Analysis of Mini-EUSO data
Research of EAS-like events

Meteor Defence - 13 March 2023

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Extensive Air Shower (EAS)

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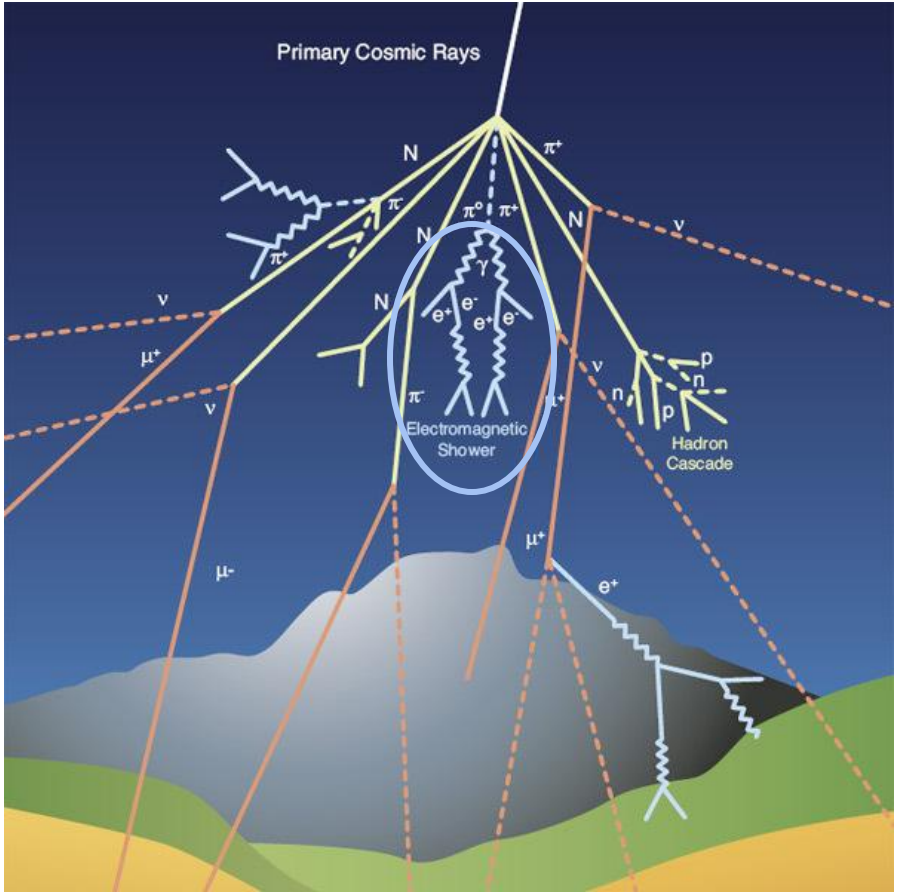
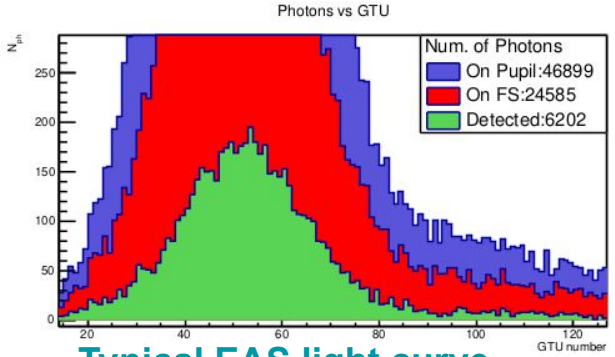


picture : CERN

Electromagnetic shower ~ 85% E_{shower}

Muons, Neutrinos ~ 15% E_{shower}

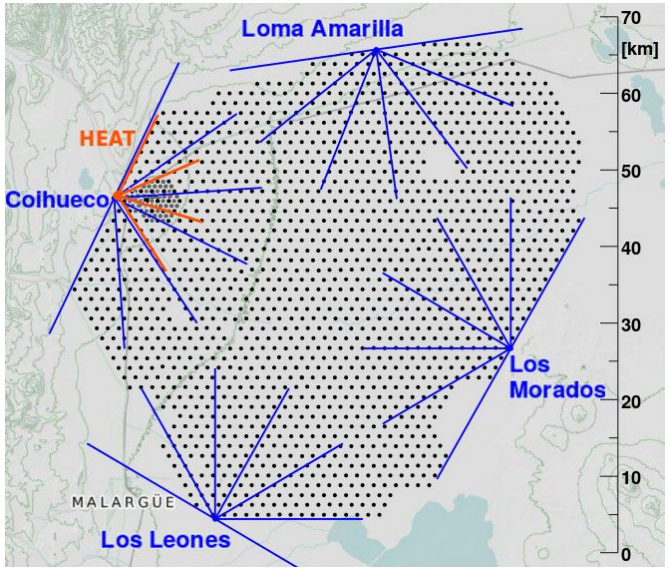
The **energy** of a **shower** can be estimated thanks to the **Electromagnetic shower**. The **electrons interact** with the N_2 in the **Atmosphere**. Those same N_2 **molecules** get in **excited state** and then **deexcite**, which is responsible of **fluorescence light.**



Typical EAS light curve

Observe the fluorescence light (from ground)

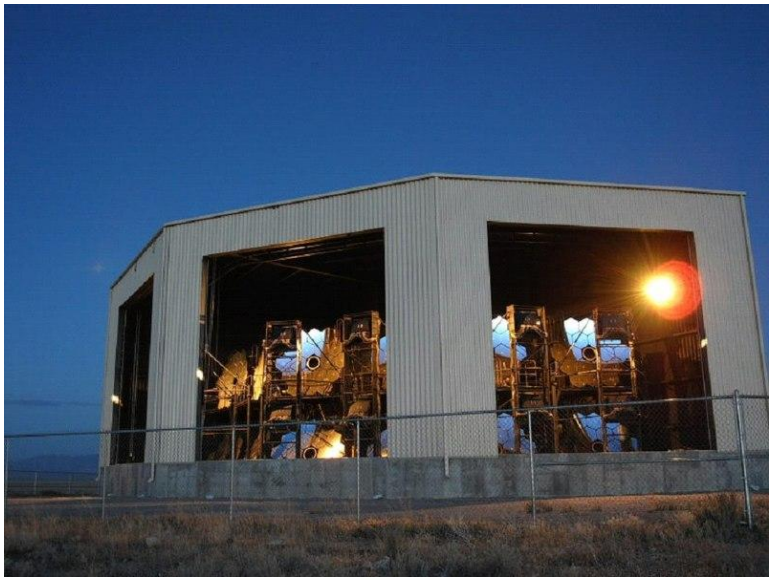
Pierre Auger observatory



Water tank

Fluorescence telescope

Telescope Array



Fluorescence Telescope of Telescope Array

Observe the fluorescence light (from ground)

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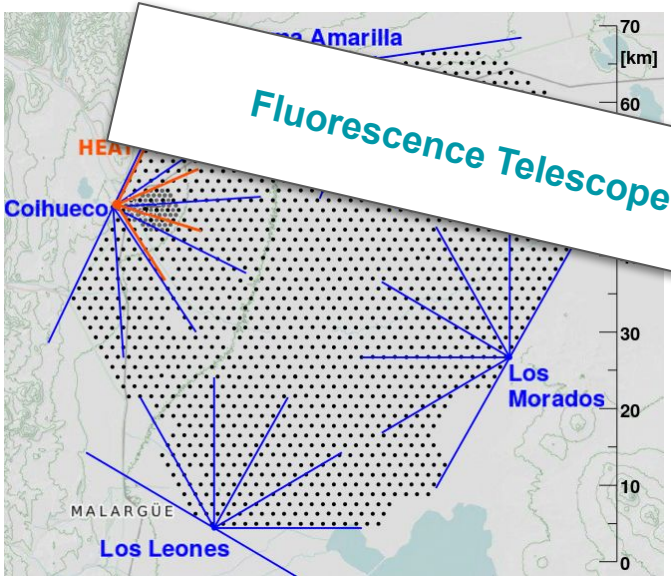


Water tank

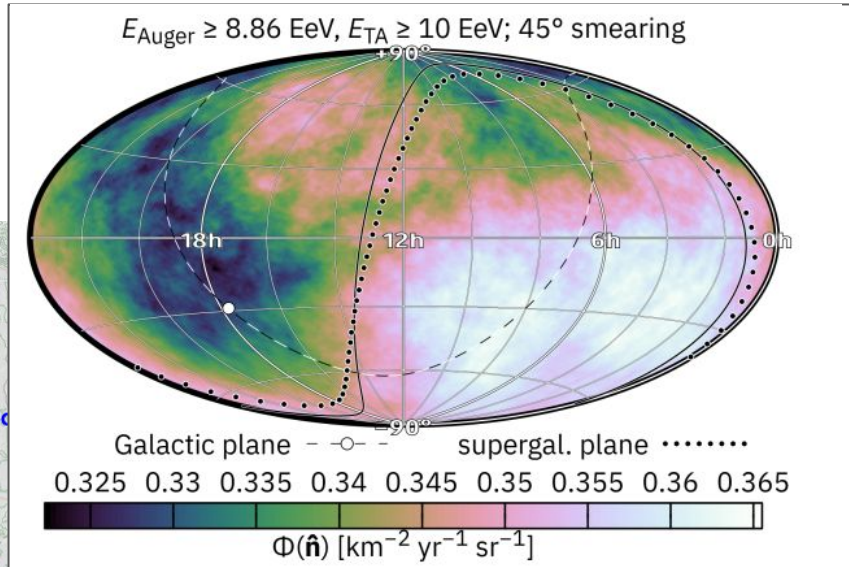
Fluorescence telescope

Telescope Array

Fluorescence Telescope of Telescope Array

Fluorescence Telescope can only operating only 10% of the time (Sun/Moon).

Observe the fluorescence light (from ground)

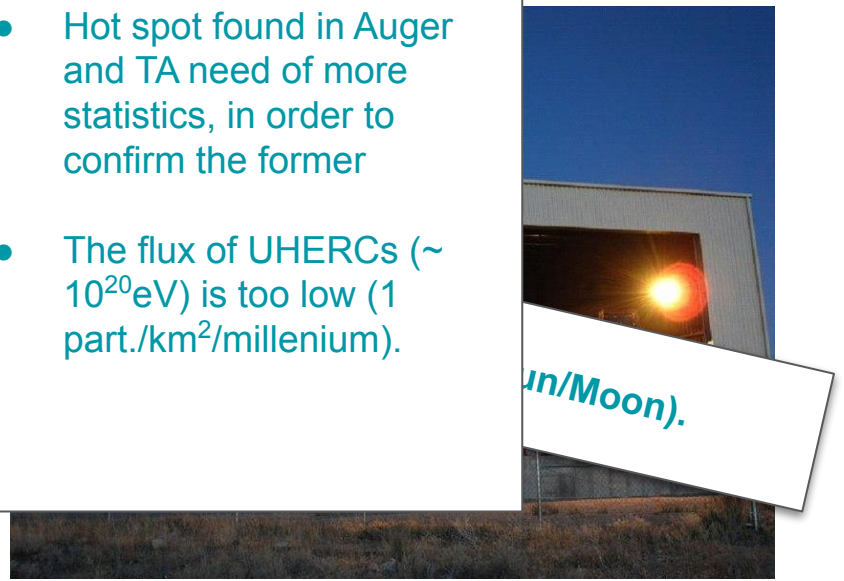


Di Matteo et al. 2019

- Issue with the energy calibration between TA and Auger.
- Hot spot found in Auger and TA need of more statistics, in order to confirm the former
- The flux of UHERCs (~ 10^{20}eV) is too low (1 part./km^2/millenium).

Water tank

Fluorescence telescope



Fluorescence Telescope of Telescope Array

JEM-EUSO program

JEM-EUSO program

Joint Experiment Missions for Extreme Universe Space Observatory program

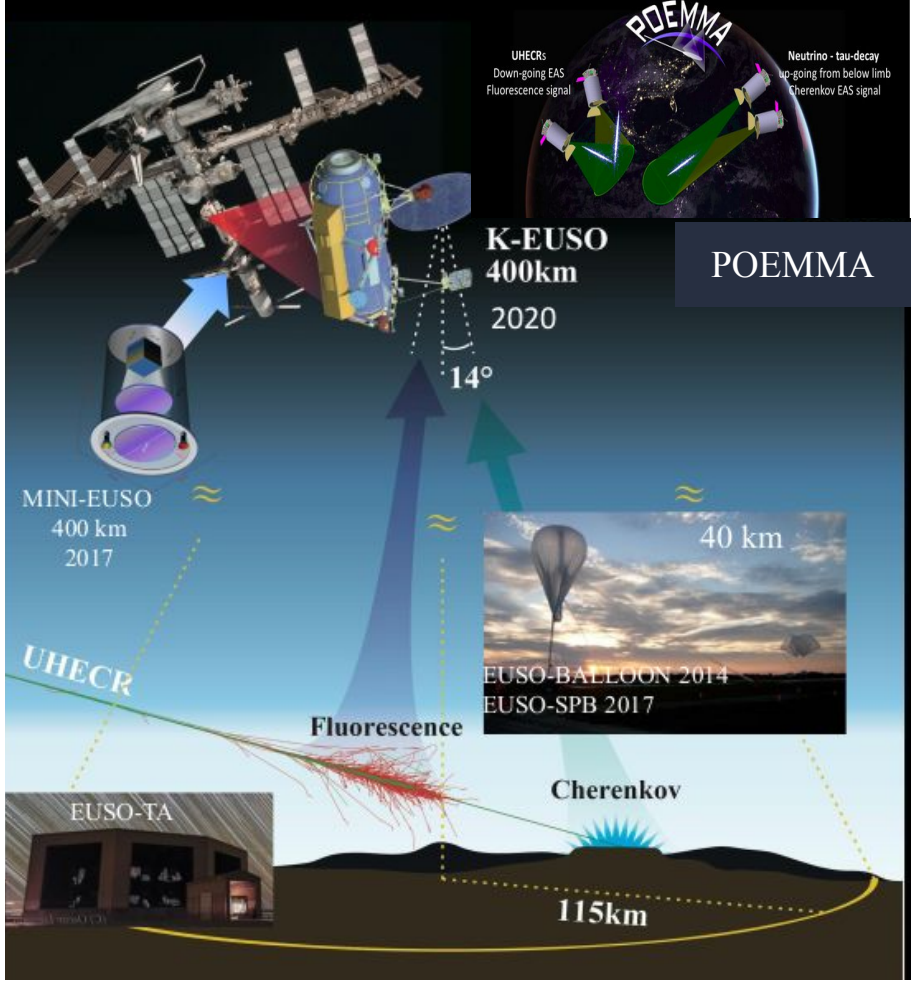
1. **EUSO-TA**:
   Ground detector installed in 2013 at Telescope Array site: currently operational

2. **EUSO-BALLOONS :**
   1st balloon flight from Timmins, CA (French Space Agency) Aug 2014; NASA Ultra long duration flight: 2017

3. **MINI-EUSO (2019):**
   Precursor from International Space Station. Lead by Italian and Russian Space agencies

4. **K-EUSO (?):**
   ISS. Approved by Russian Space Agency

5. **POEMMA (2030+):**
   NASA-sponsored concept study since 2018.



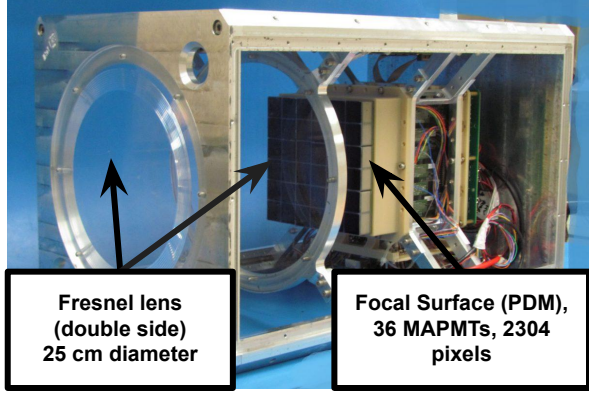
picture : Dr. Bertaina

Mini-EUSO

Multiwavelength Imaging New Instrument for the Extreme Universe Space Observatory

Mini-EUSO:

- launched on August 22 2019
- Cooperation between Italian Space Agency and Russian Space Agency
- **UV (300 - 400 nm) telescope on board of the ISS**
- **Objectives:**
  - Test the **validity** of **space observations of UHECRs**
  - **maps the UV background** produced by Earth **environnement** in **preparation** of **K-EUSO** and **POEMMA**
- **Energy threshold: 10^{21}eV**



picture : JEM-EUSO

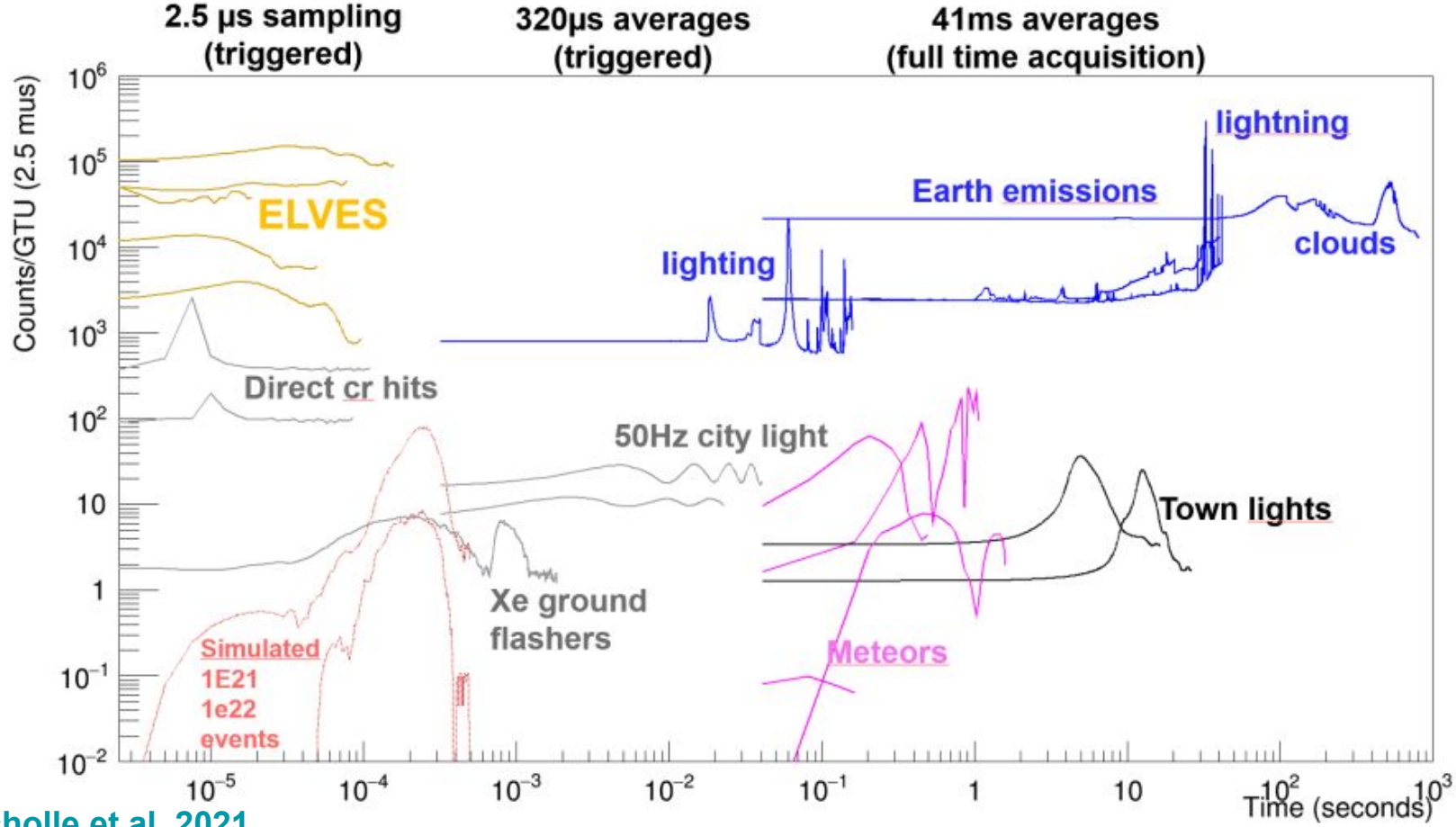
PDM: *Photo Detection module*

MAPMT: *Multi Anode Photo Multiplier Tubes*

Dimension	**37x37x62 cm^3**
Pixel number	**48x48 pixels, single photon counting**
Pixel footprint	**6.3x6.3 km^2**
Total footprint	**350x350 km^2**
FoV	**42°**
acquisition timescale	**2.5μs (D1), 320 μs (D2), 41 ms (D3)**

Mini-EUSO *acquiring data on board of the ISS, screwed to a window of ZVEZDA module.*

Mini-EUSO events zoo

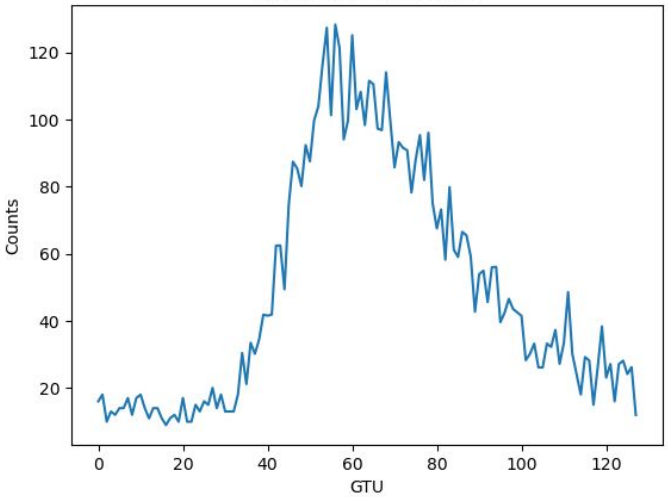


S. Bacholle et al. 2021

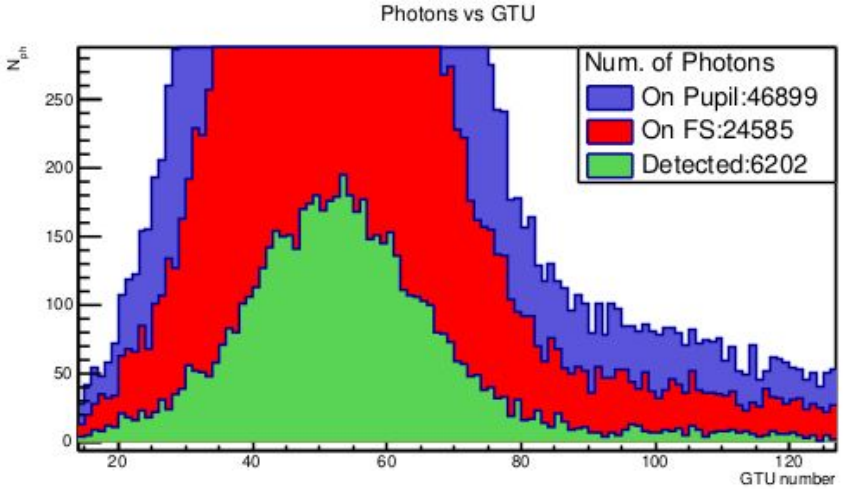
Project: Analysis of EAS-like events

EAS-like events

EAS-like events: are **brief** (t > ~0.2 ms) and **luminous** events happening in the upper part of the atmosphere, due to the shape of their **light curve** (**quick rise** and **exponential fall**) they can be **mistaken for EAS**.



Example of a EAS-like events' light curve



Example of a simulated EAS' light curve

* 1 GTU = 2.5 μs

Number of photons detected by Mini-EUSO

ESAF (EUSO Simulation and Analysis Framework)

ESAF can **simulate:**

- **EAS** and **particles interactions** with the **atmosphere**
- the **fluorescence** and **Cerenkov emission/reflection**
- **Mini-EUSO detector** (geometry,optics properties, PMTs quantum efficiency)

ESAF can **reproduce**:

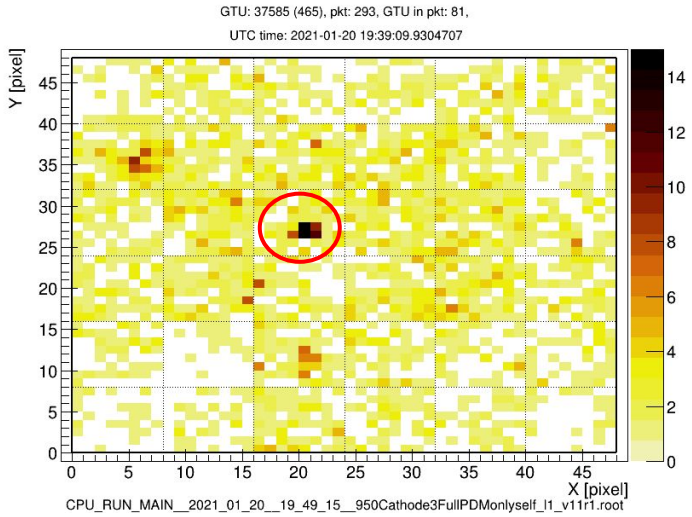
- The **footprint** of an **EAS** seen by **Mini-EUSO**
- The **light curve** of an **EAS**
- The **total number of photons produced** and **detected** by Mini-EUSO

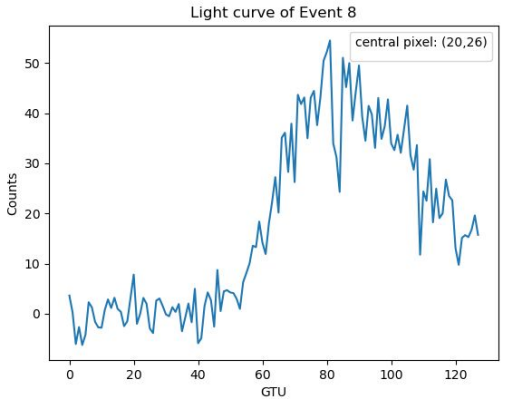
EAS-like events are not EAS

By **varying** the **inclination (θ)**, and the **Energy of the shower**:

- The **footprint** and the **maximum number of counts per pixel per GTU**
- The duration of the event (**shape of the light curve**)
- The total number of counts (**integral of the light curve**)

Total number of counts: 2152.1





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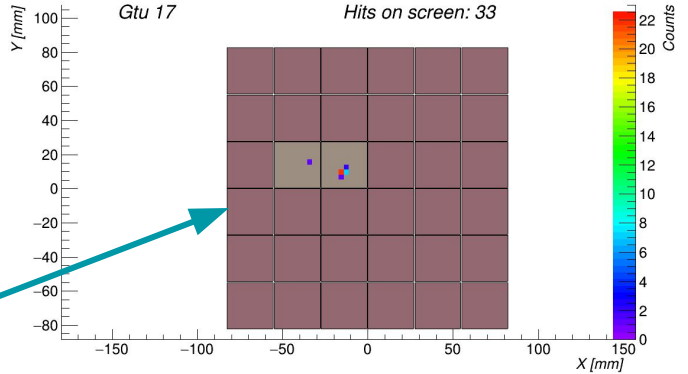
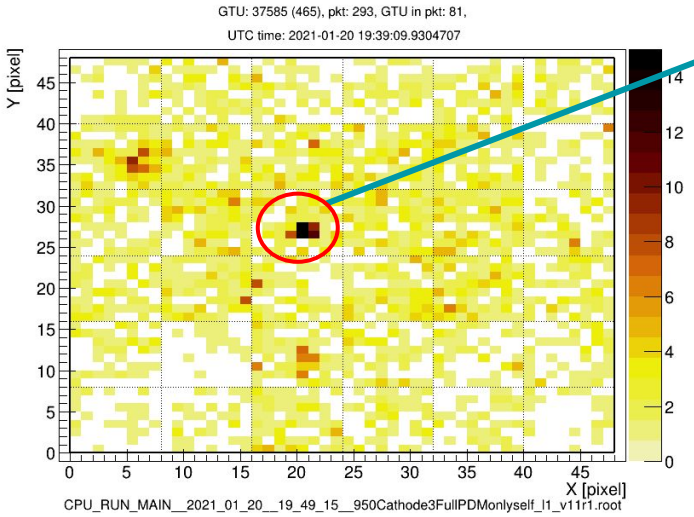
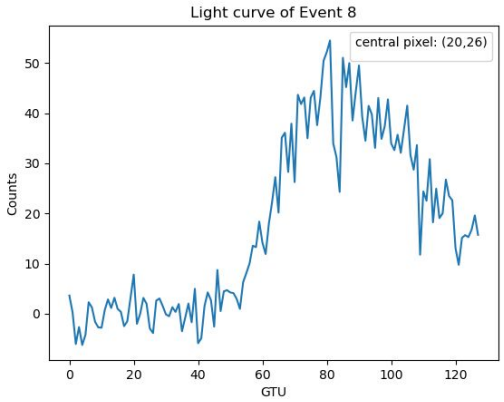


Footprint reproduction (θ= 0.41°, E= 1e22 eV)
(max counts/GTU/pixel = 23 counts)

Total number of counts: 2152.1





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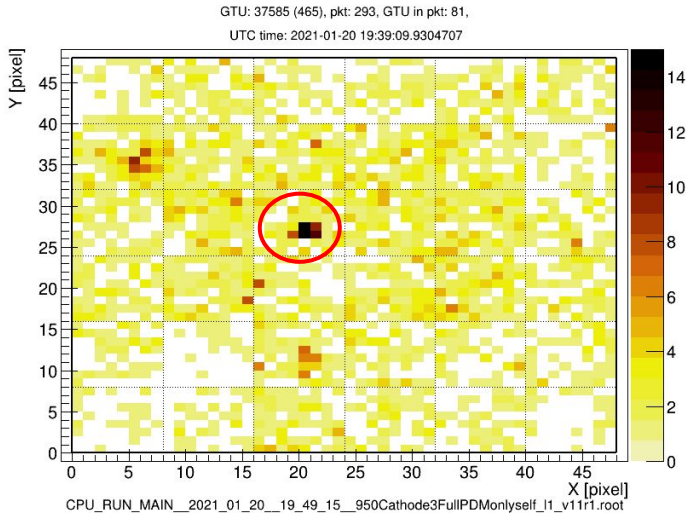

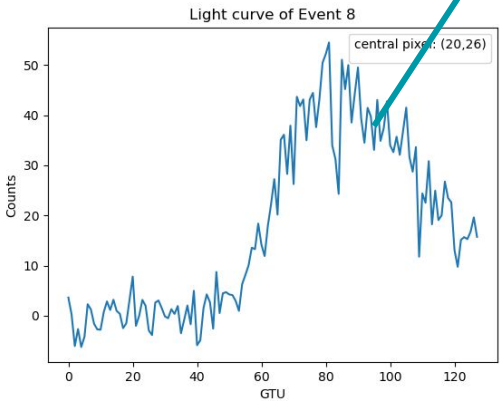

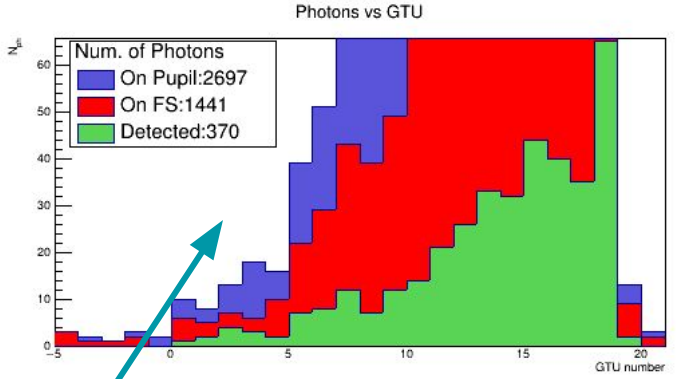

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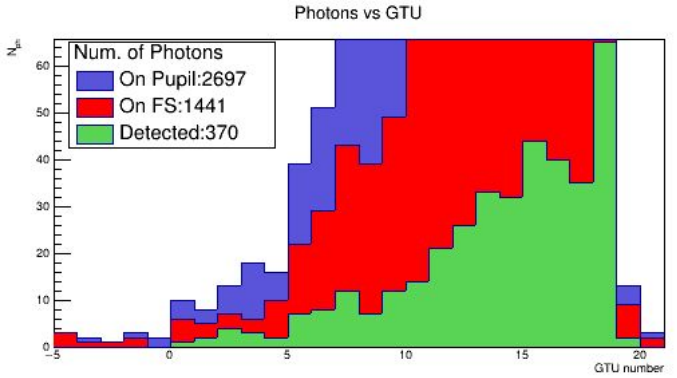

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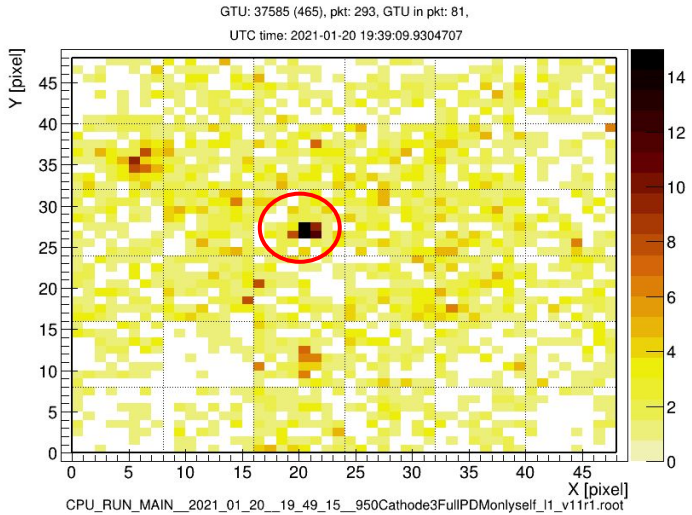

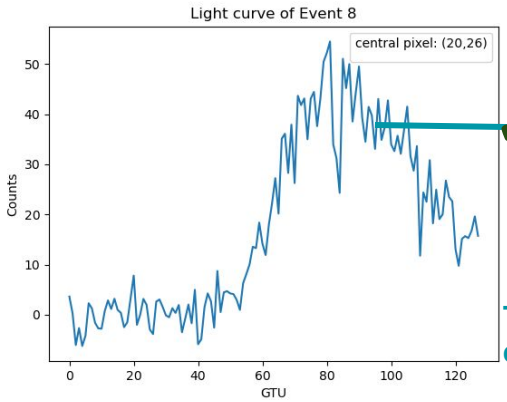

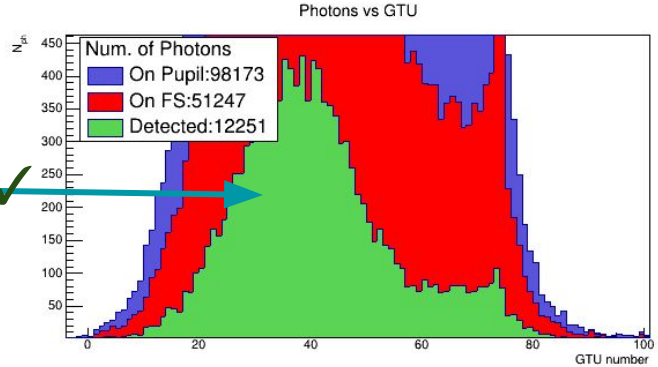

Total number of counts reproduction (θ= 70.32°, E= 1.3e22 eV)

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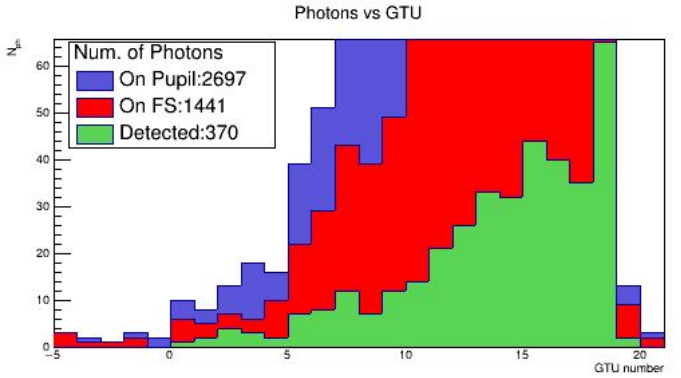

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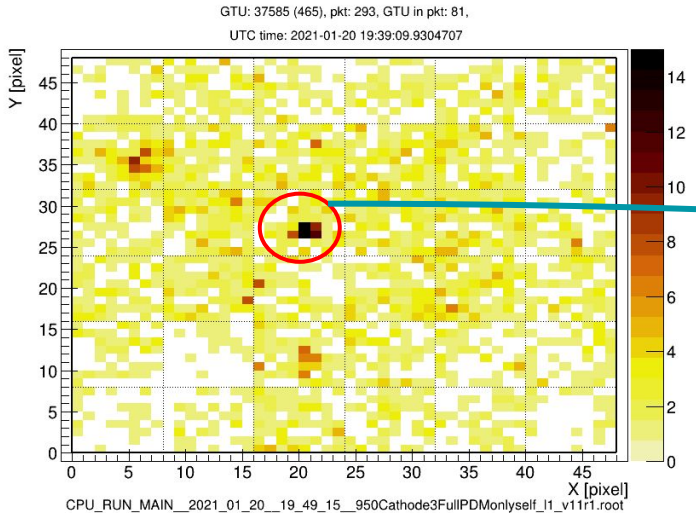

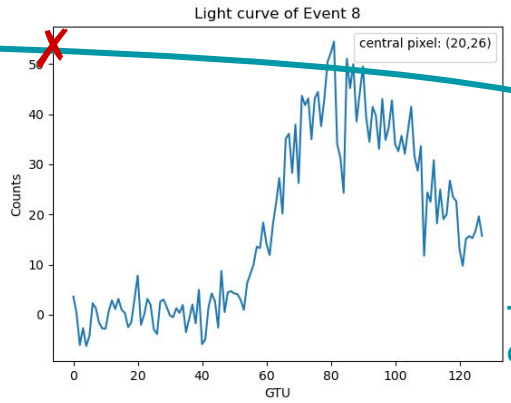

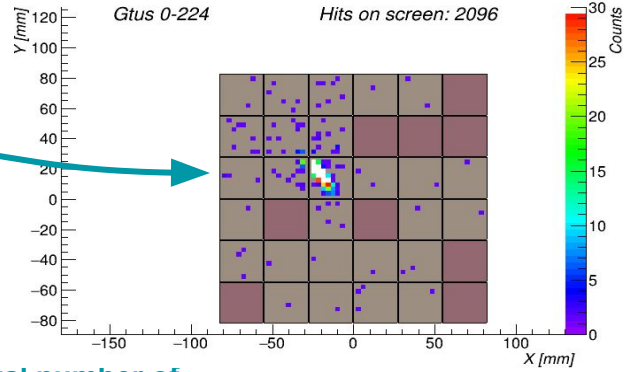

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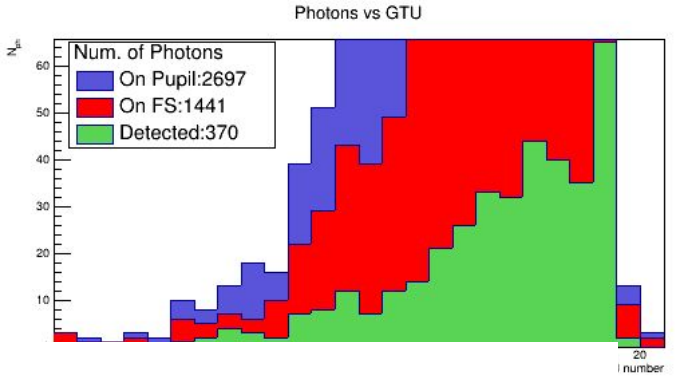
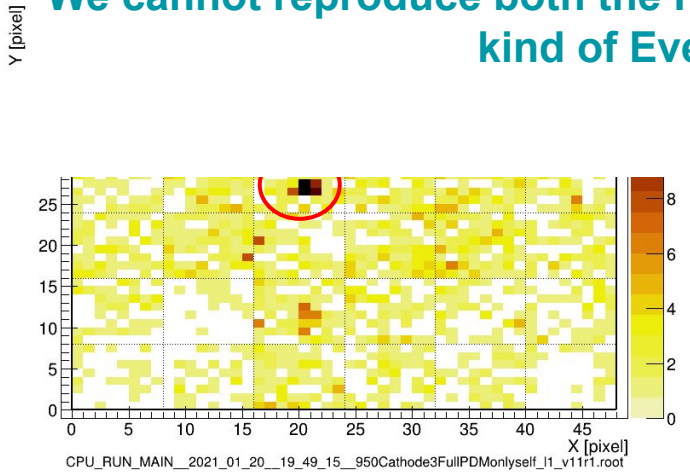
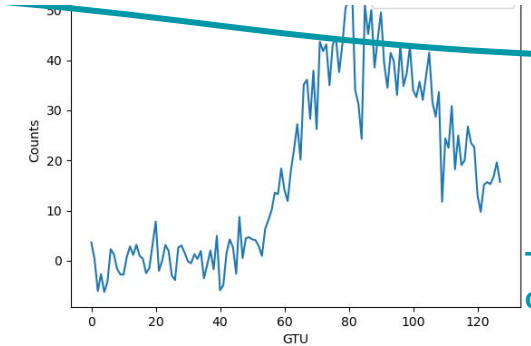


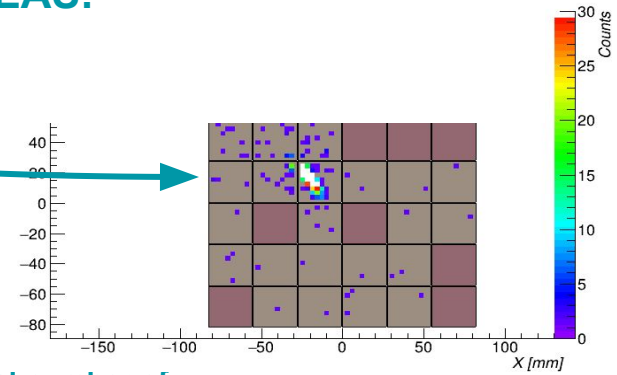
Tot

eV)

We cannot reproduce both the Footprint and the light curve of the Event. Hence, these kind of Events cannot be explained as EAS!







Total number of counts reproduction (θ= 70.32°, E= 1.3e22 eV)

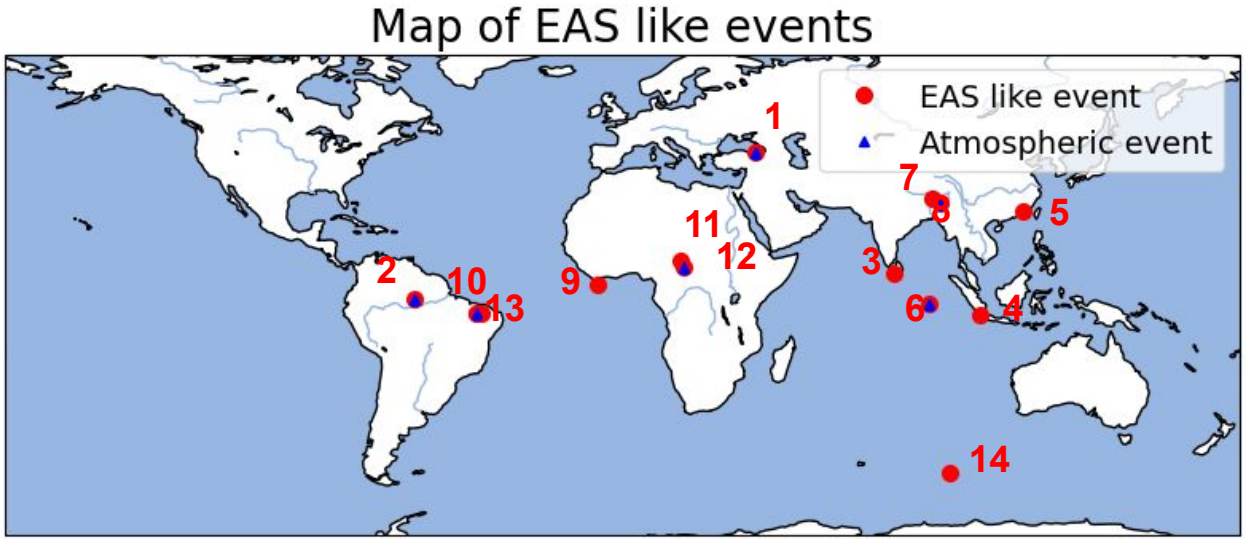
*** 1 GTU = 2.5 μs**

Position of EAS-like events

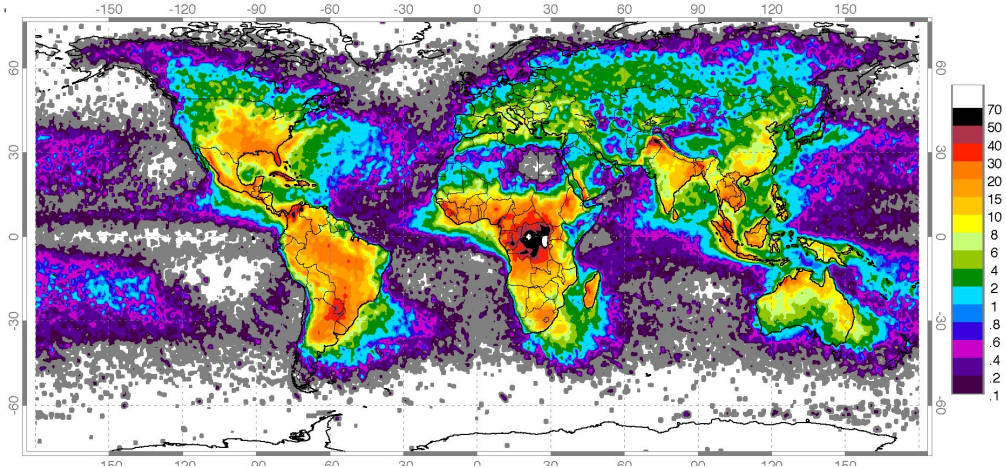
EAS-like events

The position of the EAS-like events with an uncertainty of 3 km (~ 2”).

Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lon	38.68	-60.39	79.22	104.3	116.6	89.19	90.39	92.71	-6.99	-40.93	16.78	18.05	-42.47	95.19
Lat	41.54	-1.22	6.08	-5.83	24.118	-2.57	27.62	26.55	2.73	-5.42	9.36	8.14	-5.35	-51.87



EAS-like events

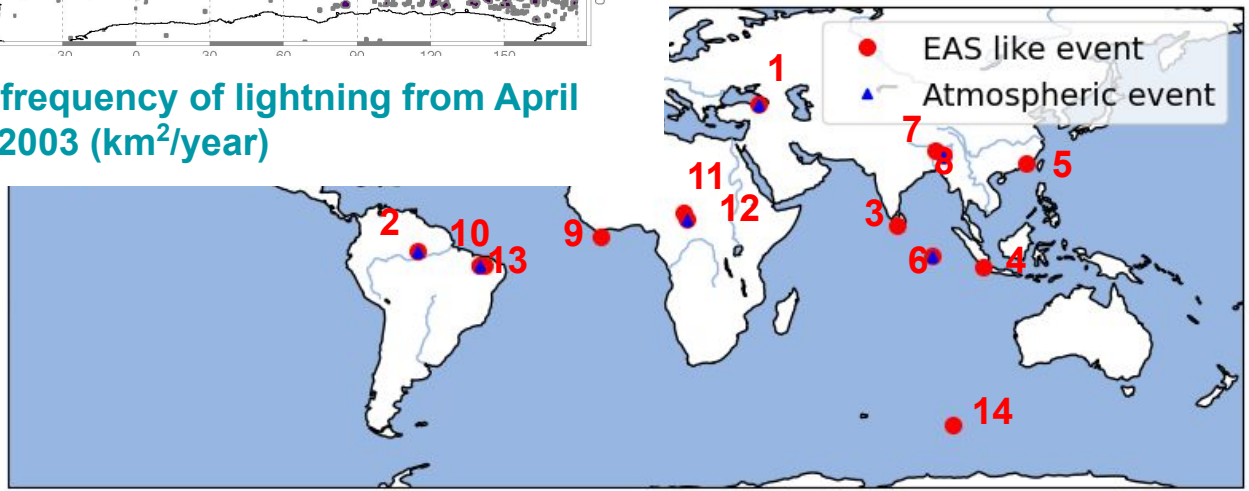


Map showing the frequency of lightning from April 1995 to February 2003 (km^2/year)

ertainty of 3 km (~ 2”).

8	9	10	11	12	13	14
92.71	-6.99	-40.93	16.78	18.05	-42.47	95.19
26.55	2.73	-5.42	9.36	8.14	-5.35	-51.87

ke events



EAS-like events

First conclusion:

- **Arguments toward an atmospherical explanation of EAS-like events**
  - Most events are located in **region** where **lightning** are **very common.**
  - More than **half of them (8/14)** are **followed** by an **atmospheric events** observed by **Mini-EUSO**.
  - Most of them are constrained within the **tropics,** in **tropical rainforest climate region**.

Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lon	38.68	-60.39	79.22	104.3	116.6	89.19	90.39	92.71	-6.99	-40.93	16.78	18.05	-42.47	95.19
Lat	41.54	-1.22	6.08	-5.83	24.118	-2.57	27.62	26.55	2.73	-5.42	9.36	8.14	-5.35	-51.87
followed by an atmospheric event	✓	✓	✗	✓	✗	✓	✗	✓	✗	✗	✓	✓	✓	✗

Are EAS-like events point like sources?

Point like source criterion

We know from fact that a point like source seen by Mini-EUSO has 50% of its light focus in one pixel.

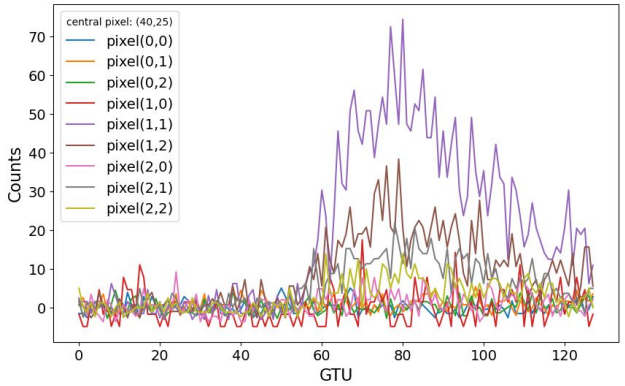
Aim:

- Have an idea of the **size** of **EAS-like events** (size of a pixel **6.3x6.3 km^2**).
- Are they **steady** or **propagating** in the atmosphere (see some **apparent movement** or **extension**)?

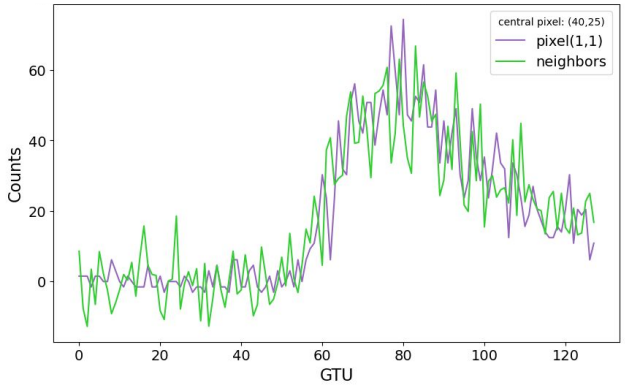
method:

- **define** for each event a **central pixel**
- **define a 3x3 mask**

central pixel
neighbors pixels

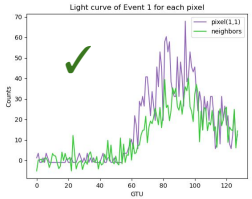


light curve of each pixel of the 3x3 mask

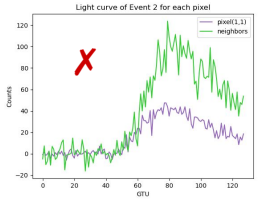


central pixel's light curve compare to neighboring pixels

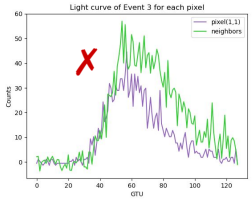
EAS-like events



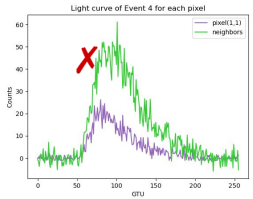
EAS-like event 1



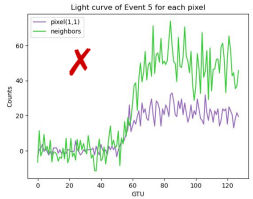
EAS-like event 2



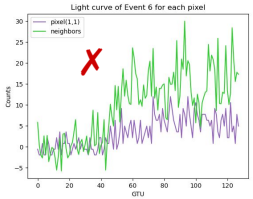
EAS-like event 3



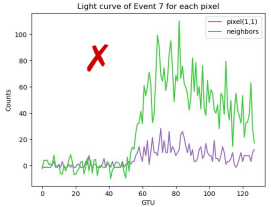
EAS-like event 4



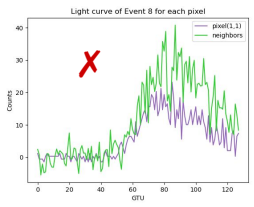
EAS-like event 5



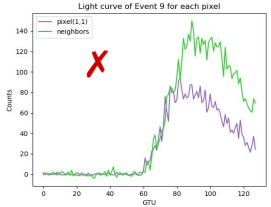
EAS-like event 6



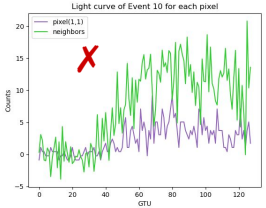
EAS-like event 7



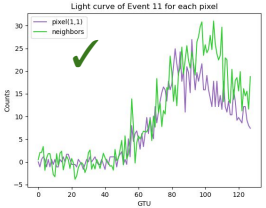
EAS-like event 8



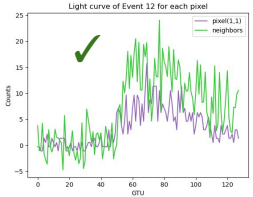
EAS-like event 9



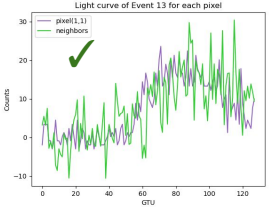
EAS-like event 10



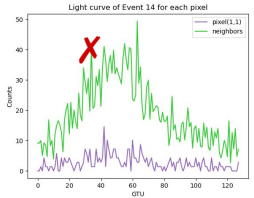
EAS-like event 11



EAS-like event 12



EAS-like event 13



EAS-like event 14

4/14✓ ~ 28.5%

central pixel

neighbors pixels

EAS-like events (conclusion)

Second conclusion:

- Only **4 EAS-like events** met the **criterion,** so we conclude that they might the sources might be of the **size of few km**. Moreover we can note that there is a wide variety of **light curves**, which could explained by the fact that the **sources** might be **differents**, and that **different phenomena** could **cause EAS-like events**.
- **No increase** of a **pixel to another** (**no propagation observed**).

Conclusions and Prospects

Conclusion:

- We may have find a new kind of transient atmospheric phenomenon(>0.2 ms), that may have never been seen before, as Mini-EUSO is the only one that can observed such phenomena (spatial, temporal resolution, lowest threshold).

Prospect:

- Developed a new data analysis to study further those events, classify them.
- POEMMA with its spatial resolution 100 times smaller than the one of Mini-EUSO, could show us the structure of EAS-like events, and maybe open to a new physics of transient atmospheric events.

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The Blue Marble (Earth), NASA/Apollo 17 crew: https://en.wikipedia.org/wiki/Earth#/media/File:The_Blue_Marble_(remastered).jpg

Extensive Air Shower (EAS), Cern: https://home.cern/science/physics/cosmic-rays-particles-outer-space

Mini-EUSO picture 1: https://www.jemeuso.org/missions/mini-euso/

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Neubert T., Østgaard N., Reglero V., Blanc E., Chanrion O., Oxborrow C.~A., Orr A., et al., 2019, arXiv, arXiv:1906.12178. doi:10.48550/arXiv.1906.12178

Chanrion O., Neubert T., Lundgaard Rasmussen I., Stoltze C., Tcherniak D., Jessen N.~C., Polny J., et al., 2019, SSRv, 215, 28. doi:10.1007/s11214-019-0593-y

Østgaard N., Balling J.~E., Bjørnsen T., Brauer P., Budtz-Jørgensen C., Bujwan W., Carlson B., et al., 2019, SSRv, 215, 23. doi:10.1007/s11214-018-0573-7

Appendix

Are EAS-like events atmospheric precursors?

ASIM

The **Atmosphere-Space Interactions Monitor (ASIM)** is an instrument suite on Columbus module of the ISS. This instrument was made for measurements of **lightning**, **Transient Luminous Events (TLEs)** and **Terrestrial Gamma-ray Flashes (TGFs)**.

"*Instruments are an **x- and gamma-ray monitor (MXGS)** measuring photons from 15 keV to 20 MeV, and an array of three **photometers and two cameras (MMIA)** measuring in bands at: 180–250 nm, 337 nm and 777.4 nm*"

Torsten Neubert et al. 2019

Nasa ID: iss057e055411

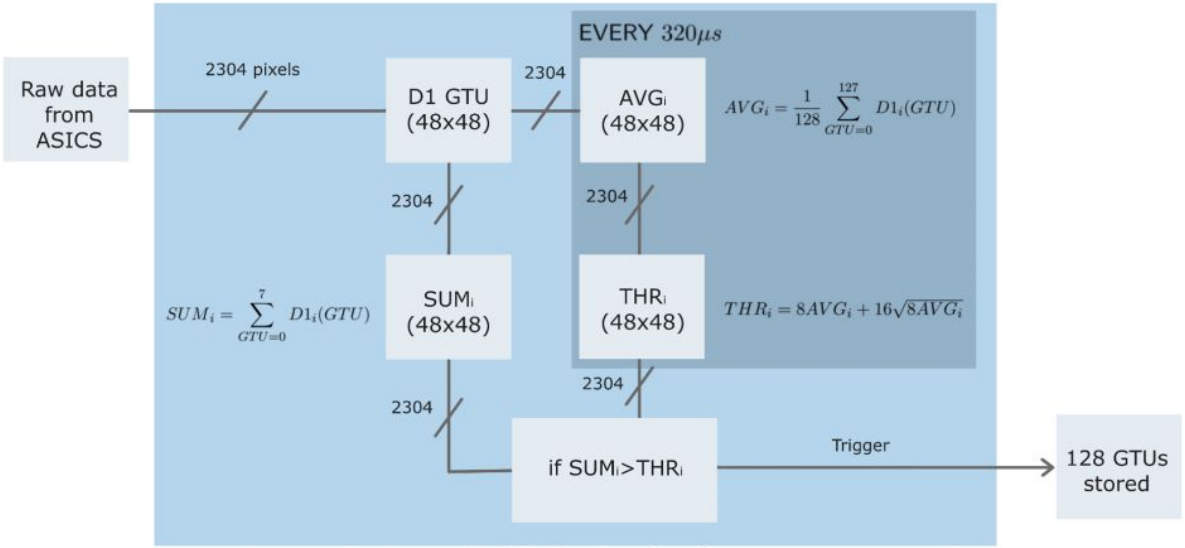
Conclusion about the cross match ASIM/Mini-EUSO

Second conclusion:

- **Few correlation between ASIM and Mini-EUSO events (4/14)**
  - We discard trigger made with MMIA which have a high **$\Delta t_{MXGS\text{-}Mini\_EUSO}$, because MMIA can trigger a lots of in few seconds (~ 35 light./s). Moreover MMIA has FoV (80°) which is much bigger than the one of Mini-EUSO (42°). Hence, It can trigger in region out of Mini-EUSO FoV.**
  - For **MXGS (LED and HED) triggers** are, at least, **30s** apart from the **EAS-like events**, which is way **too long**.
  - **Possible explanation: Mini-EUSO** observed **phenomena** that **have never been seen before** due to **Mini-EUSO time resolution and energy threshold.**

Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$\Delta t_{MMIA\text{-}Mini\_EUSO}$ (s)	…	…	62.838	0.165	17.761	…	…	1.478	19.556	…	…	…	…	…
$\Delta t_{MXGS\text{-}Mini\_EUSO}$ (s)	…	…	62.688	0.008	17.918	…	…	1.635	19.557	…	30.298	31.700	31.057	…
Trigger MXGS	…	…	LED	MMIA	MMIA	…	…	MMIA	MMIA	…	LED	HED	LED	…
followed by an atmospheric event	✓	✓	✗	✓	✗	✓	✗	✓	✗	✗	✗	✓	✓	✗

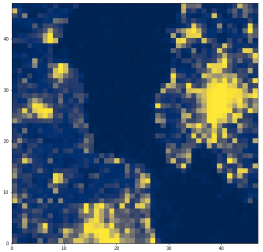
Mini-EUSO trigger logic

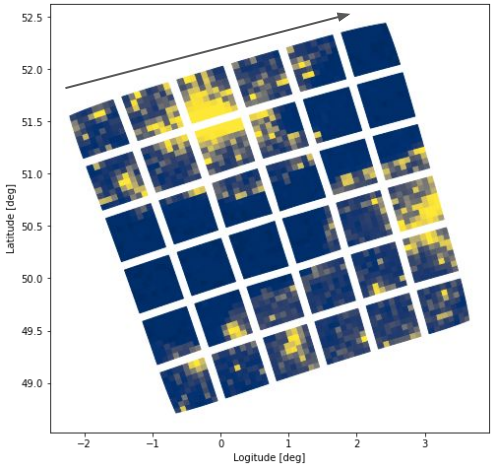


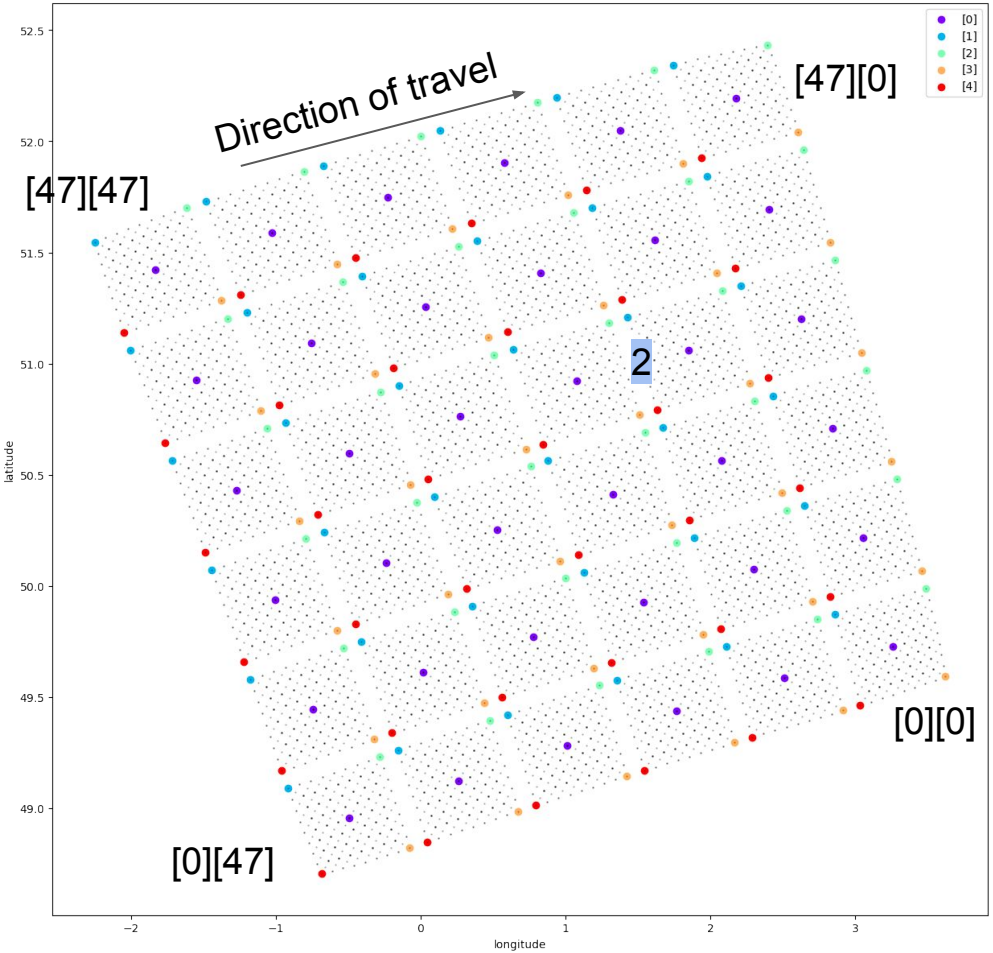
D1 trigger logic

How we found the position of EAS-like events?

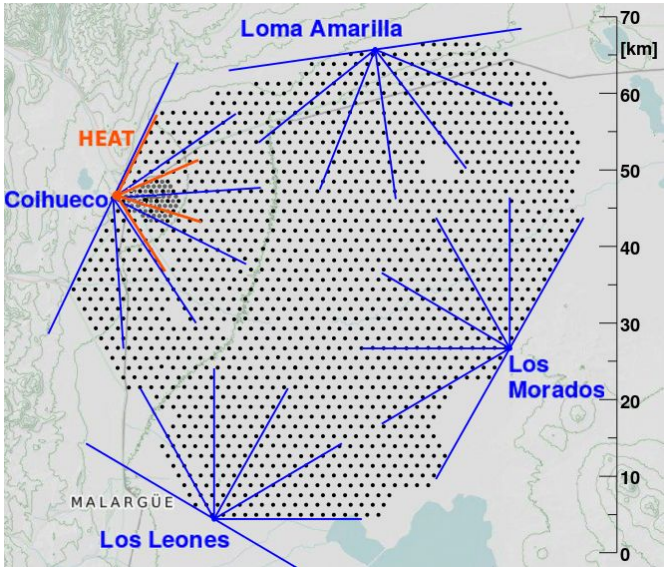
```
pmt_geo_surf
[ccb][pdm][x][y][corner][component]
[1]  [1]  [6][6][5]     [3]
```







Why Mini-EUSO cannot observed EAS (E ~ 10^{21}eV)



Integrated exposure: 122 000 km^2/sr/year
Most energetic event recorded: 1.66e20 eV

Integrated exposure: less than 4 300 km^2/sr/year
Energy Threshold: ~ 1e21 eV

ASIM

The Atmosphere-Space Interactions Monitor (ASIM) is an instrument suite on Columbus module of the ISS. This instrument was made for measurements of lightning, Transient Luminous Events (TLEs) and Terrestrial Gamma-ray Flashes (TGFs).

"ASIM goal:
– To conduct a comprehensive global survey of TLEs and TGFs covering all local night
times and seasons
– To secure data for understanding the fundamental kinetic processes of TLEs and TGFs
– To understand the relationship of TLEs and TGFs to lightning activity"
Torsten Neubert et al. 2019

"*Instruments are an x- and gamma-ray monitor measuring photons from 15 keV to 20 MeV, and an array of three photometers and two cameras measuring in bands at: 180–250 nm, 337 nm and 777.4 nm*"
Torsten Neubert et al. 2019

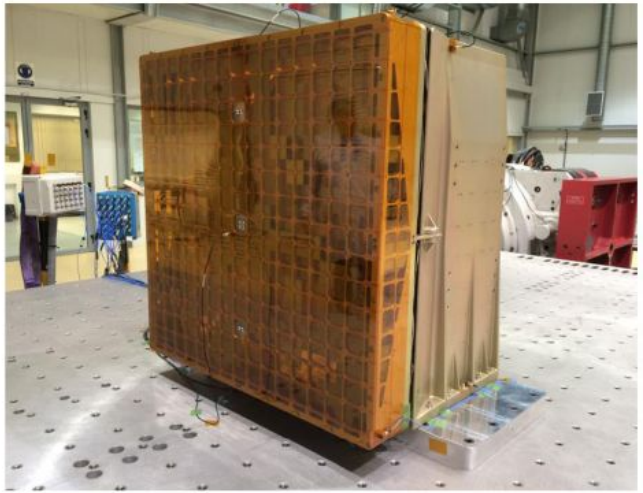
Nasa ID: iss057e055411

If we saw a correlation between Mini-EUSO and ASIM, then we could have discovered some precursor to atmospheric events that never had been observed before due to the fact that Mini-EUSO is the only instrument observing directly the atmosphere in the UV with high temporal resolution (2.5μs).

The Modular X- and Gamma-ray Sensor (MXGS)

MXGS	LED	HED
Geometrical area (cm^2)	1024	900
Energy range	15–400 keV	200 keV–20 MeV
Energy resolution	< 10% @ 60 keV	< 15% @ 662 keV
Angular resolution point source	< 0.7°	
Relative time accuracy	10 µs	10 µs
Sensitivity (signal/noise)	> 7	> 15

Torsten Neubert et al. 2019



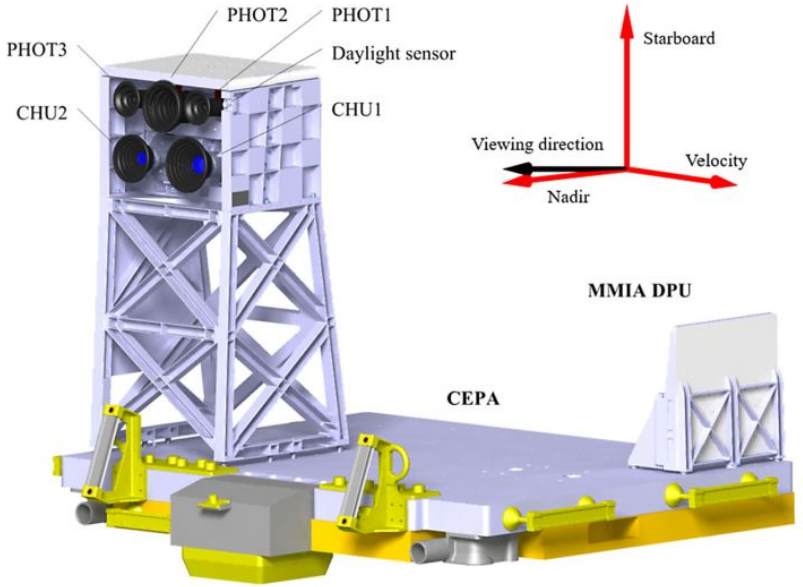
Nikolai Østgaard et al. 2019

LED: low energy detector
HED: high-energy detector

The Modular Multispectral Imaging Array (MMIA)

MMIA	Cameras	Photometers
FOV (nadir) diagonal/diameter	80°	80°
Pixels	1024 × 1024	
Spatial resolution (ground)	400–500 m	
Temporal resolution	83 ms	10 µs
Relative time accuracy	10 µs	10 µs
Spectral bands (nm) (center/width)	CA1: 337/5	PH1: 337/5
		PH2: 180–230
	CA2: 777.4/3	PH3: 777.4/5
Sensitivity (ph/m^2/s)	CA1: 3.2×10^6	PH1: 1.5×10^{12}
Flux at aperture		PH2: 6.9×10^{12}
(CA1, 2 single pixel)	CA2: 4.2×10^7	PH3: 2.2×10^{12}

Torsten Neubert et al. 2019

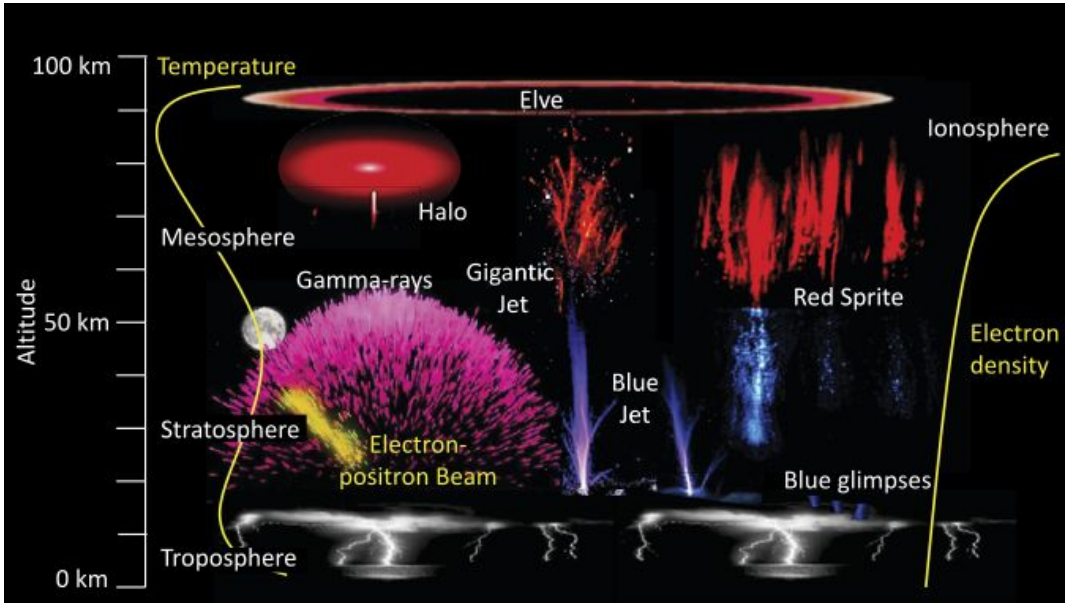


Olivier Chanrion et al. 2019

"For example, the transmission from the thunderstorm cloud tops at 15 km altitude is below ~ 0.001% in 180–230 nm. At 337 nm it is ~ 75% from 15 km altitude and ~ 50% from 10 km altitude (Neubert and Chanrion 2010)."

Torsten Neubert et al. 2019

TLEs and TGFs

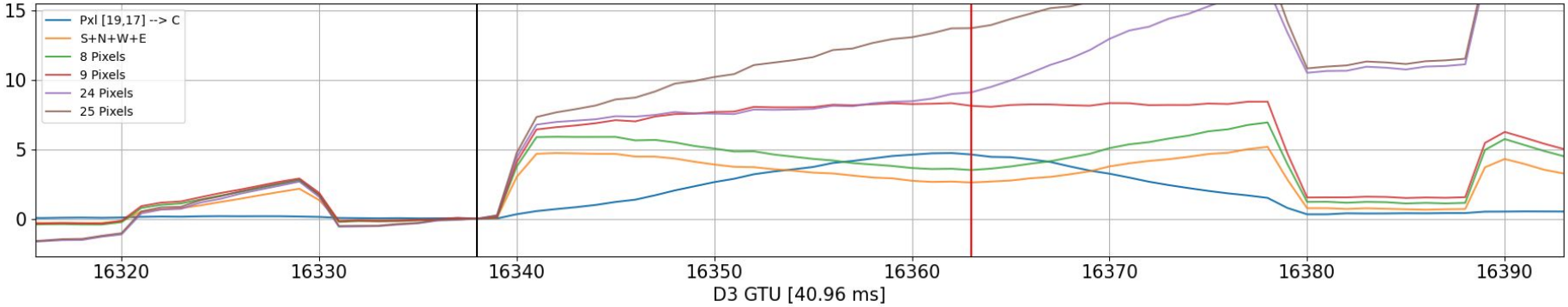


Transient Luminous Events (TLEs): TLE is the common name for glimpses of light in the stratosphere and mesosphere above thunderstorms. They include electrical discharges such as sprites, jets and gigantic jets, and luminous excitation of the atmosphere such as the elves. (MMIA)

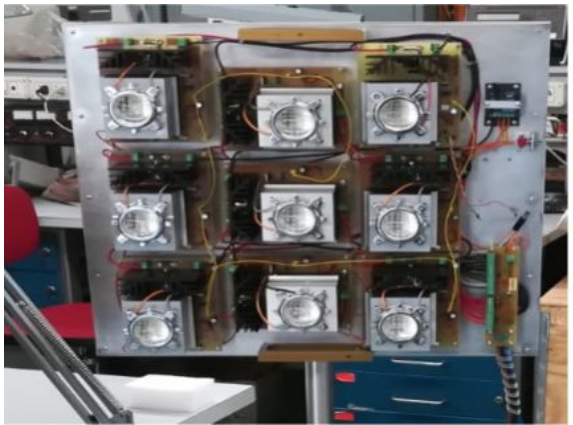
Terrestrial Gamma-ray Flashes (TGFs): TGFs are bursts of bremsstrahlung from energetic particle beams accelerated in thunderstorm processes.

Torsten Neubert et al. 2019

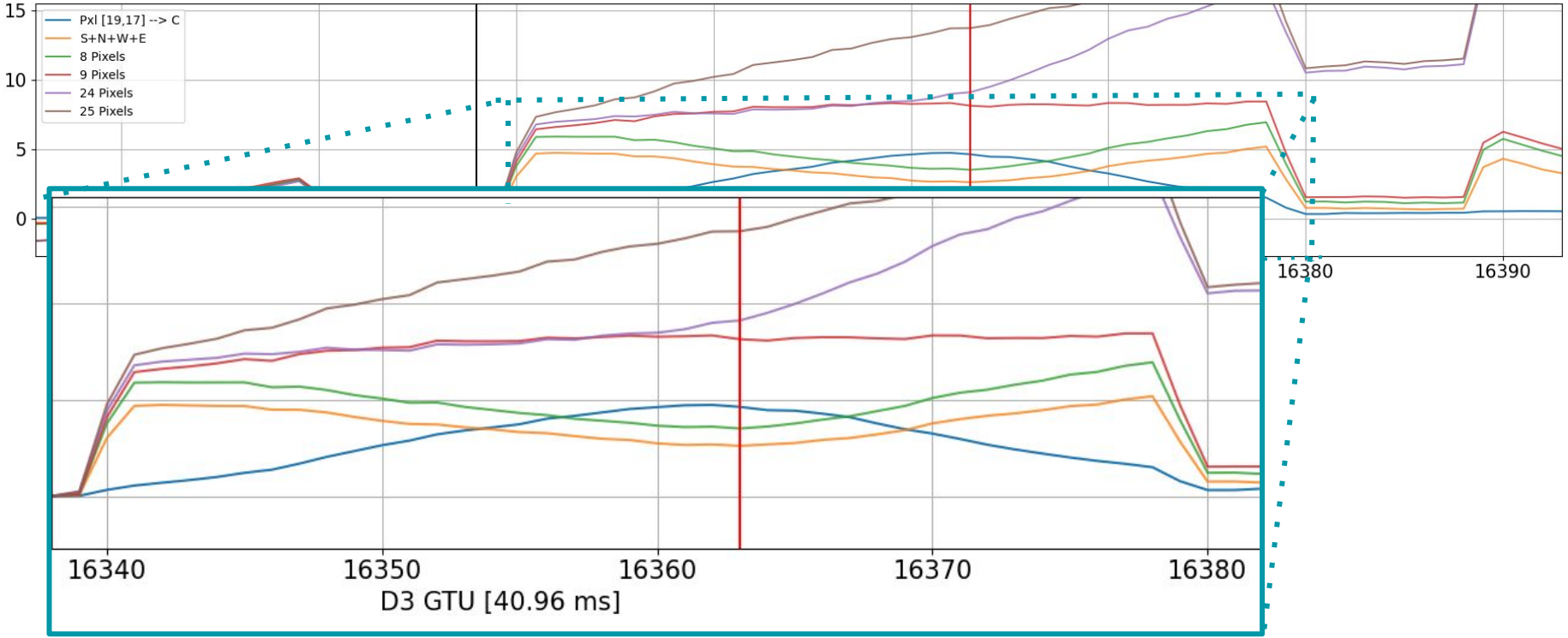
Flasher (Point like source?)



29-30 October 2022, Tuscany, flasher attempt



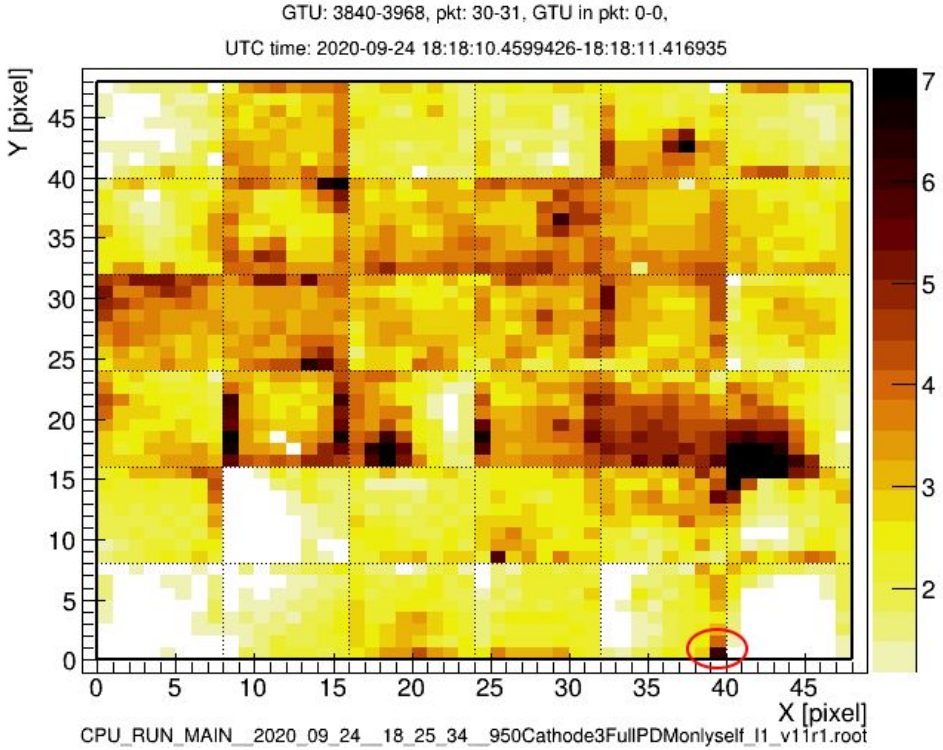
Flasher (Point like source?)



In case of a point like source more than 50% of the light should be focused in the central pixel.

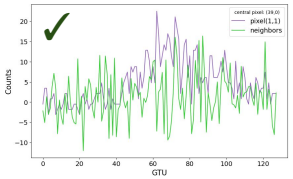
Flasher

Session 26, orbit 2, packet 30-60

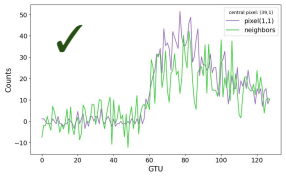


location: in middle of field (Saratov Oblast, next to Aleksashkino)

Flasher's light curve



packet 30



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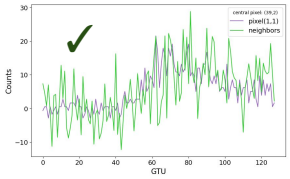

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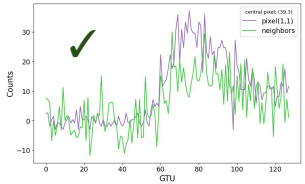

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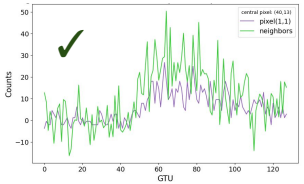

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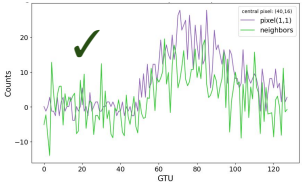

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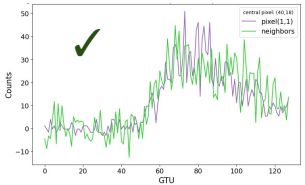

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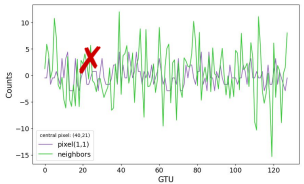

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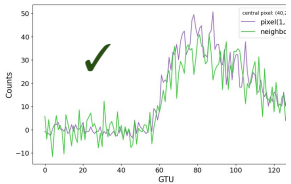

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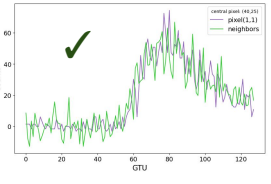

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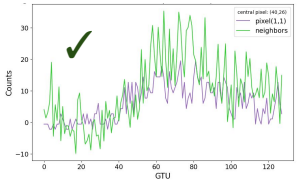

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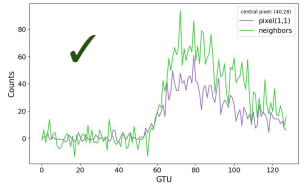

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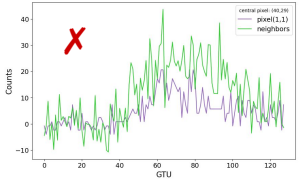

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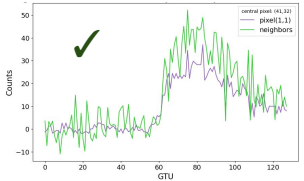

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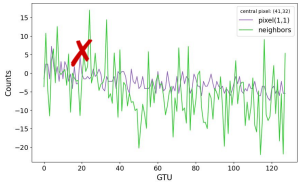

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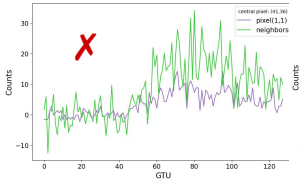

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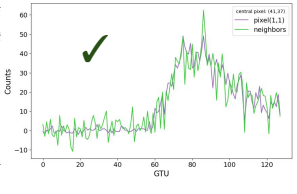

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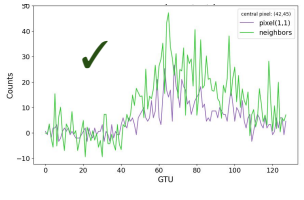
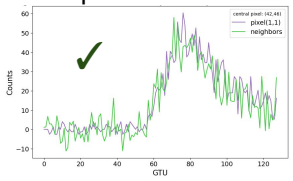


packet 59



packet 60

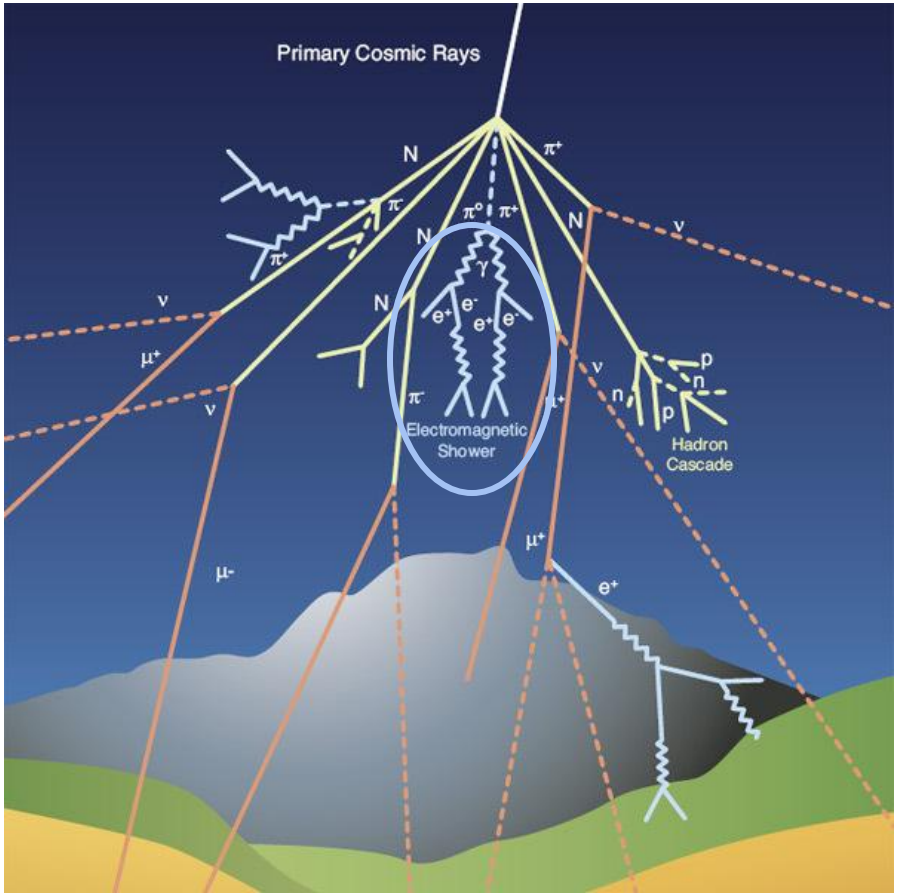
15/19✓ ~ 79%

central pixel
neighbors pixels

Summary

- Cosmic Rays (CR) and Extensive Air shower (EAS)
- JEM-EUSO program
- Mini-EUSO
- Project: Analysis of EAS-like events
- EAS-like events
- ESAF
- Are EAS-like events atmospheric precursors ?
- Conclusions and prospect

Extensive Air Shower (EAS)



picture : CERN

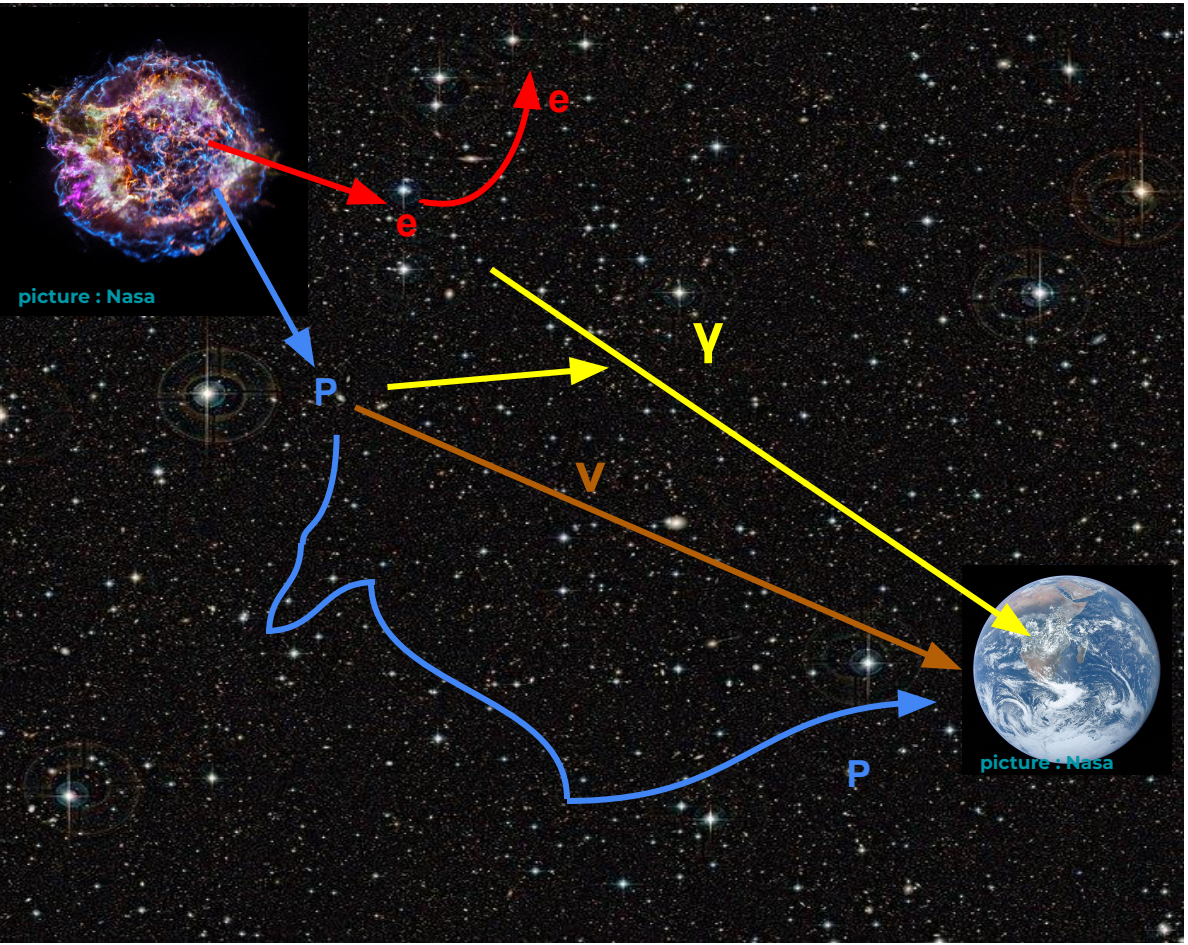
Electromagnetic shower ~ 85% E_{shower}

Muonic component ~ 15% E_{shower}

The number of electrons and muons is characteristic of a specific primary (cosmic ray). For a given energy the EAS caused by a proton will be composed of fewer photons than the one made out of muons. Thanks to this knowledge, one can estimate the primary by looking at the number of muons (**mass composition**).

$$log(N_\mu) \propto log\left(\frac{E}{A}\right)$$

Cosmic Ray (CR)

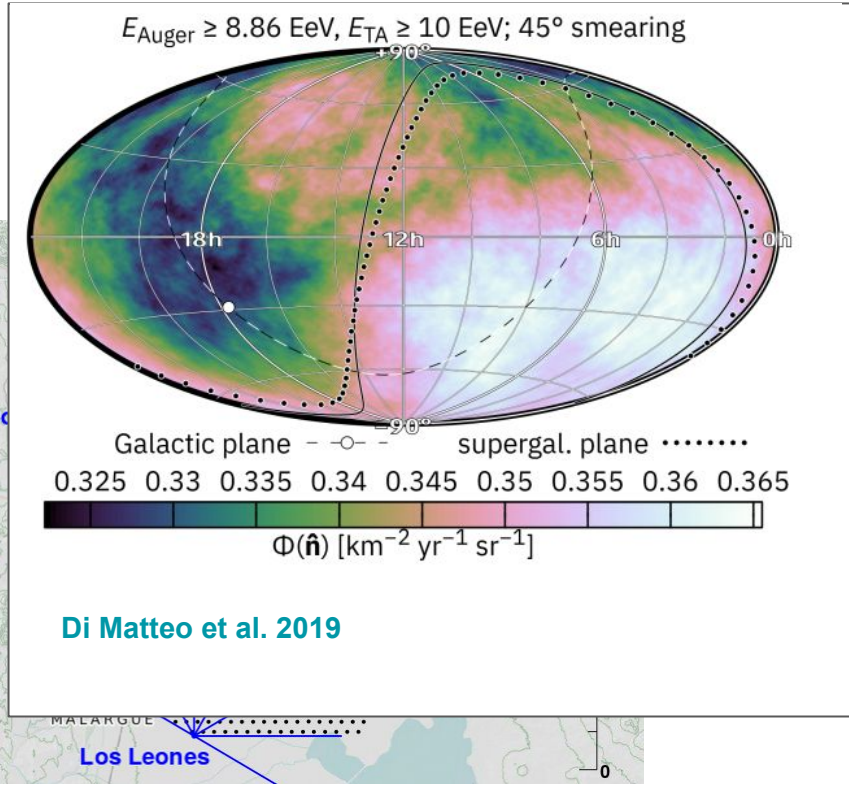


Cosmic rays: nuclei of various chemical elements, produced in astrophysical environments like supernovae, that propagate through galactic and extra-galactic space.

Due to their charge they can be deflected during their propagation, due to the presence of strong Magnetic fields in galactic and inter-galactic medium.

sources: SuperNovae Remnant (SNR), Active Galactic Nuclei (AGN), etc.

Observe the fluorescence light (from ground)



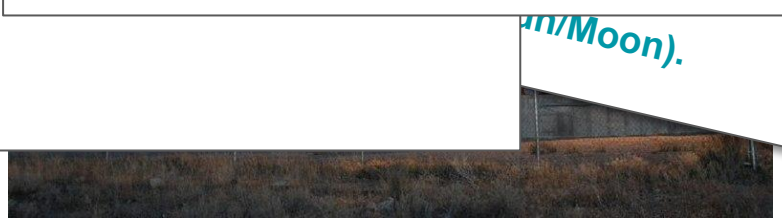
Di Matteo et al. 2019

By going to space, we could enhance the statistics,operate longer and and cover both North and south, and thus avoiding any energy calibration issues.

Main effect: Increase the exposure and the chance to detect UHERCs with an energy which is higher than 10^{20}eV.

Water tank

Fluorescence telescope

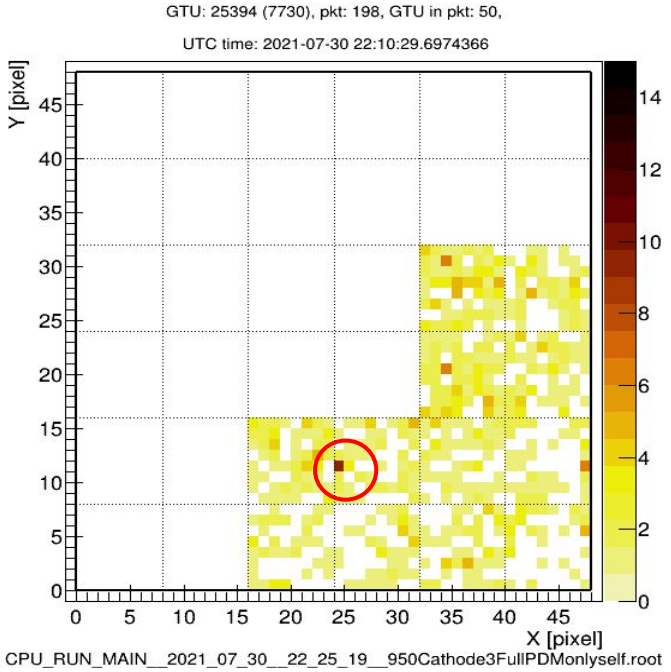


Fluorescence Telescope of Telescope Array

Correlation with observation made by ASIM

EAS like events (12/15) - “ Tchad 2” - Session 43, orbit 3, packet 198
(followed by an atmospheric event)

- Mini-EUSO observation:
  - D3 time: 2021-07-30 22:14:13.1148527
  - Presence of a cloud coverage
  - followed by an atmospheric event
- Correlation found:
  - **no trigger found with MMIA*** :
  - **1 trigger with MXGS** :
    - 2021-07-30 22:14:44.814364 HED



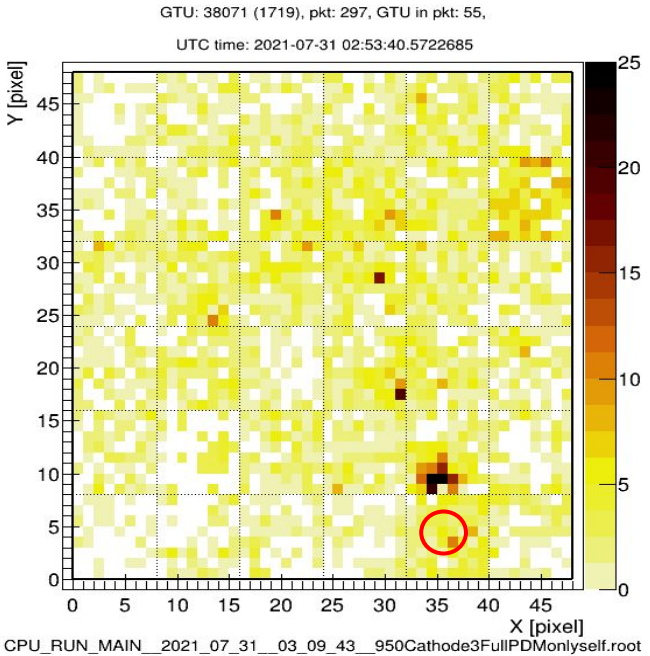
*** MMIA seems off for this session**

This event is followed by an atmospheric events 1 GTU after (2021-07-30 22:14:14.425575 **)**

Correlation with observation made by ASIM

EAS like events (13/15) - “ North Brasil 1 ” - Session 43, orbit 6, packet 297 (followed by an atmospheric event)

- Mini-EUSO observation:
  - D3 time: 2021-07-31 02:57:23.27934
  - Presence of a cloud coverage
  - followed by an atmospheric event
- Correlation found:
  - **no trigger found with MMIA*** :
  - **1 trigger with MXGS** :
    - 2021-07-31 02:56:52.221924 LED



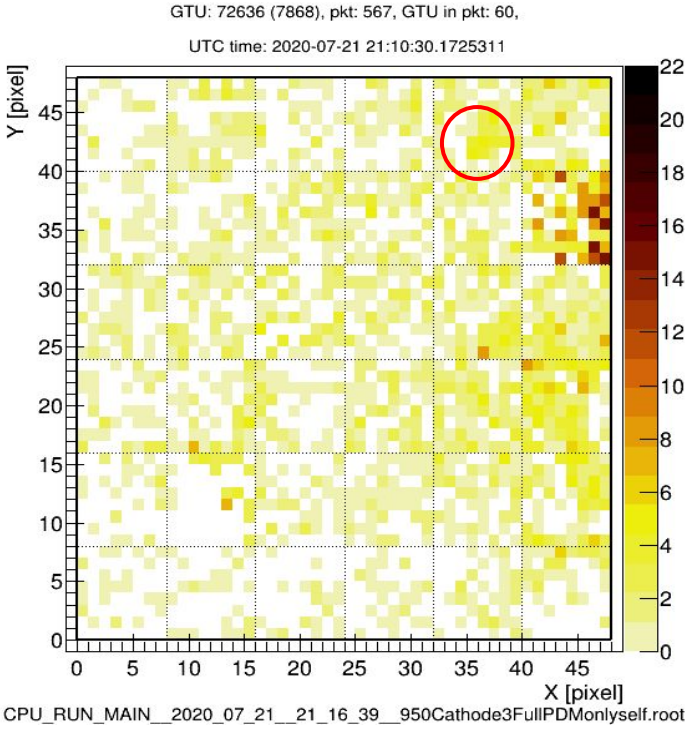
*** MMIA seems off for this session**

This event is followed by an atmospheric events 1 D3 GTU after (2021-07-31 02:57: 23.27934**)**

Correlation with observation made by ASIM

EAS like events (4/15) - “ Indonesian coast ” -Session 20, orbit 2, packets 567 - 568

- Mini-EUSO observation:
  - D3 time: 2020-07-21 21:11:23.6147003
  - Presence of a cloud coverage
- Correlation found:
  - **1 trigger with MMIA** :
    - 2020-07-21 21:11:23.448772 Lightning
  - **1 trigger with MXGS** :
    - 2020-07-21 21:11:23.606662 MMIA

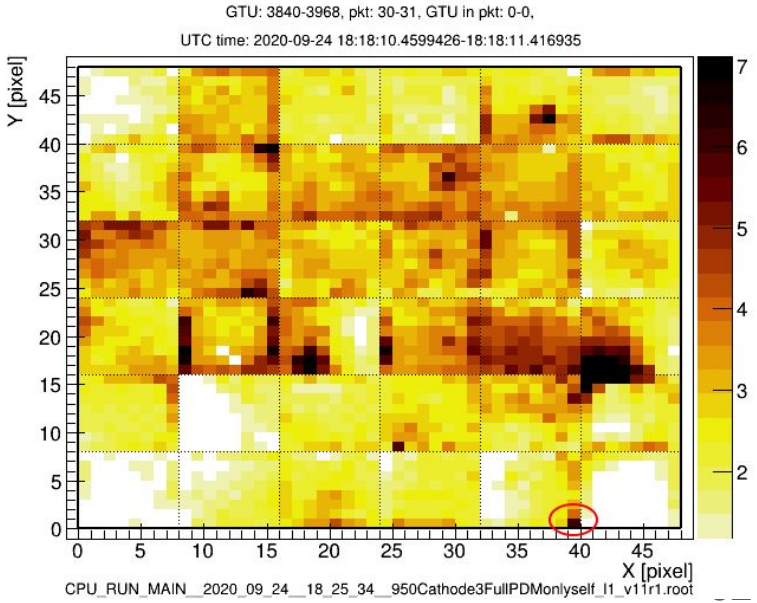


On D3 GTU a lightning strike is observed outside the FOV

Flasher

sources:

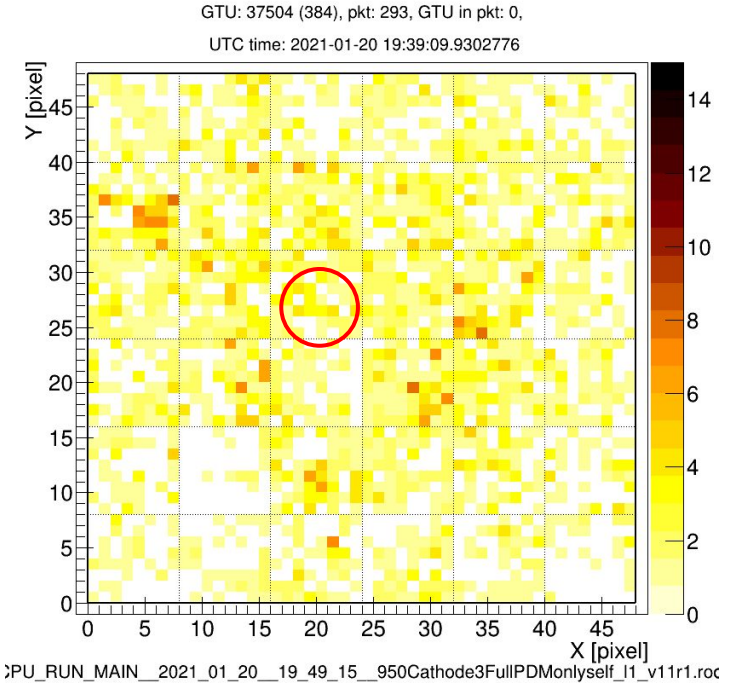
- ground sources(go through the Mini-Euso FOV at ISS speed (7.7 km/s))
- possible sources type (related to an airport, to indicate the landing runaway or control tower)



Correlation with observation made by ASIM

EAS like events (8/15) - “ India, river Brahmaputra ” - Session 33, orbit 2, packet 293
(possible precursor of an atmospheric event)

- Mini-EUSO observation:
  - D3 time: 2021-01-20 19:39:15.1634963
  - After, ~ 0,1ms this event is followed by an atmospheric event at the same position than the EAS-like event
  - Presence of a cloud coverage
- Correlation found:
  - **1 trigger with MMIA** :
    - 2021-01-20 19:39:16.641650 Lightning
  - **1 trigger with MXGS** :
    - 2021-01-20 19:39:16.798864 MMIA

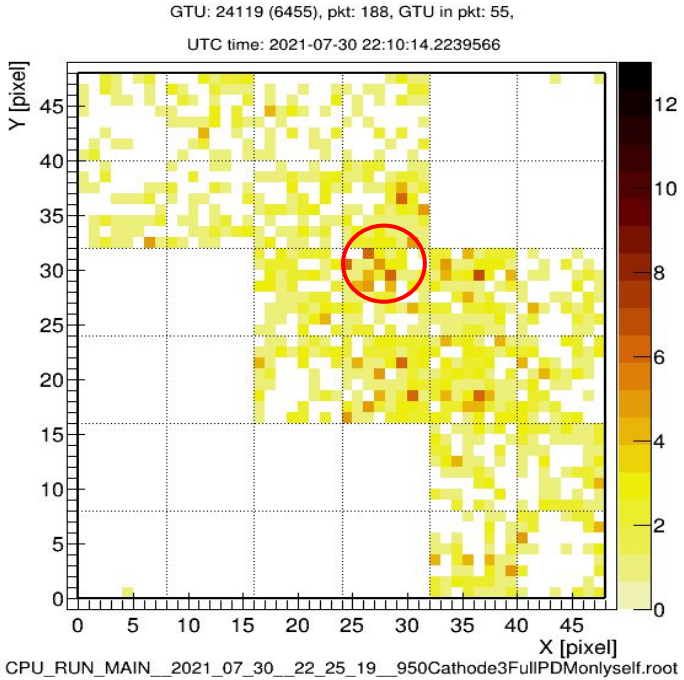


ASIM detected the atmospheric events that follows the EAS-like event.

Correlation with observation made by ASIM

EAS like events (11/15) - “ Tchad 1 ” - Session 43, orbit 3, packet 188

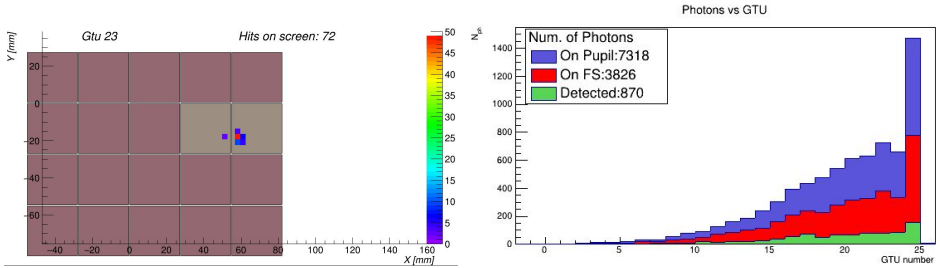
- Mini-EUSO observation:
  - D3 time: 2021-07-30 22:13:57.7958133
  - Presence of a cloud coverage
- Correlation found:
  - **no trigger found with MMIA*** :
  - **1 trigger with MXGS** :
    - 2021-07-30 22:13:27.498059 LED



*** MMIA seems off for this session**

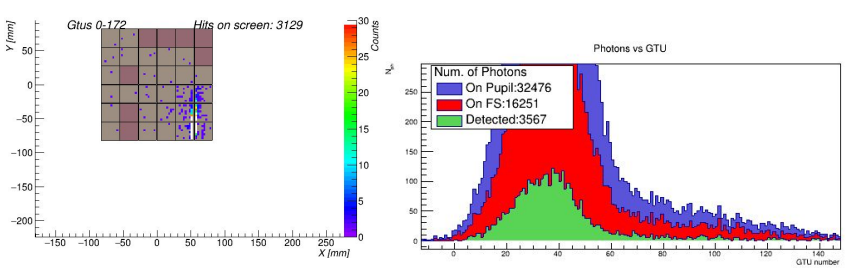
This event is followed by a lightning strike 18 GTU after (2021-07-30 22:13:58.4102144 **) and another one 5 GTU after (**2021-07-30 22:13:58 .6150148 **).**

Reproduction of the Flasher's light curve



Reproduction of the footprint and the maximum number of counts per pixel per GTU

θ = 0.67 deg
Energy = 3.02e22 eV



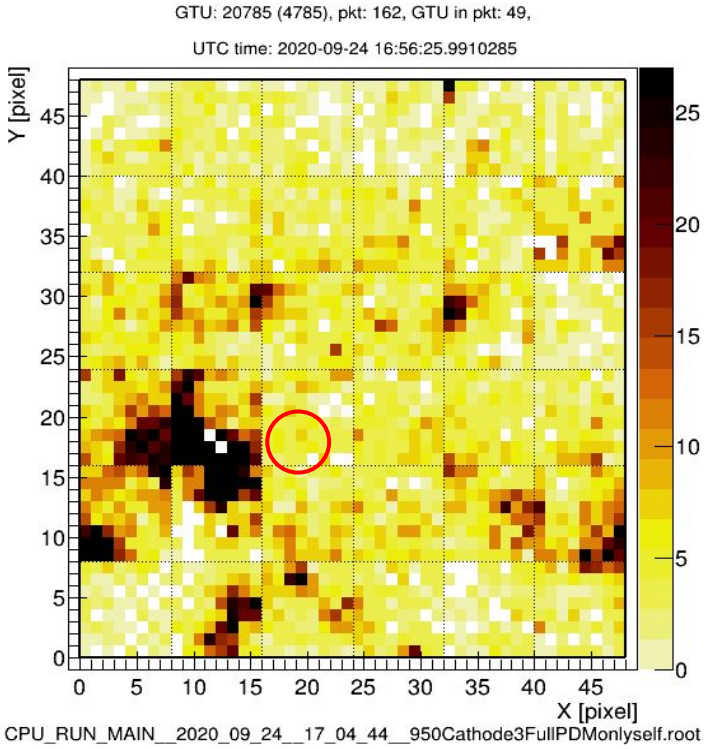
Reproduction of the total number of count

θ = 80.09 deg
Energy = 1.598e22 eV

Correlation with observation made by ASIM

EAS like events (5/15) - “ China ” - Session 26, orbit 1, packet 162

- Mini-EUSO observation:
  - D3 time: 2020-09-24 16:57:31.0403004
- Correlation found:
  - **1 trigger with MMIA** :
    - 2020-09-24 16:57:48.801700 Lightning
  - **1 trigger with MXGS** :
    - 2020-09-24 16:57:48.957980 MMIA

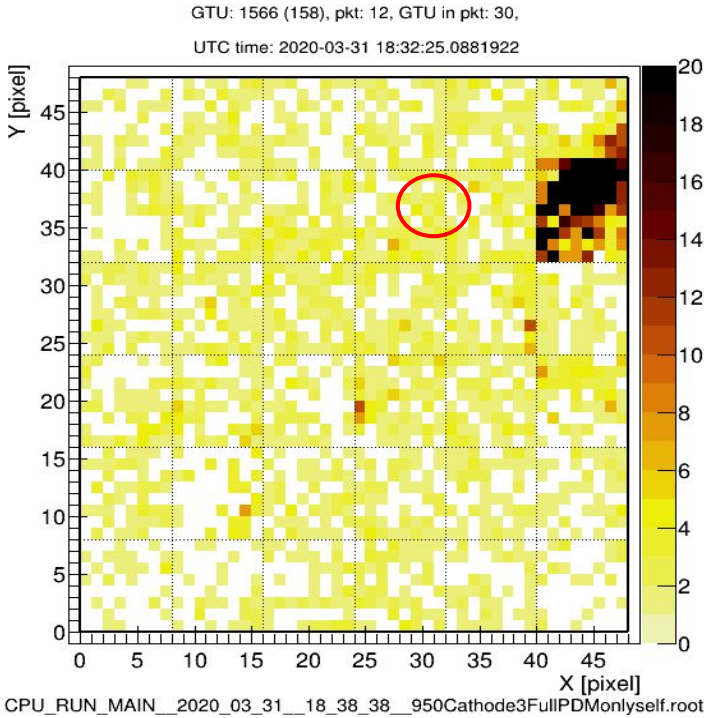


Nothing appear on D3 GTU (no lightning strike, Elves, etc.)

Correlation with observation made by ASIM

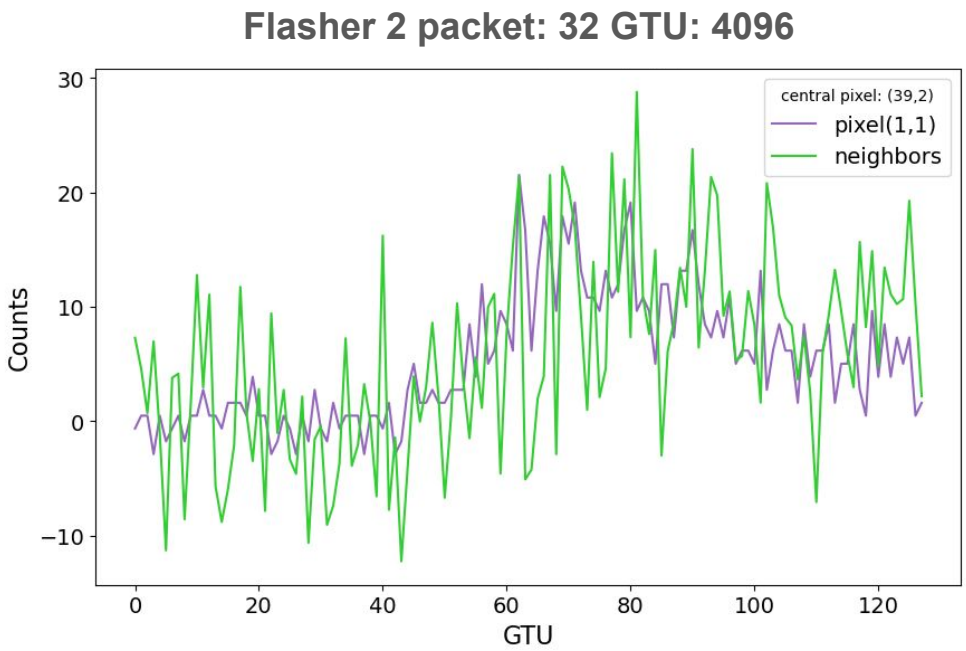
EAS like events (3/15) - “Sri Lanka event” - Session 14, orbit 1, packet 12

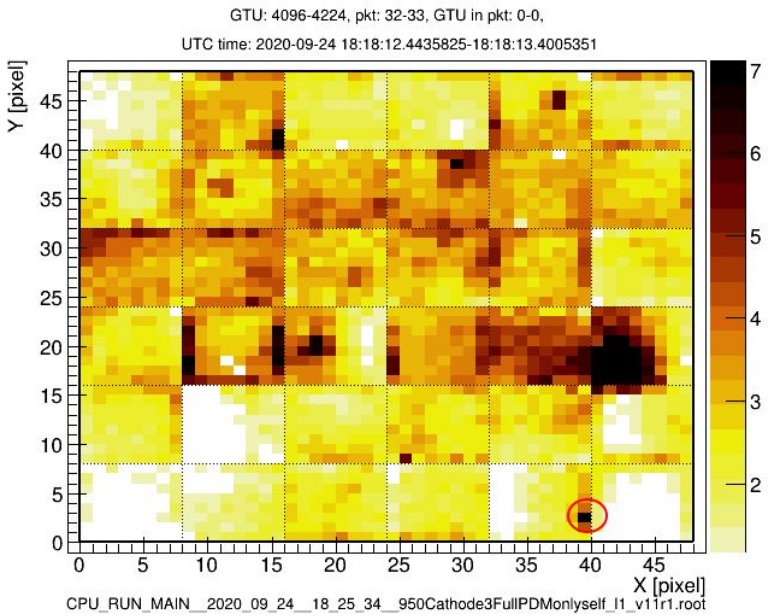
- Mini-EUSO observation:
  - D3 time: 2020-03-31 18:32:48.2866924
- Already analysed by F.Fenu
  - Equivalent energy: 2e22 eV
- Correlation found:
  - **2 triggers with MMIA** :
    - 2020-03-31 18:30:57.114632 Lightning
    - 2020-03-31 18:31:45.448607 Lightning
  - **2 triggers with MXGS** :
    - 2020-03-31 18:31:45.598290 LED
    - 2020-03-31 18:30:57.246228 LED



Nothing appear on D3 GTU (no lightning strike, Elves, etc.)

Flasher's light curve

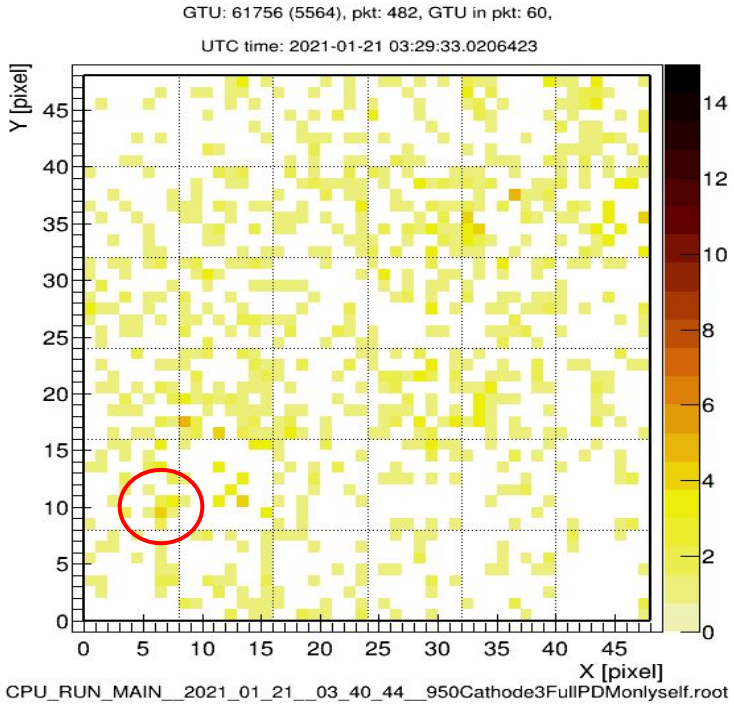




Correlation with observation made by ASIM

EAS like events (9/15) - “ Ivory coast ” - Session 33, orbit 7, packet 482

- Mini-EUSO observation:
  - D3 time: 2021-01-21 03:31:22.2617376
  - Presence of a cloud coverage
  - In the middle of a storm
- Correlation found:
  - **2 triggers with MMIA** :
    - 2021-01-21 03:31:41.818615 Lightning 1
    - 2021-01-21 03:31:41.818615 Lightning 3
  - **1 trigger with MXGS** :
    - 2021-01-21 03:31:41.976845 MMIA

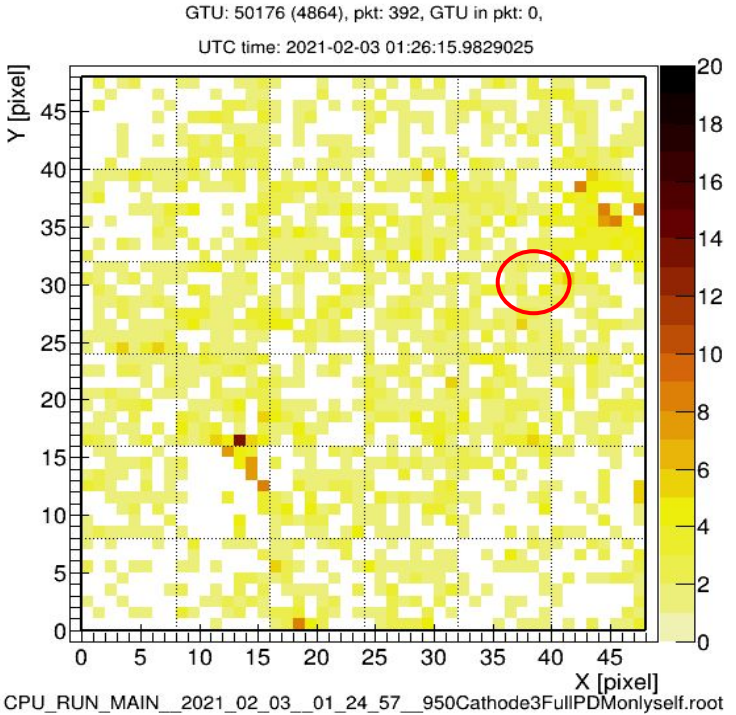


D3 GTU one can see multiple lightning. The one found by MMIA is observed by Mini-EUSO at 2021-01-21 03:31:42.90.

Correlation with observation made by ASIM

EAS like events (10/15) - " North of Brazil 0" - Session 35, orbit 5, packet 392

- Mini-EUSO observation:
  - D3 time: 2021-02-03 01:15:58.1852531
  - Presence of a cloud coverage
- Correlation found:
  - **1 trigger with MMIA** :
    - 2021-02-03 01:16:11.376399* Lightning
  - **1 trigger with MXGS** :
    - 2021-02-03 01:16:11.615349 MMIA



***instrument time**

After 6 D3 GTU (2021-02-03 01:15:43)**, a lightning occurs out of the FOV of Mini-Euso and this could be the lightning observed by MMIA.**

Summary

- Cosmic Ray
- Auger and TA
- EUSO programm
- Mini-EUSO
- Characterise EAS-like event (look at the central pixel, kernel 3x3) criterion
- test on a flasher (single point source 11/5 good results ~)
- Criterion apply of EAS

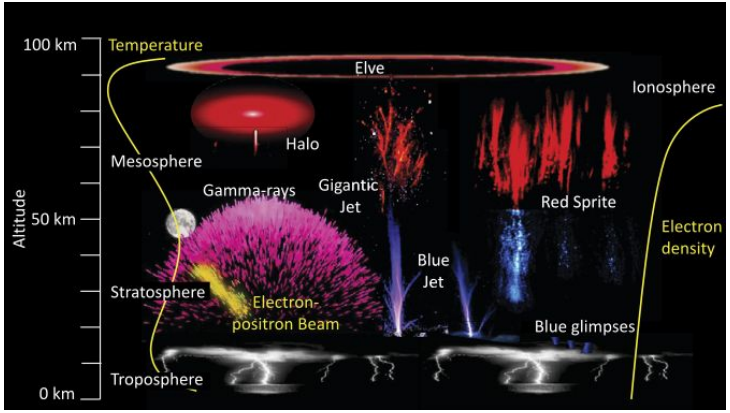
Theory

- Cosmic Ray
- Experiments (Auger and TA)
- Mini-Euso (Fluorescence light)

EAS like events

methods:

- Use of esaf for the simulation of the EAS like event
- Etos to analyse the observation made by Mini-EUSO



Torsten Neubert et al. 2019

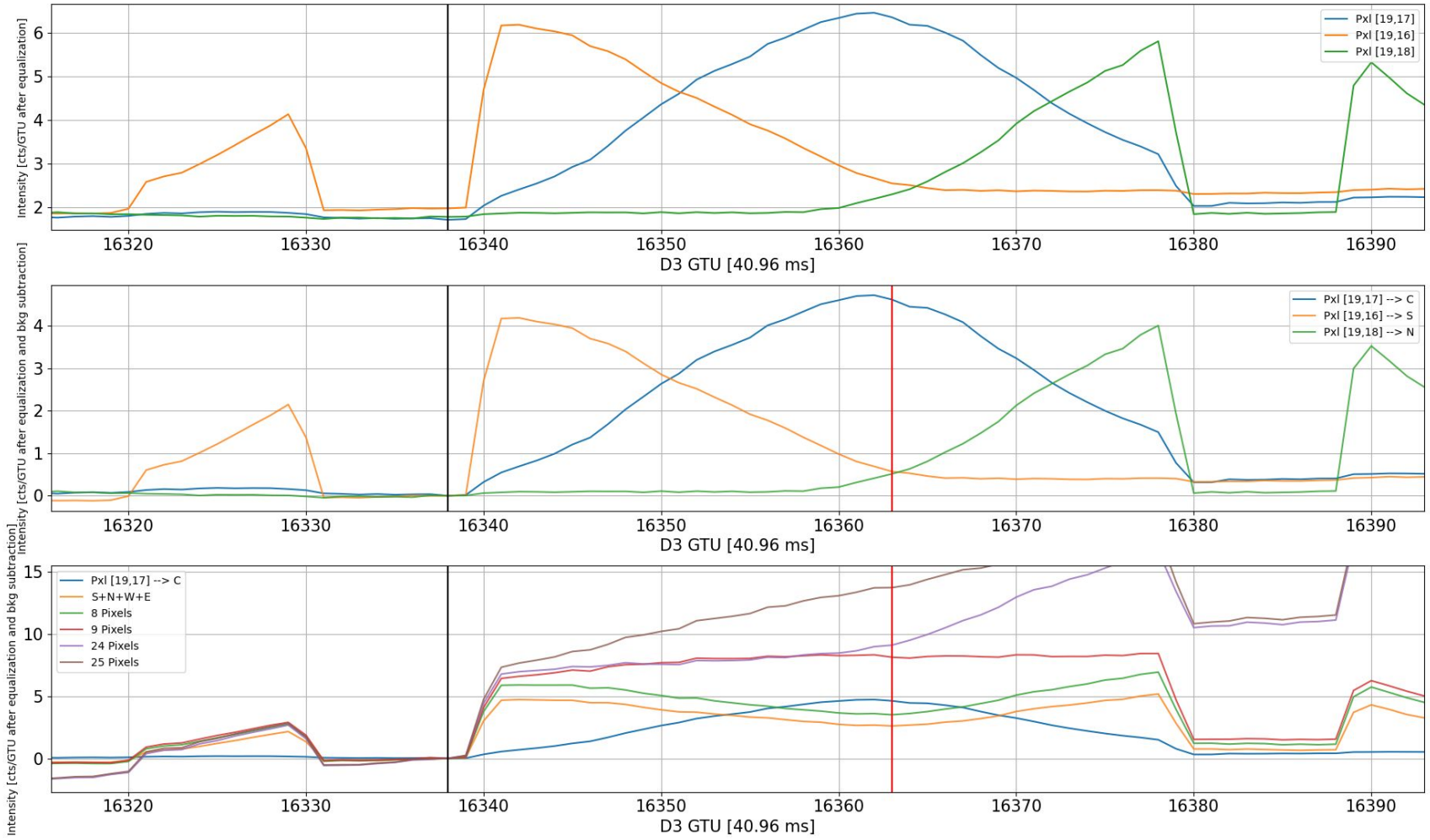
EAS like events

goals:

- reproduce the light curve of the observed event
- reproduce the signal of the event as it appeared in Mini-EUSO focal plane
- reproduce the duration of the event

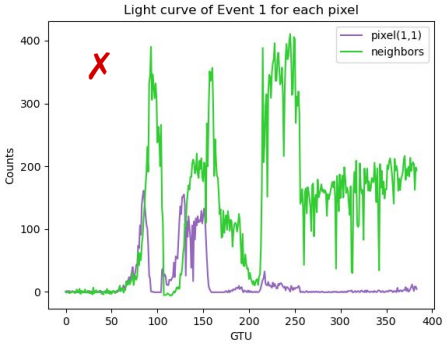
methods:

- Use of esaf for the simulation of the EAS like event
- Etos to analyse the observation made by Mini-EUSO

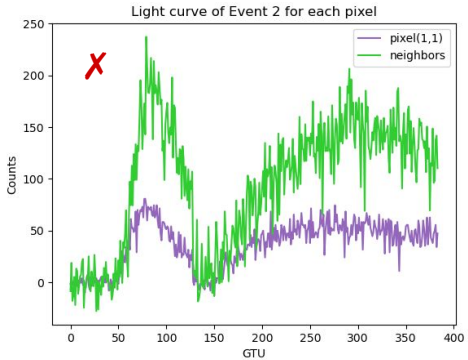

Intensity [cts/GTU after equalization]
Pxl [19,17]
Pxl [19,16]
Pxl [19,18]
D3 GTU [40.96 ms]
Intensity [cts/GTU after equalization and bkg subtraction]
Pxl [19,17] --> C
Pxl [19,16] --> S
Pxl [19,18] --> N
D3 GTU [40.96 ms]
Intensity [cts/GTU after equalization and bkg subtraction]
Pxl [19,17] --> C
S+N+W+E
8 Pixels
9 Pixels
24 Pixels
25 Pixels
D3 GTU [40.96 ms]

Are atmospheric events point like sources?

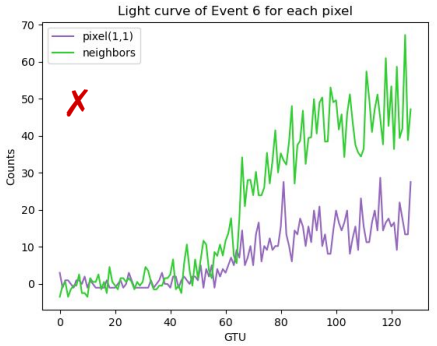
Atmospheric events



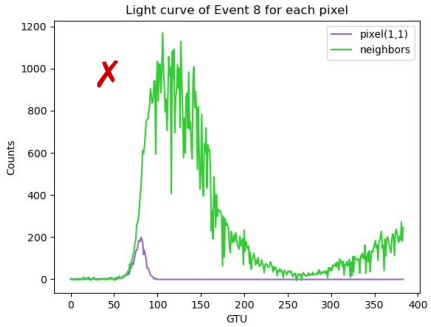
atmospheric event 1



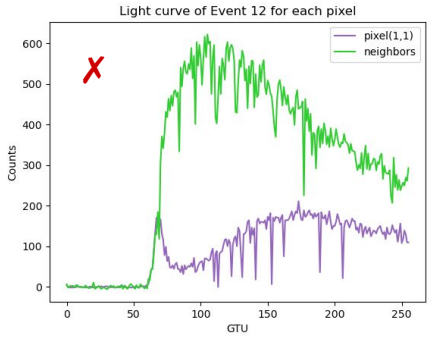
atmospheric event 2



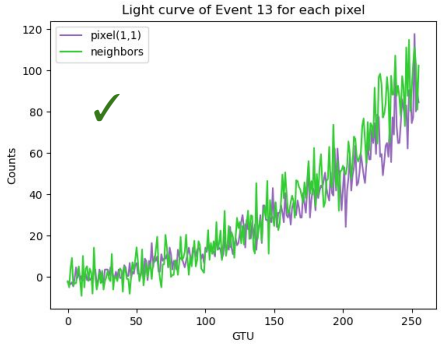
atmospheric event 3



atmospheric event 4



atmospheric event 5



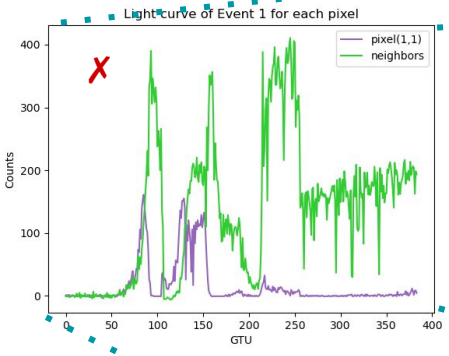
atmospheric event 6

1/6✓ ~ 16%

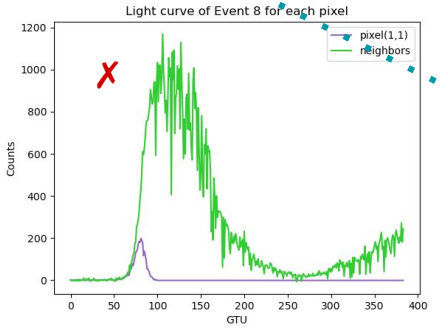
central pixel

neighbors pixels

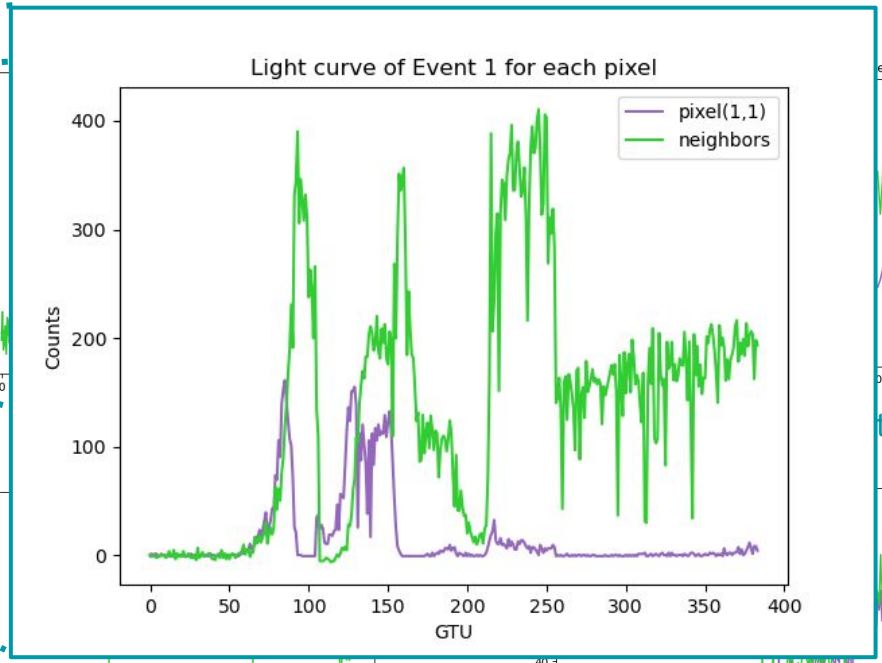
Atmospheric events



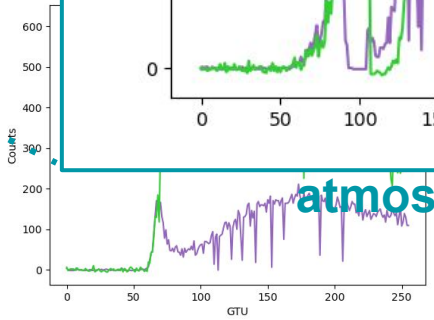
atmospheric event 1



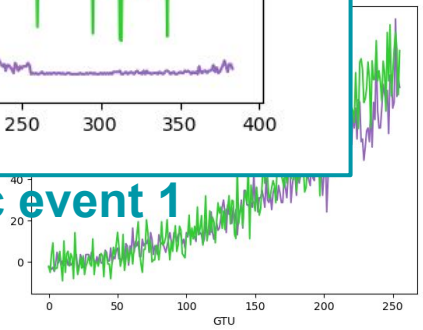
atmospheric event 4



atmospheric event 1



atmospheric event 5



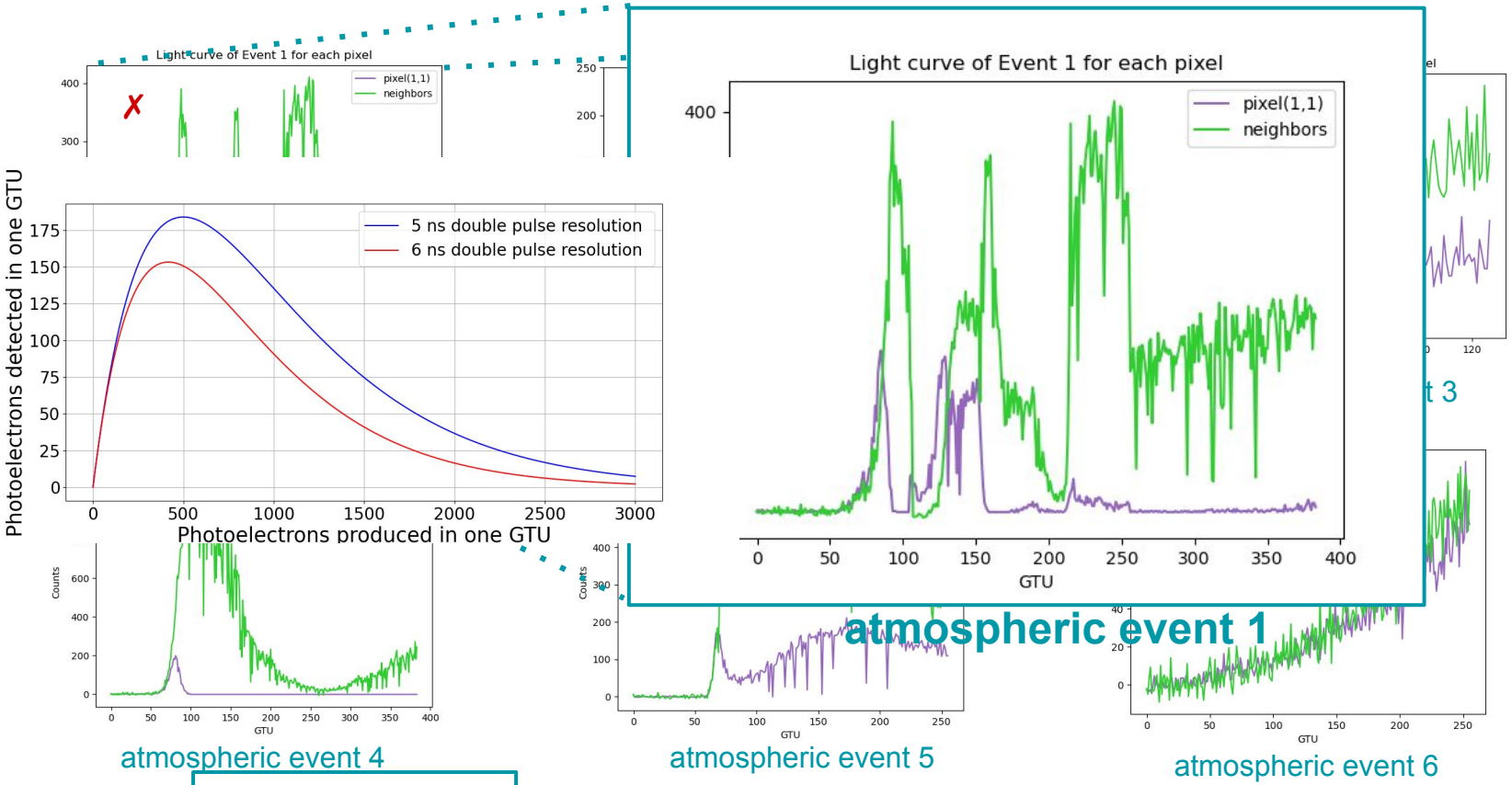
atmospheric event 6

1/6✓ ~ 16%

central pixel

neighbors pixels

Atmospheric events



1/6✓ ~ 16%

central pixel

neighbors pixels

Atmospheric events (conclusion)

Most atmospheric events are not compatible with a point like source. Moreover their analysis is harder due to pile up effect and their very high luminosity put most of the PMTs into Cathode 2 mode. Hence, we cannot access the real number of photons gathered by Mini-EUSO. We cannot derive the energy of the atmospheric event.