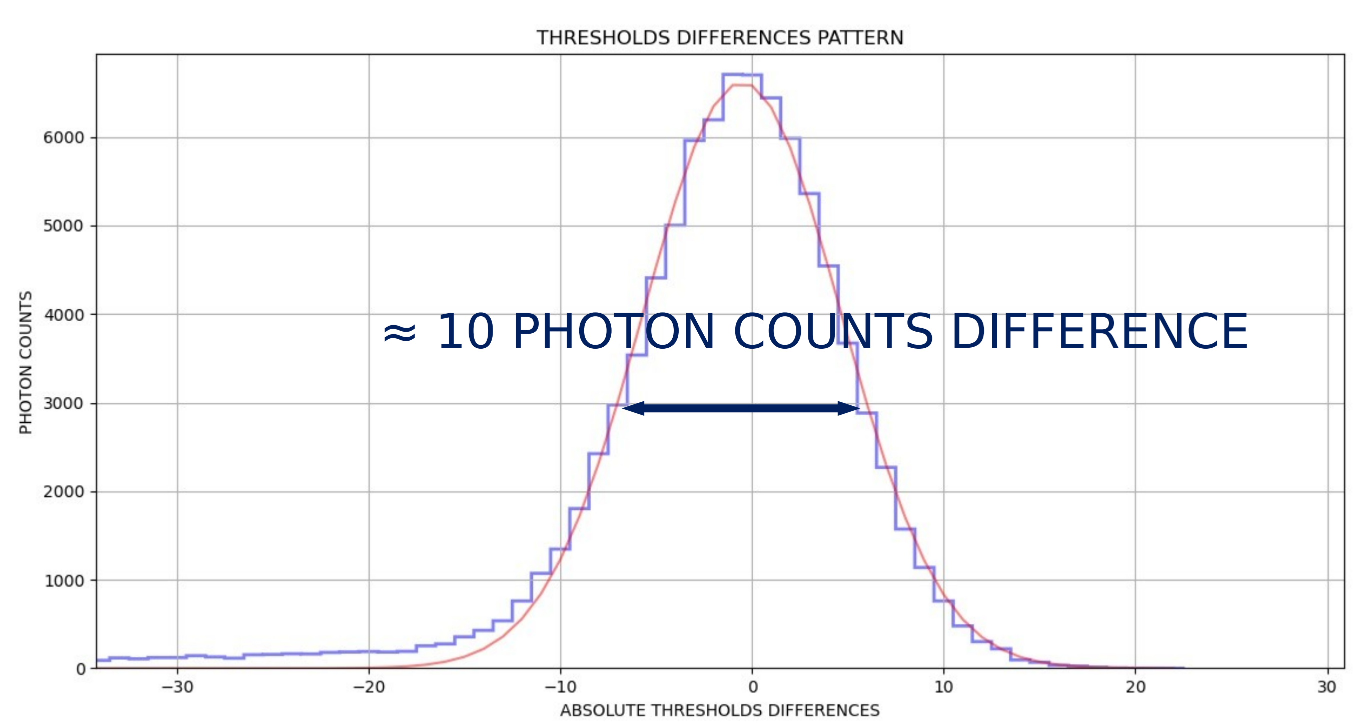
- Both thresholds have nearly the same value for each packet, within the statistical fluctuations.
- Both thresholds detect most of

Threshold over 32 GTU error= 5.4 photon counts
Threshold over 40.96ms error= 0.23 photon counts

The first threshold is only over 32 GTU, while the second method is on 16384 GTU, and its error is lower.

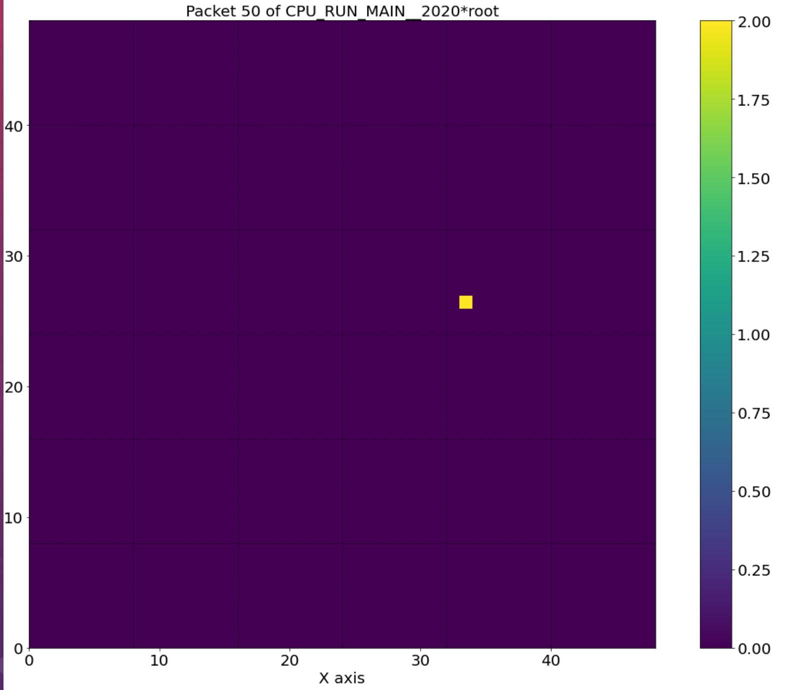
We expect a gaussian width to half height about 10 photon counts difference, which is the

Since both methods are valid, we could choose the lower threshold for each packet, to detect more events.



The ANITONS research

With a coding software we selected (offline) the lower threshold for each packet. Our goal was to detect events similar to the anomalous ANITA events.



An example of a candidate signal in the trigger software

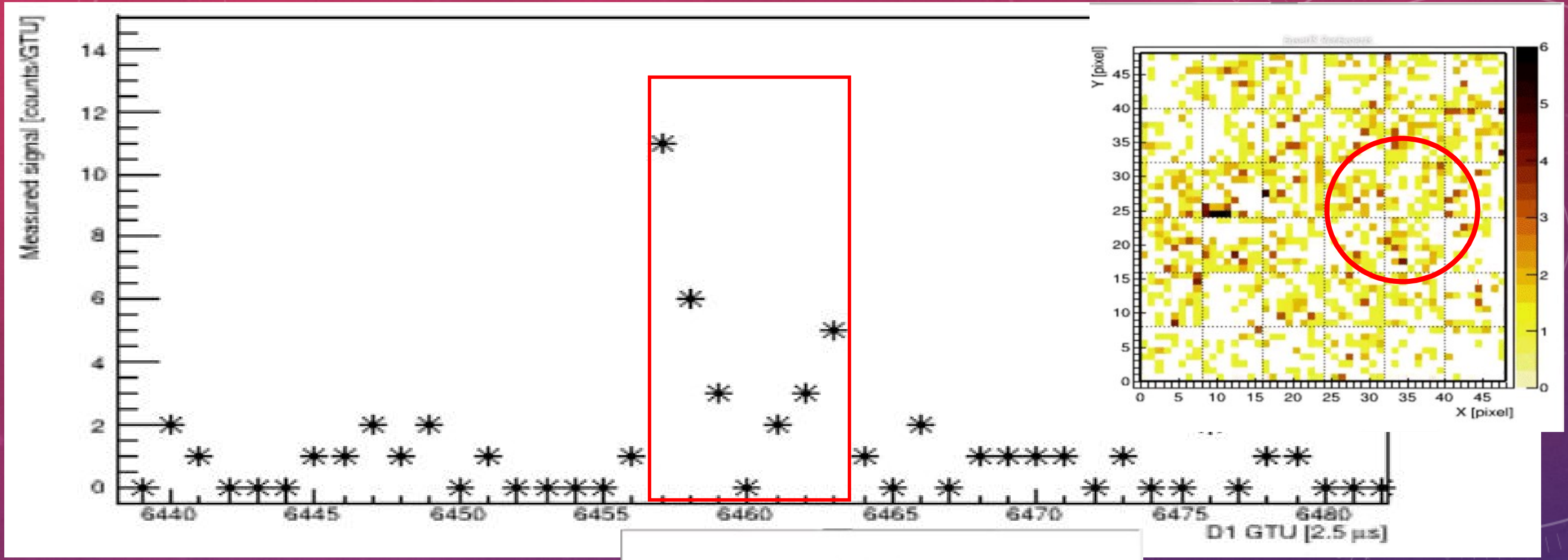
WHAT KIND OF EVENTS WE ARE LOOKING

- Short events (L1 level of the trigger), about 1-2 GTU long.
- Small events, max a 2x2 pixels square.
- Most of the photon counts concentrated in 1-2 GTU in the 8 GTU integral
- Photon count should be high respect to background

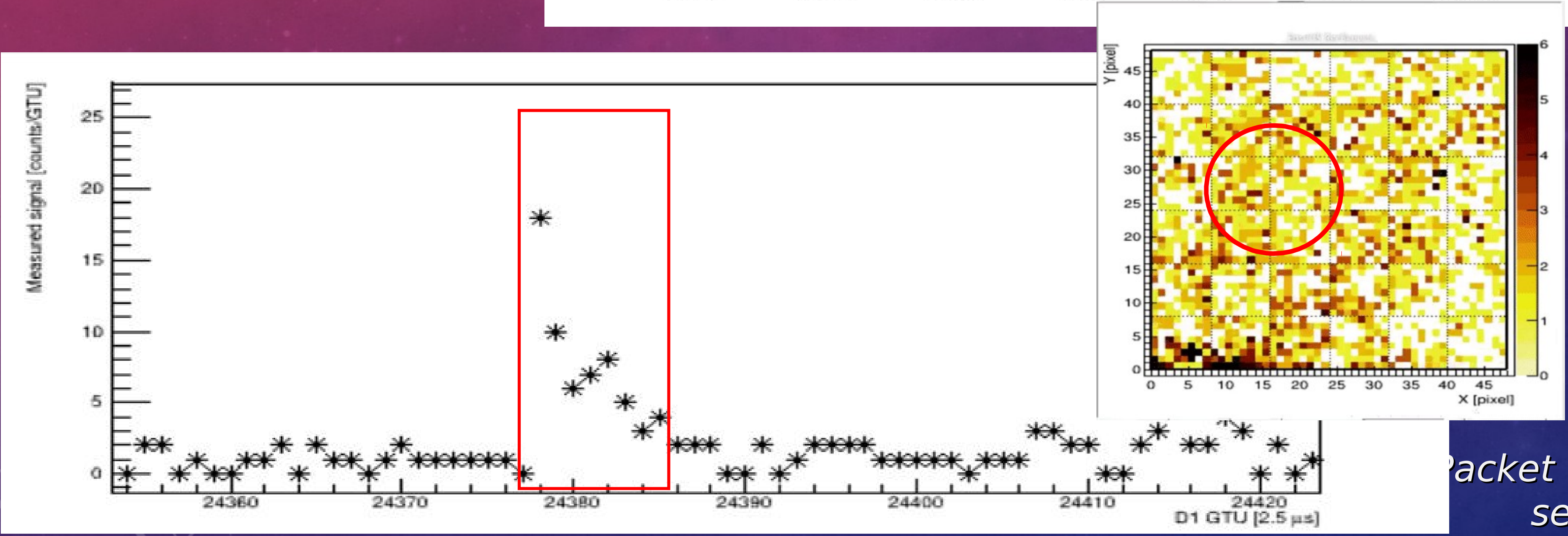
Mini-EUSO has a very low chance to see this kind of events. An ANITONS-like event is small and concentrated, and Mini-EUSO can detect limited photons/second.

Anitons candidate

We found 1-2 candidates per orbit (of events discarded)



Packet 50, orbit 1, session 16



Packet 190, last orbit, session 19

<u>If a candidate has the conditions required, it does not mean it is an aniton!</u>

These events could still be:

- Anthropogenic sources
- Electrical signal from a pixel
- Noise
- Clouds phenomena (as lightning)
- Direct cosmic ray

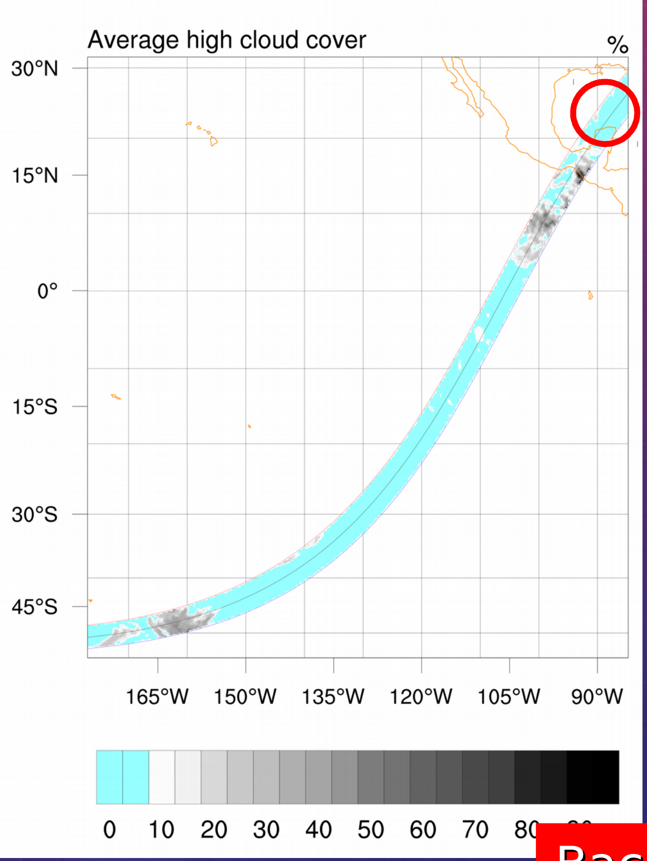
Clouds cover session 16-19(pa

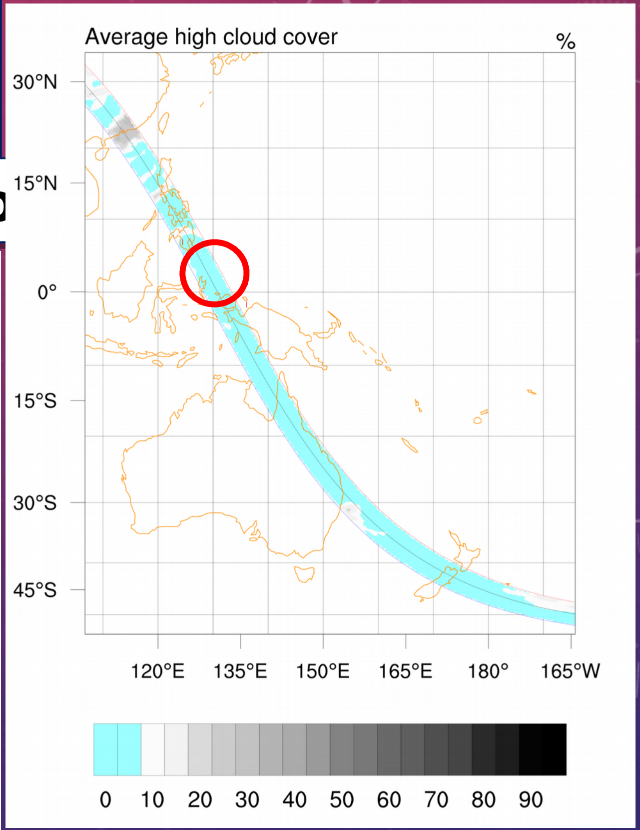
We checked the geographic location and the weather co

Two candidates of session 16-19

Far from cities and lights

Mostly on the sea (low background)





The high clouds coverage was low

Background level and threshold

Atmospheric phenomena research (lightning/flash)

Electrical noise and issues on the pixels

Further analysis required, in

CONCLUSIONS

What we observed:

- It's possibile to make a good estimation offline of the thresholds used by Mini-EUSO to detect the events.
- The code for detecting events can be modified to look for specific events in the actual data.
- First parameters gave few ANITONS candidates: it is necessary to analyse further in the data, considering weather/location/possible other sources.

What we can expect from the future:

- Instruments with higher resolution and higher double pulse resolution could see ANITONS-like events.
- ANITONS could result in a systematic ANITA error not a physical phenomena.
- JEM-EUSO launch and the first complete EECRs lab in space!

Thanks for your attention!

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