Observation of air shower fluorescence at the TA site with an ultraviolet imaging telescope

M. Casolino
on behalf of the
JEM-EUSO collaboration

25-01-2022

The EUSO program

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

2. **EUSO-BALLOONS:**
   - ***2014, Timmins, Canada***
   - ***2017 NASA Ultra long duration flight. EUSO-SPB***

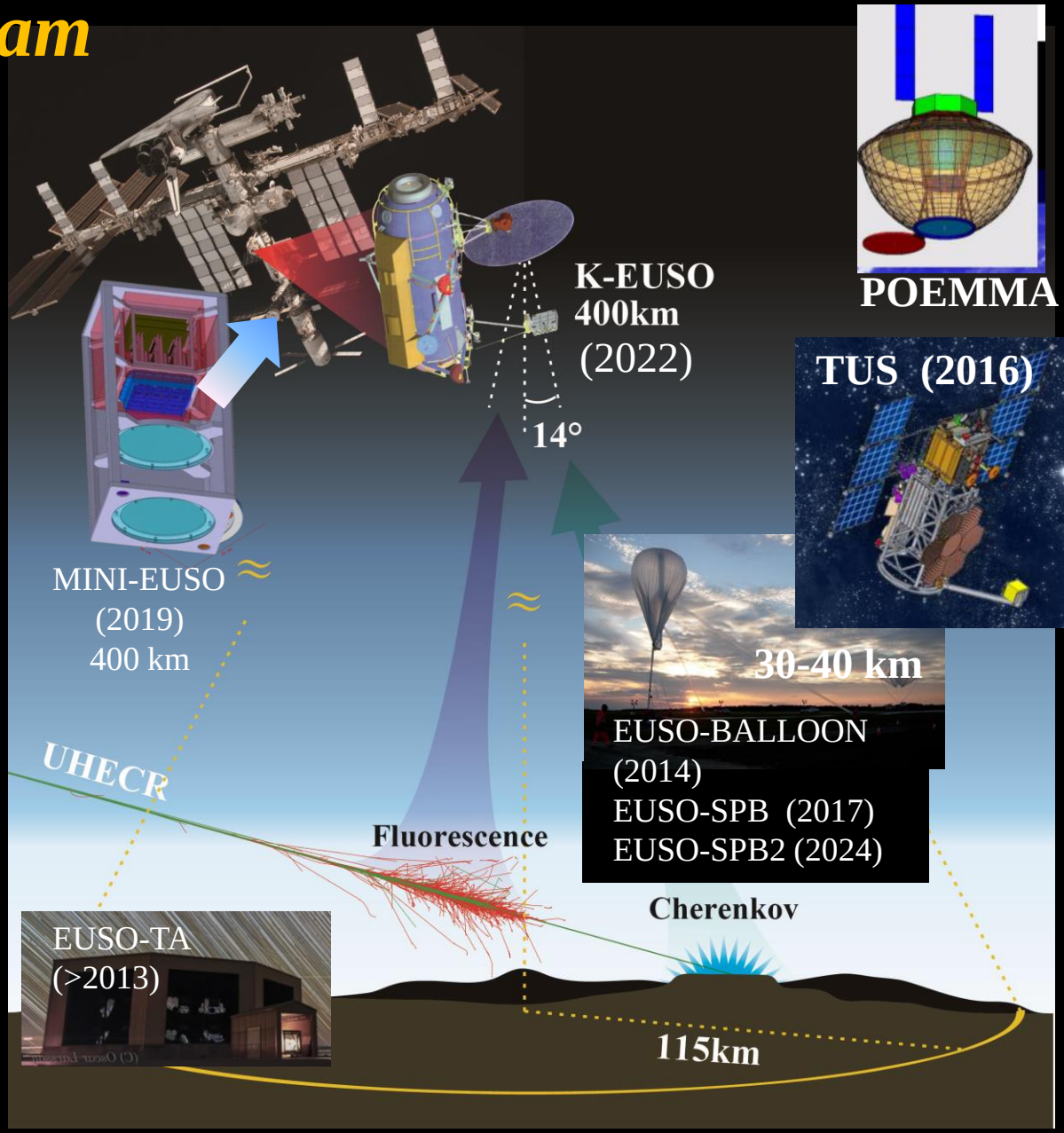
3. **TUS (2016):** free-flyer on Lomonosov Russian Satellite

4. **MINI-EUSO (2019):** ***Detector from International Space Station (ISS): 40 kg total.***

5. ***SPB-2 (NASA) (2024)***

6. **K-EUSO (2023):** ***ISS Phase A, Russian Space Agency***

7. **POEMMA (2025+):** ***NASA twin free-Flyer***



JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people


EUSO-TA
(C) Oscar Larsson

EUSO-TA

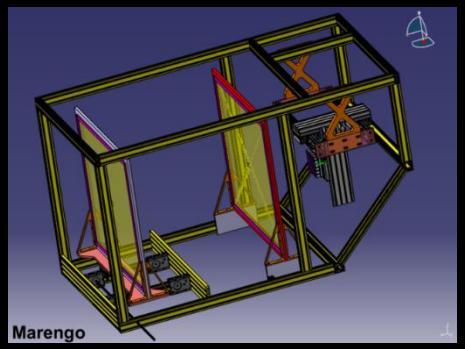
2013: Installation, building, lenses

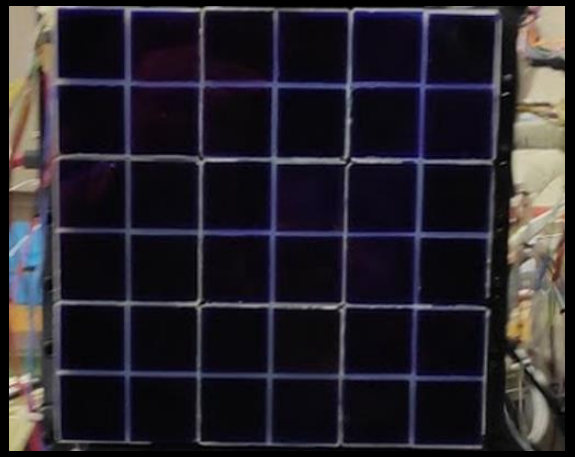
2014: Auger/Fast tests

2015:Cosmic ray observations
CLF laser observations

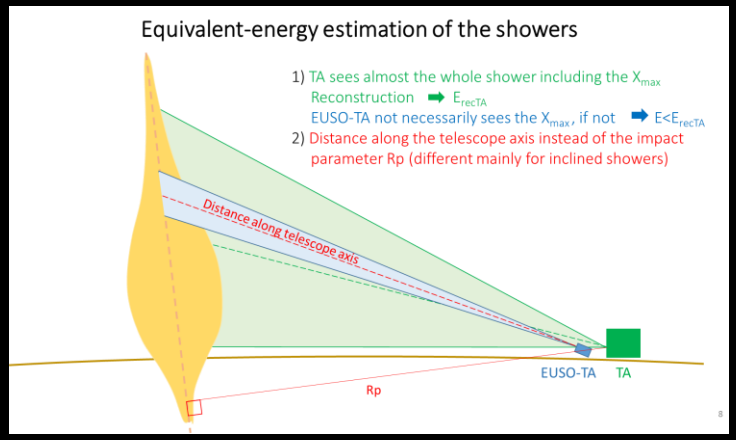
2016: joint tests with Super Pressure Balloon, first payload

Subsequently: reburbishment of Focal surface electronics





Example of detected cosmic ray shower

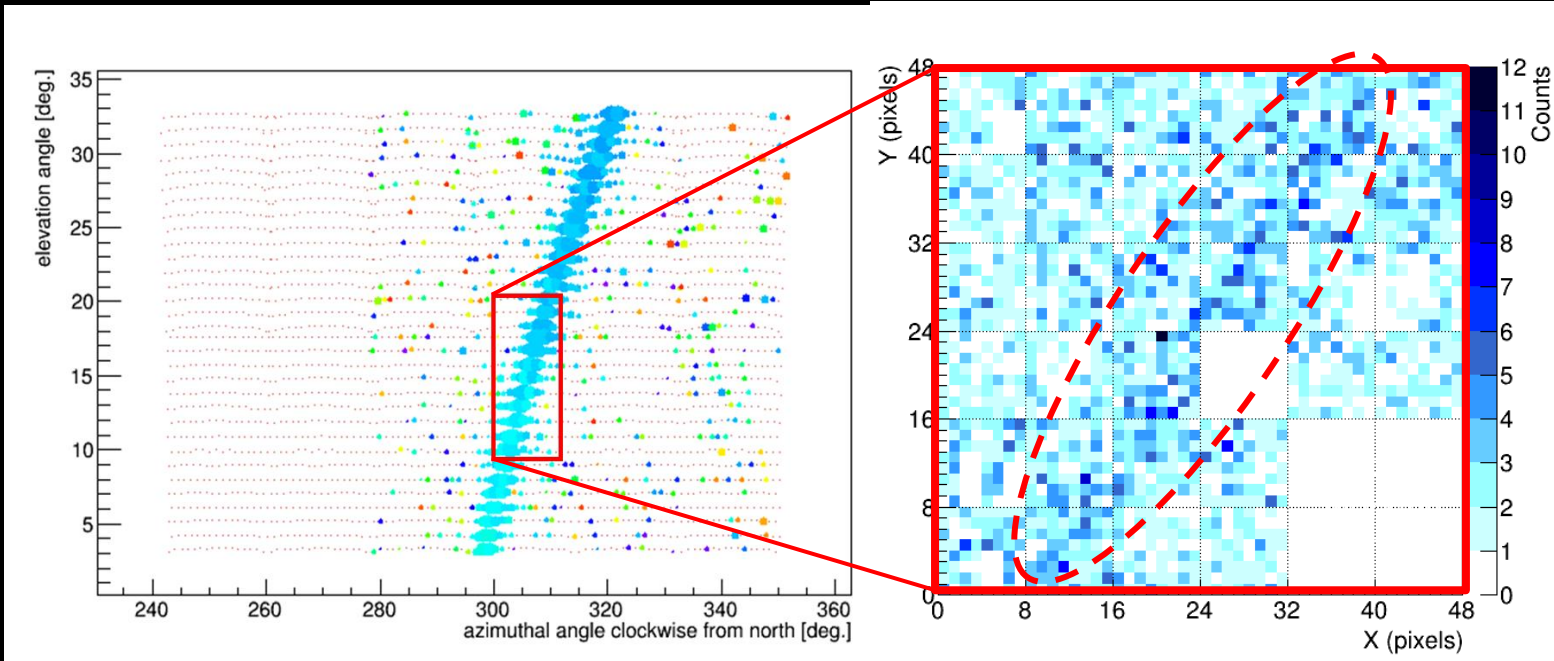


Telescope Array Black Rock Mesa FDs

Time resolution = 100 ns (image over 51.2 μs)
FOV = 110°x30°
Pixel FOV = 1°

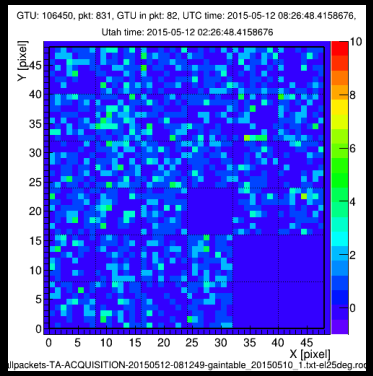
EUSO-TA

Time resolution = 2.5 μs
FOV = 10.5°x10.5°
Pixel FOV = 0.19°

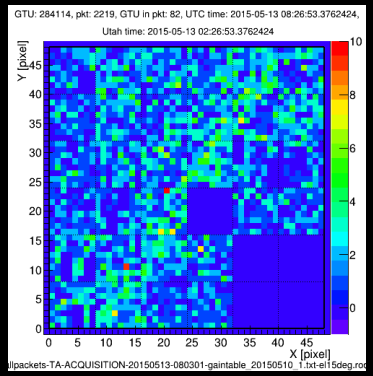


From F. Bisconti

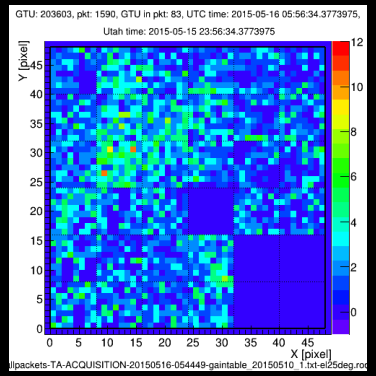
Detected events



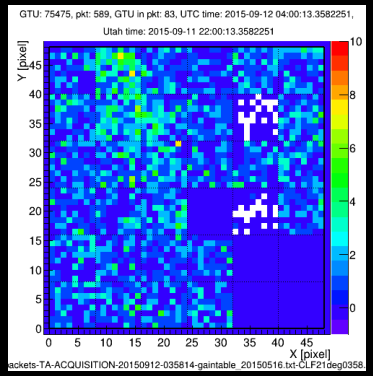
1. logE = 18.69 -> 18.52
   Rp = 8.3, D = 8.67
   Zen = 56.9, Azi = 15.7



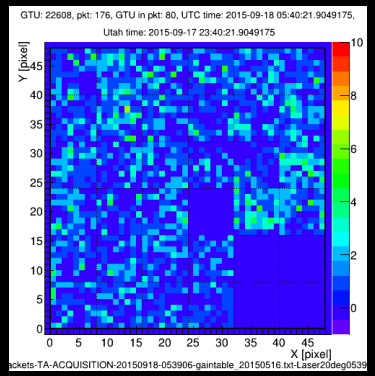
2. logE =18.06 -> 17.86
   Rp = 2.5, D = 2.88
   Zen = 34.5, Azi = 82.8



3. logE = 18.20 -> 15.98
   Rp = 0.8, D = 1.04
   Zen = 62.9, Azi = 27



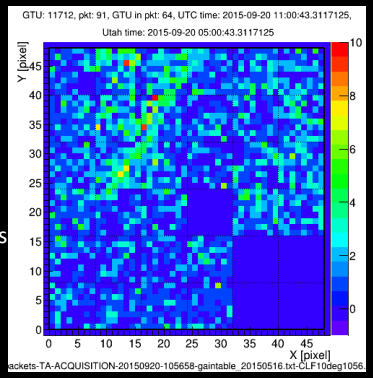
4. logE = 18.05 -> 18.01
   Rp = 5.0, D = 5.12
   Zen = 29.5, Azi = 254.9



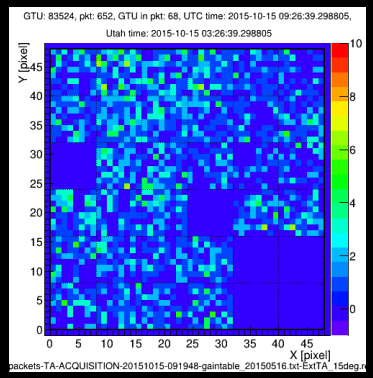
5. logE = 18.51 -> 18.48
   Rp = 9.1, D = 19.81
   Zen = 60.4, Azi = 169.3

Azimuth
from East
Counterclockwis

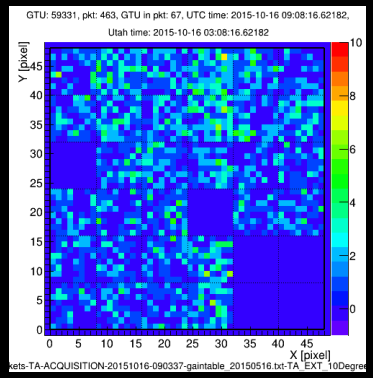
Azimuth
EUSO-TA
143.5 deg



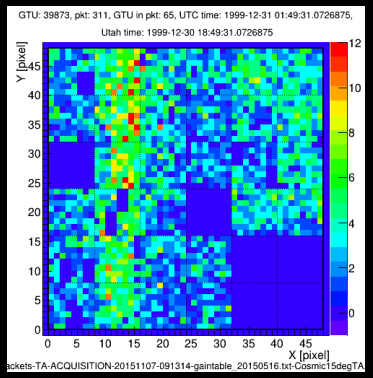
6. logE = 18.38 -> 18.18
   Rp = 6.7, D = 10.03
   Zen = 41.2, Azi = 114.8



7. logE = 18.52 -> 18.45
   Rp = 9.0, D = 10.07
   Zen = 40.6, Azi = 210.5



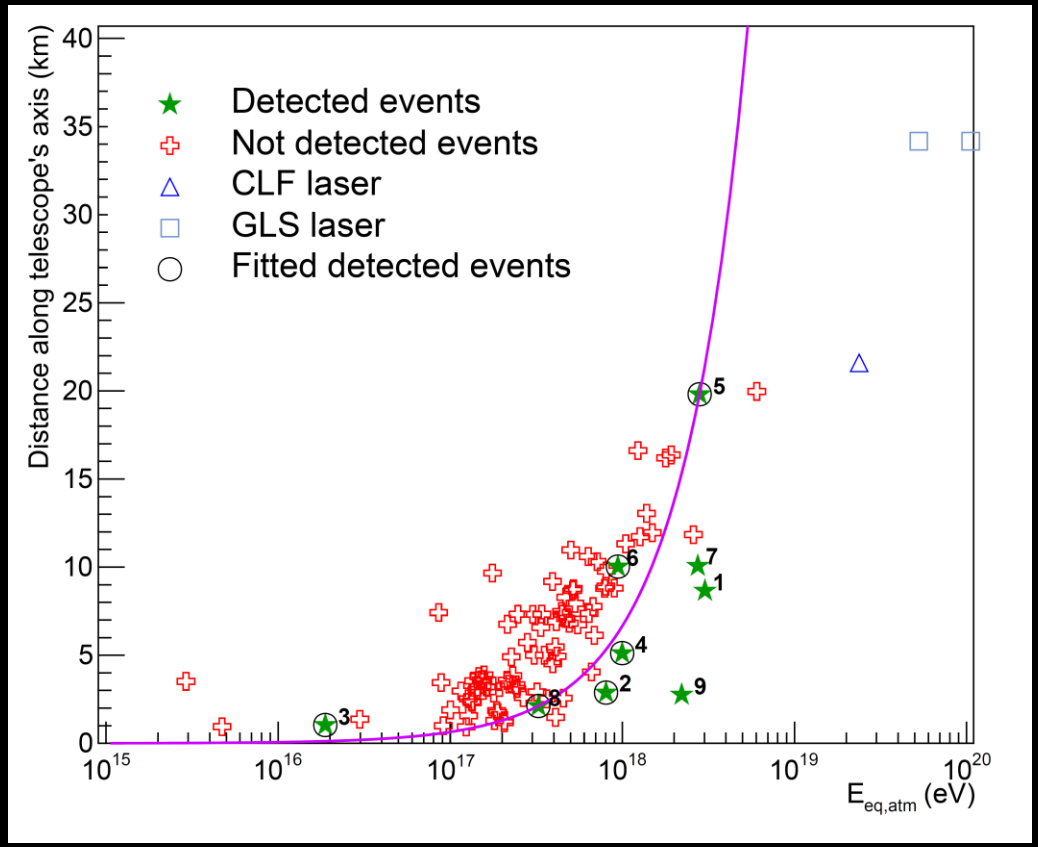
8. logE = 17.71 -> 17.61
   Rp = 1.7, D = 2.12
   Zen = 10.6, Azi = 130.5



9. logE = 18.42 -> 18.38
   Rp = 2.6, D = 2.76
   Zen = 8.1, Azi = 8

From F. Bisconti

CR events observed at TA



Abdellaoui, G., et al. EUSO-TA - First results from a ground-based EUSO telescope. Astroparticle Physics, 102:98 111, November 2018.

https://arxiv.org/abs/1909.03028

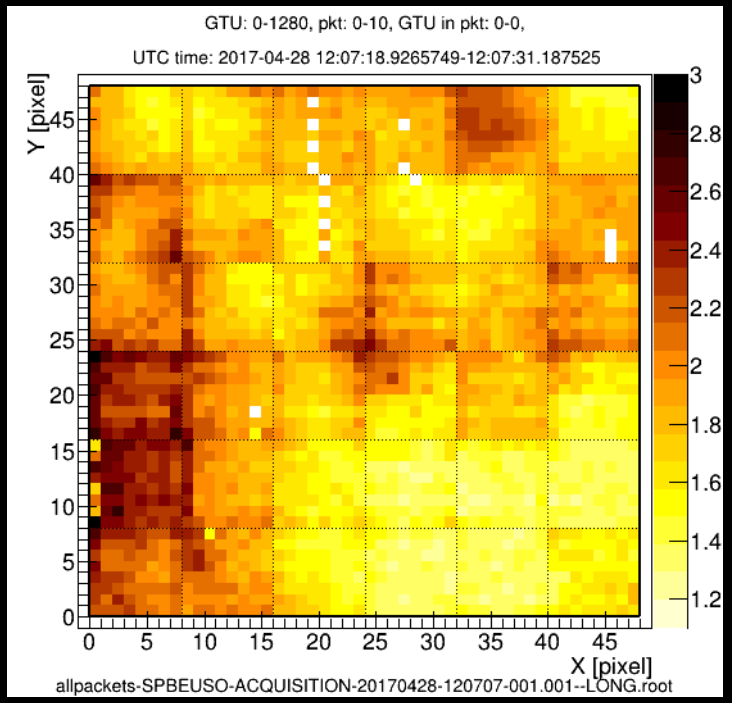
2016 EUSO-SPB EUSO-TA joint campaign

EUSO-SPB, April 2017
Wanaka, New Zealand

NASA Mission. 2nd Payload built by JEM-EUSO collaboration
New lenses, Focal Surface,
Improved Electronics

ICRC presentation
[306] [CRI306] EUSO-SPB Mission and Science
[1261] [CRI054] Calibrating and Testing EUSO-SPB in Flight using a Laser and LEDs on an Aircraft
[1273] [CRI201] The EUSO-SPB instrument
[1274] [CRI061] The trigger logic of EUSO-SPB and its performance
[1280] [CRI041] Preflight calibration and testing of EUSO-SPB in the lab and the desert
[1294] [CRI088] Expected number of Extensive Air Showers observable by EUSO-SPB
[1336] [CRI030] The Data Processor System of EUSO-SPB
1337] [CRI074] UCIRC: Infrared Cloud monitor for EUSO-SPB

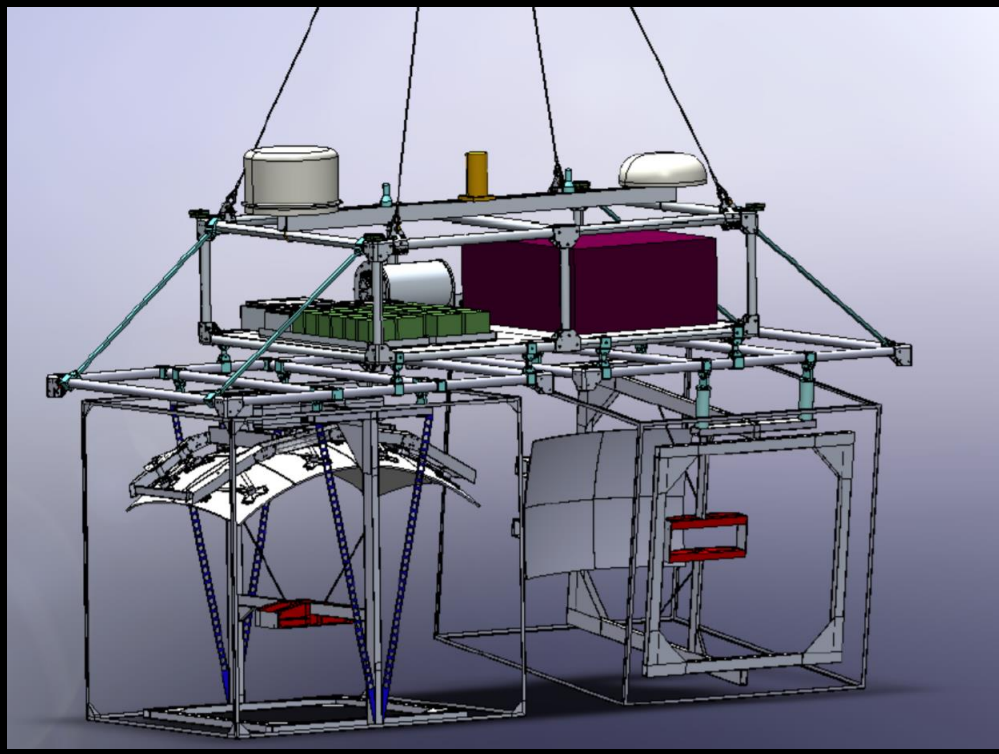
RAW data after launch



[Launch April 25th 2017 (4/24 23:50 UTC)]

EUSO-SPB2

- Approved by NASA
- UHECR air-showers, Cherenkov light from stratosphere. $10^{16} < E < 10^{17}$ eV
- Discrimination of p, nuclei, photons looking at Cherenkov profile
- Mission in 2024



→Will be tested in TA site in Summer 2022

Arxiv 1703.04513

Mini-EUSO/UV-Atmosfera

JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people

40kg, 60 W, 62*37*37 cm3

Ultraviolet, with Fresnel lenses

Near Infrared camera

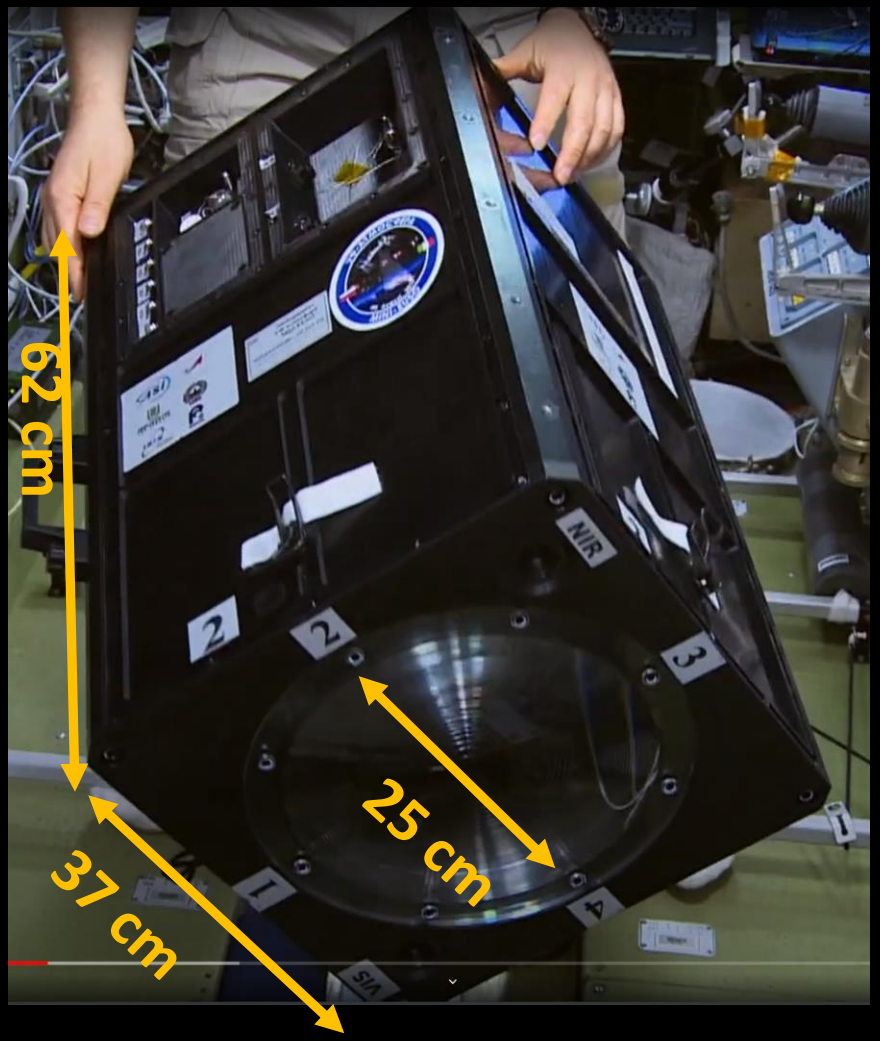
Visible camera

SiPM

2304 pixel

Same light/pixel of K-EUSO design

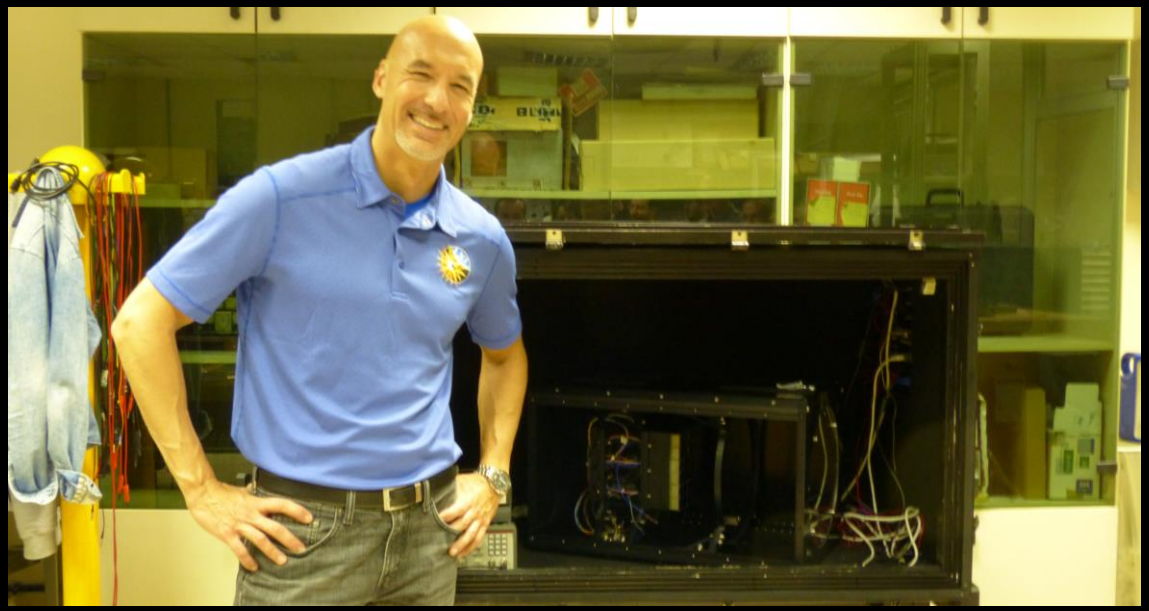
HVPS switch and dynamic range extension



Mini-EUSO: A high resolution detector for the study of terrestrial and cosmic UV emission from the International Space Station. ASR 62(10):2954{2965, Nov 2018.

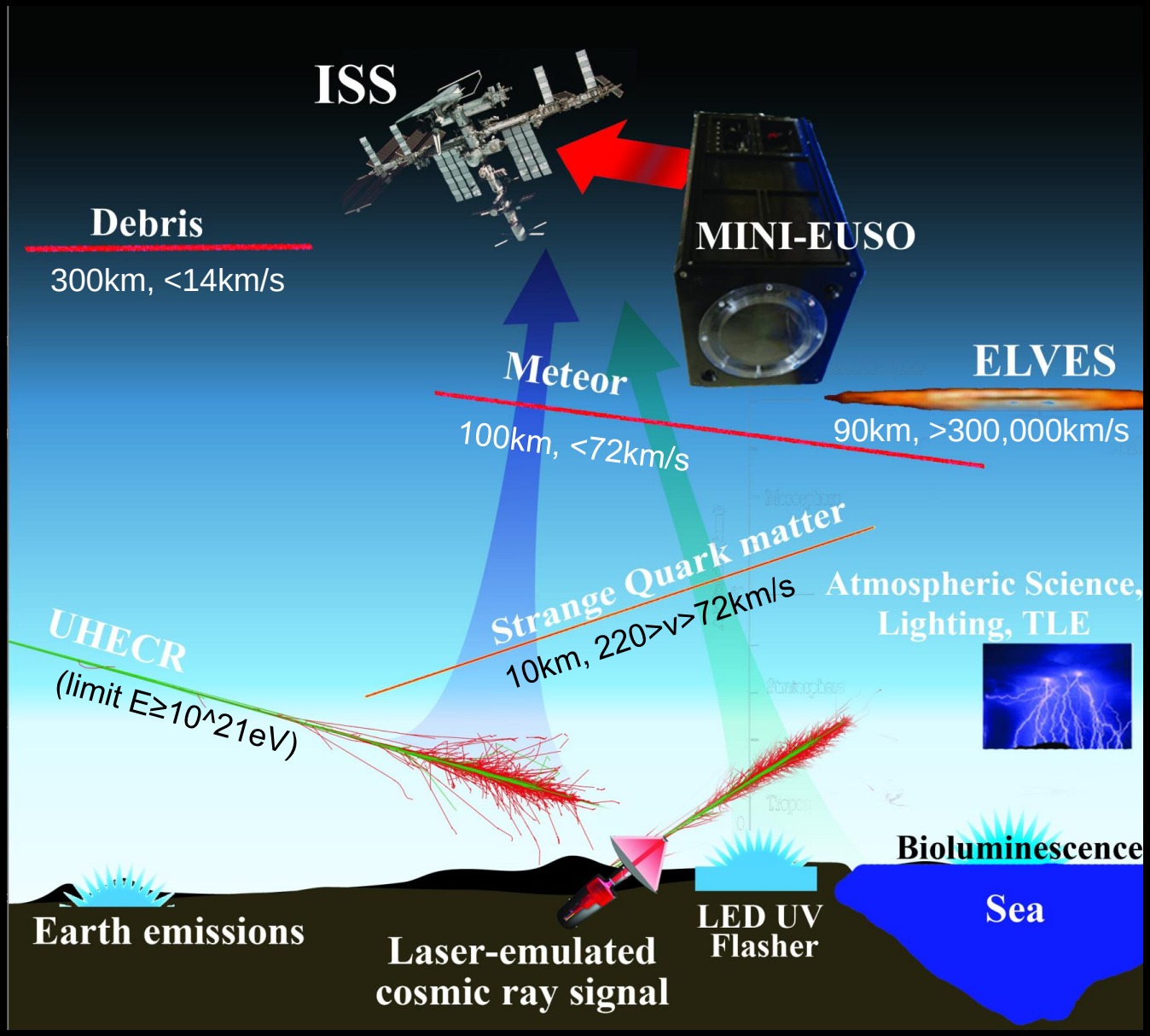
Capel, F., et al. Mini-EUSO data acquisition and control software. JATIS, 5(4), OCT 2019. ISSN 2329-4124. doi:10.1117/1.JATIS.5.4.044009.

The integration and testing of the Mini-EUSO multi-level trigger system, ASR62 Issue: 10 Pages: 2966-2976 , 2018

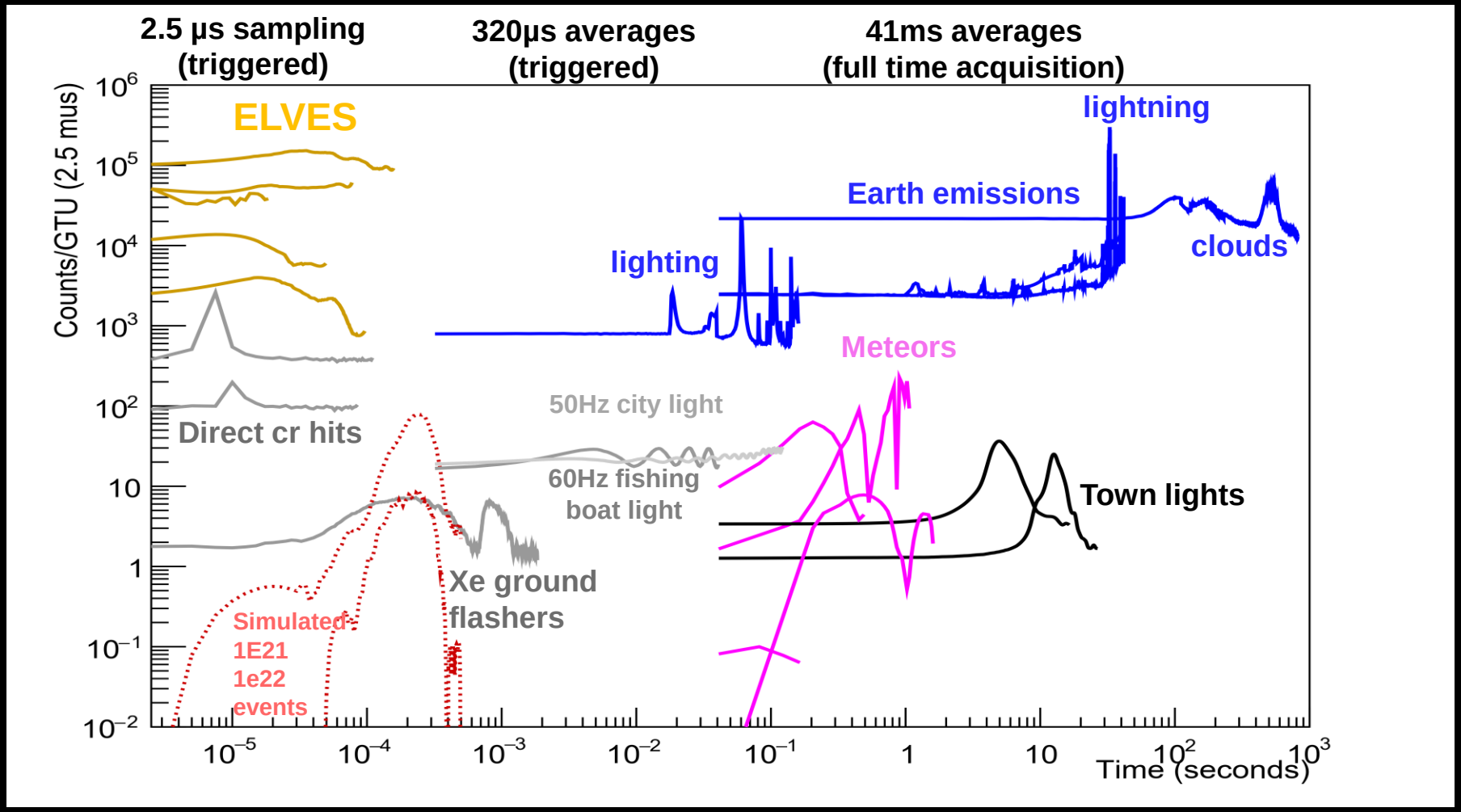


https://www.youtube.com/watch?v=OKIFN1u_Wdk

Science Objectives



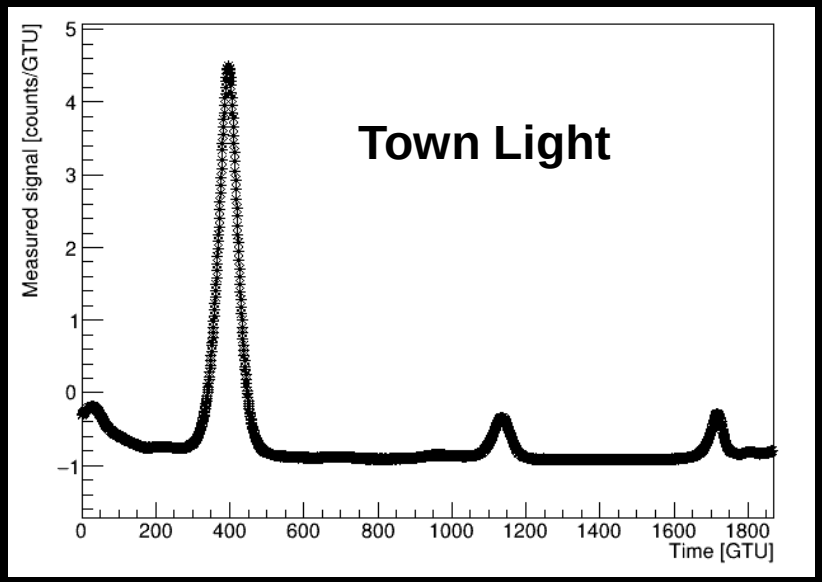
Time profile of various events



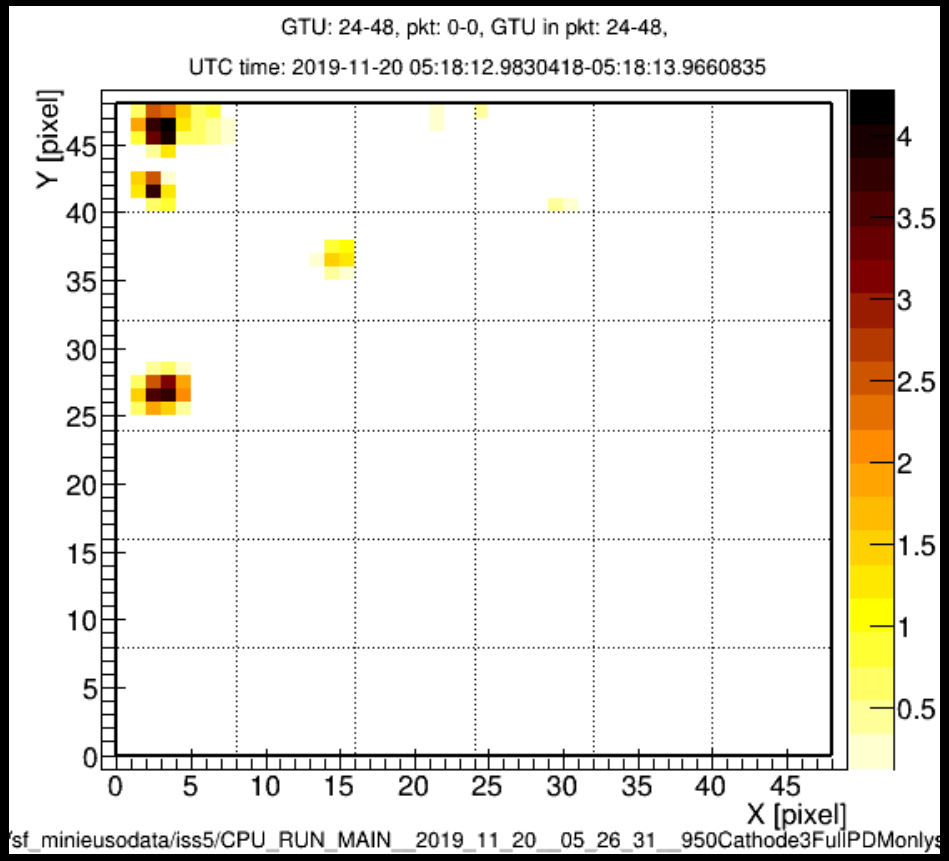
Ground emissions
(between Vancouver and Calgary)

41ms continuous sampling

Pixel size 6.1km
ISS speed 7km/s
Yaw of 4 degrees

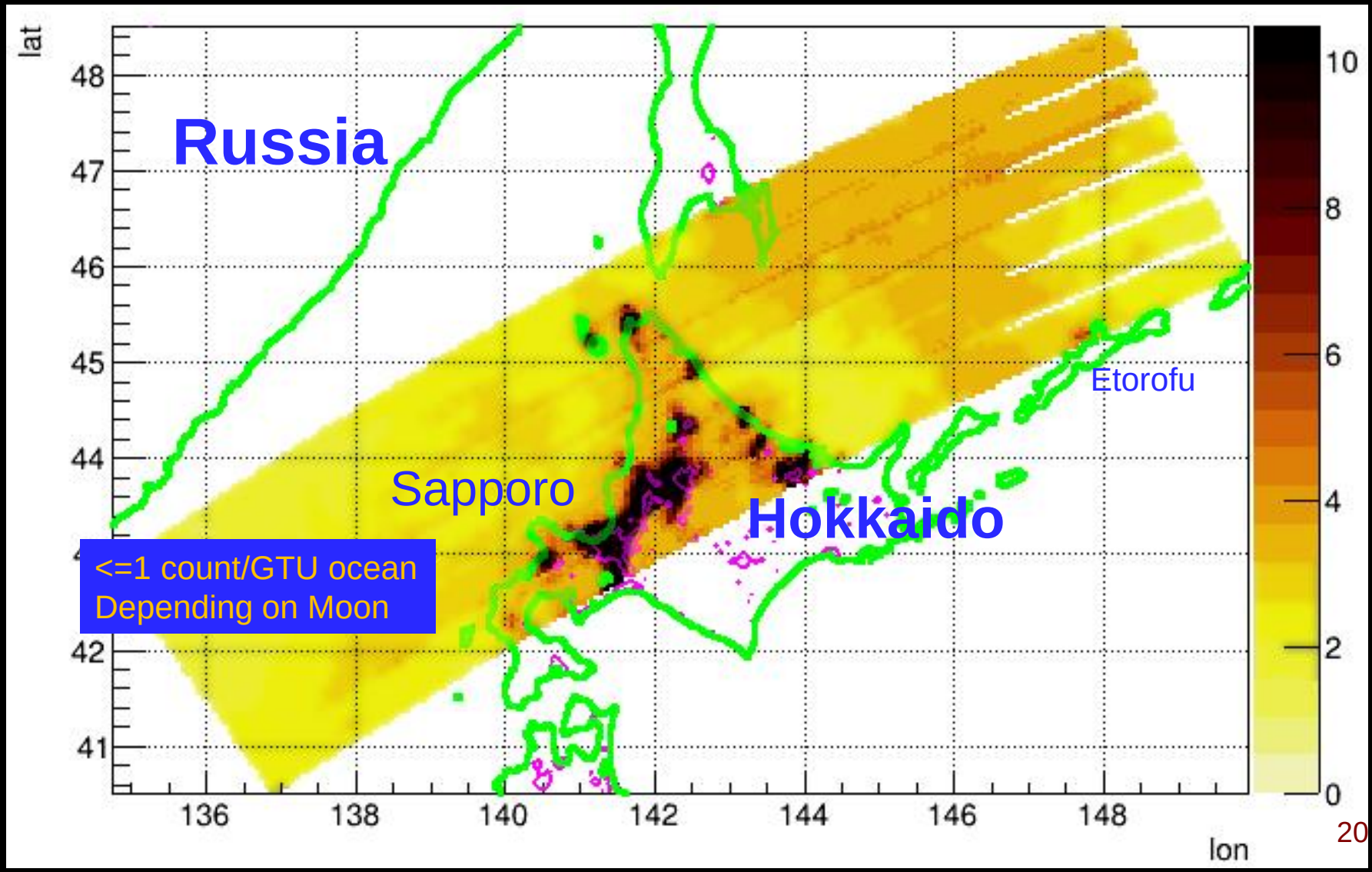


41ms samples

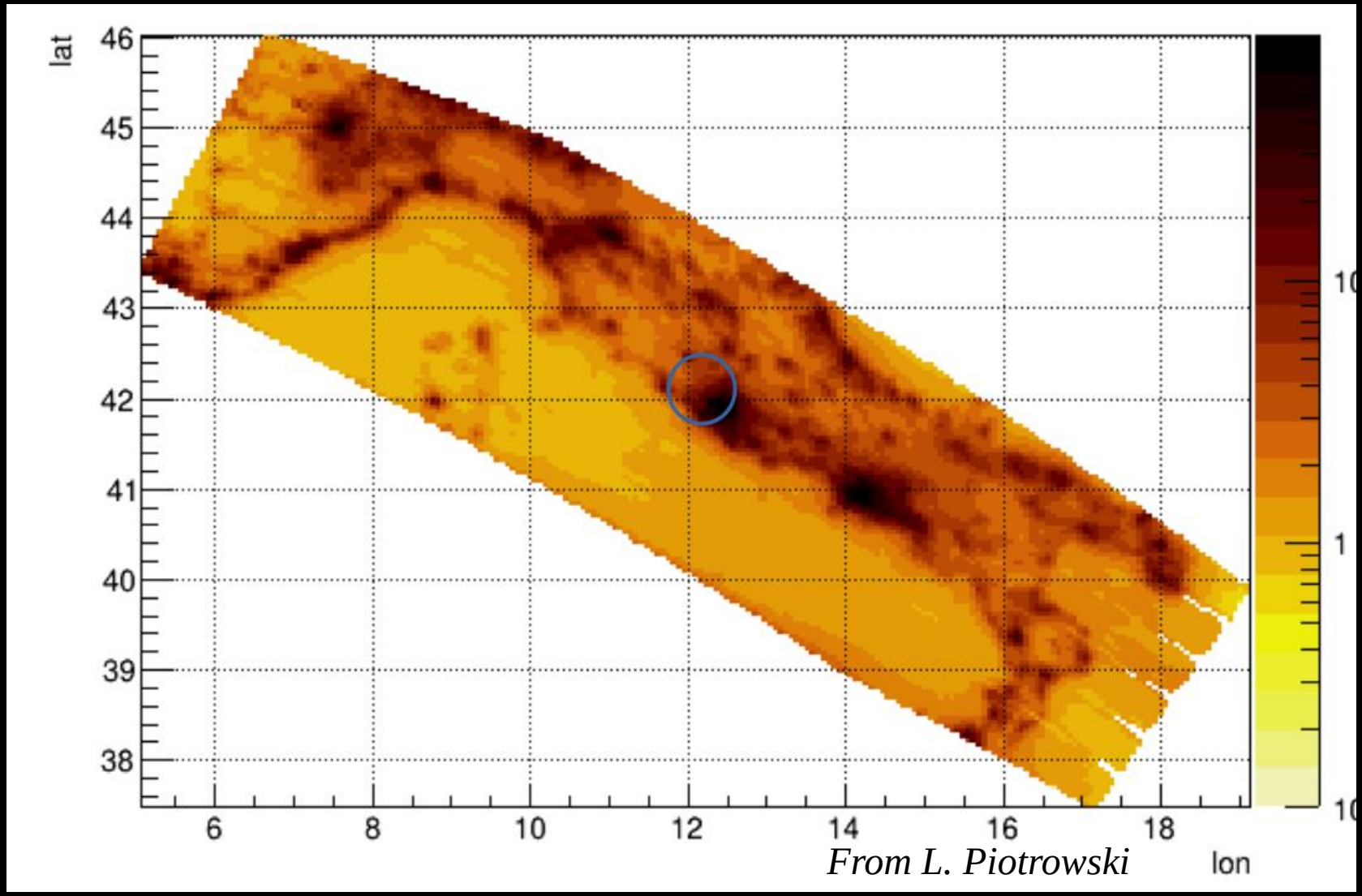


1s 25D3 frames average

UV maps: Northern Japan



Italy, 15-9-2019



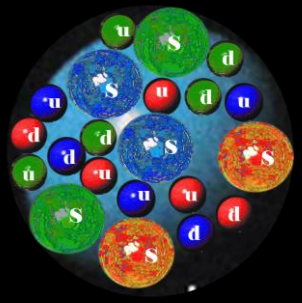
1count about 1E20 ph/km2 s sr

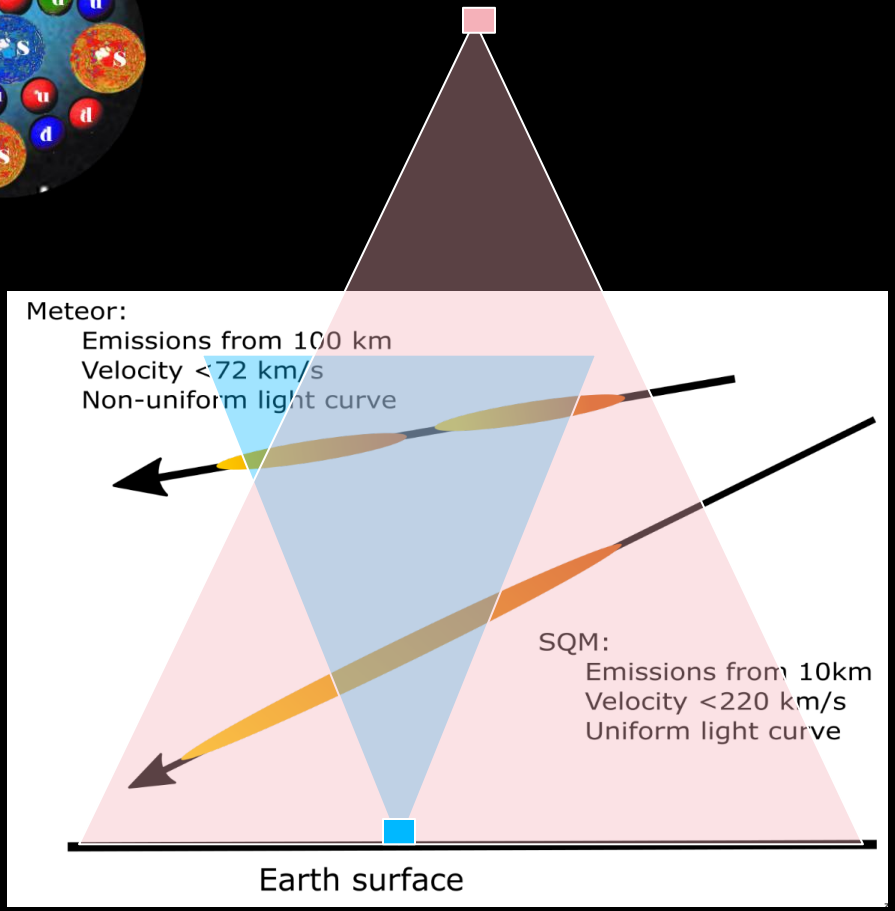
SQM observations in the atmosphere

SQM brightness $\sim v^3$

Signal deposited in pixel $\sim \frac{1}{t} = \frac{1}{v}$

Detection efficiency $\sim v^2$





De Rújula, A., Glashow, S., Nuclearites—a novel form of cosmic radiation, Nature 312, 734–737 (1984).

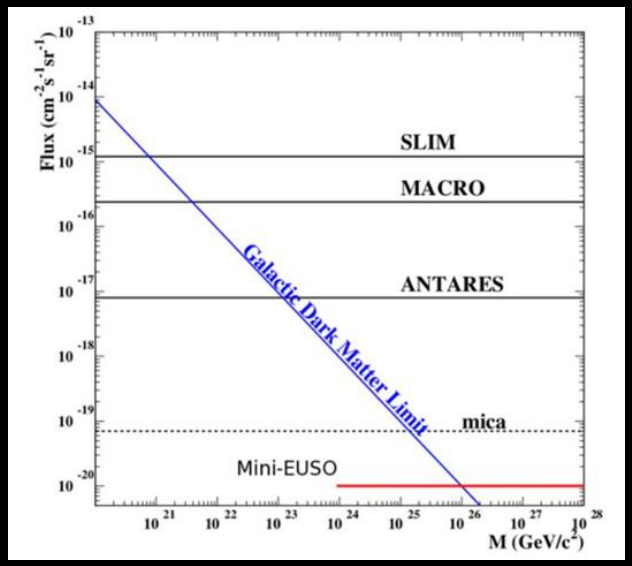
*Witten, Cosmic separation of phases. Phys. Rev. D **30**, 272, 1984*

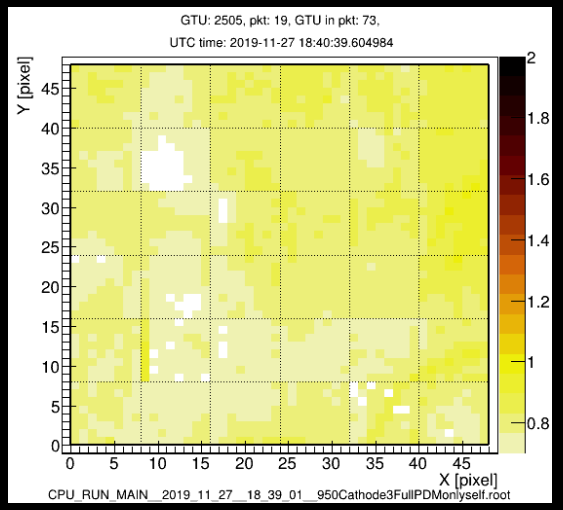
Interstellar Meteors and Search for Strange quark matter

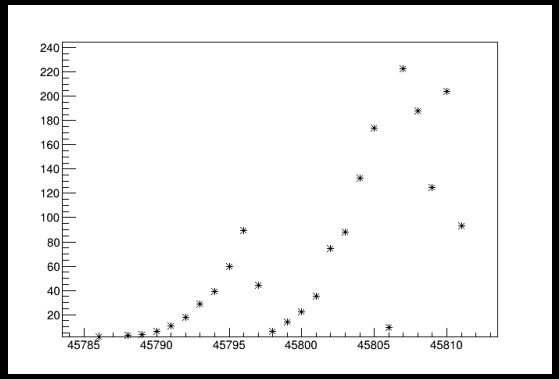
About 5000 meteors in data cards

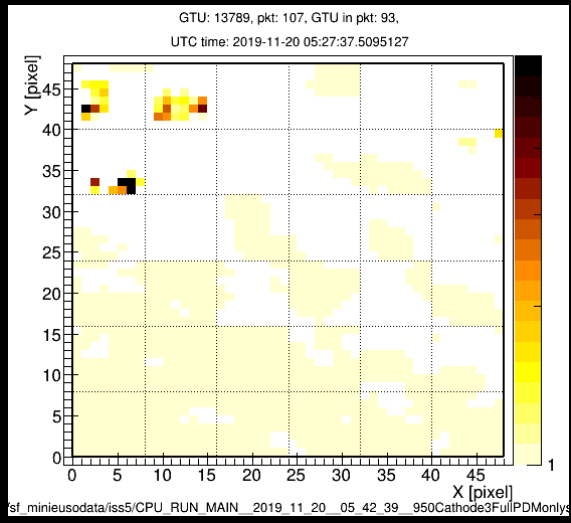
Maximum speed 72 km/s
Interstellar meteors:
220km/s>V>72 km/s
Relevance for solar system formation, Kuiper belt.

SQM: 220km/s>V>72km/s
Long continuous track





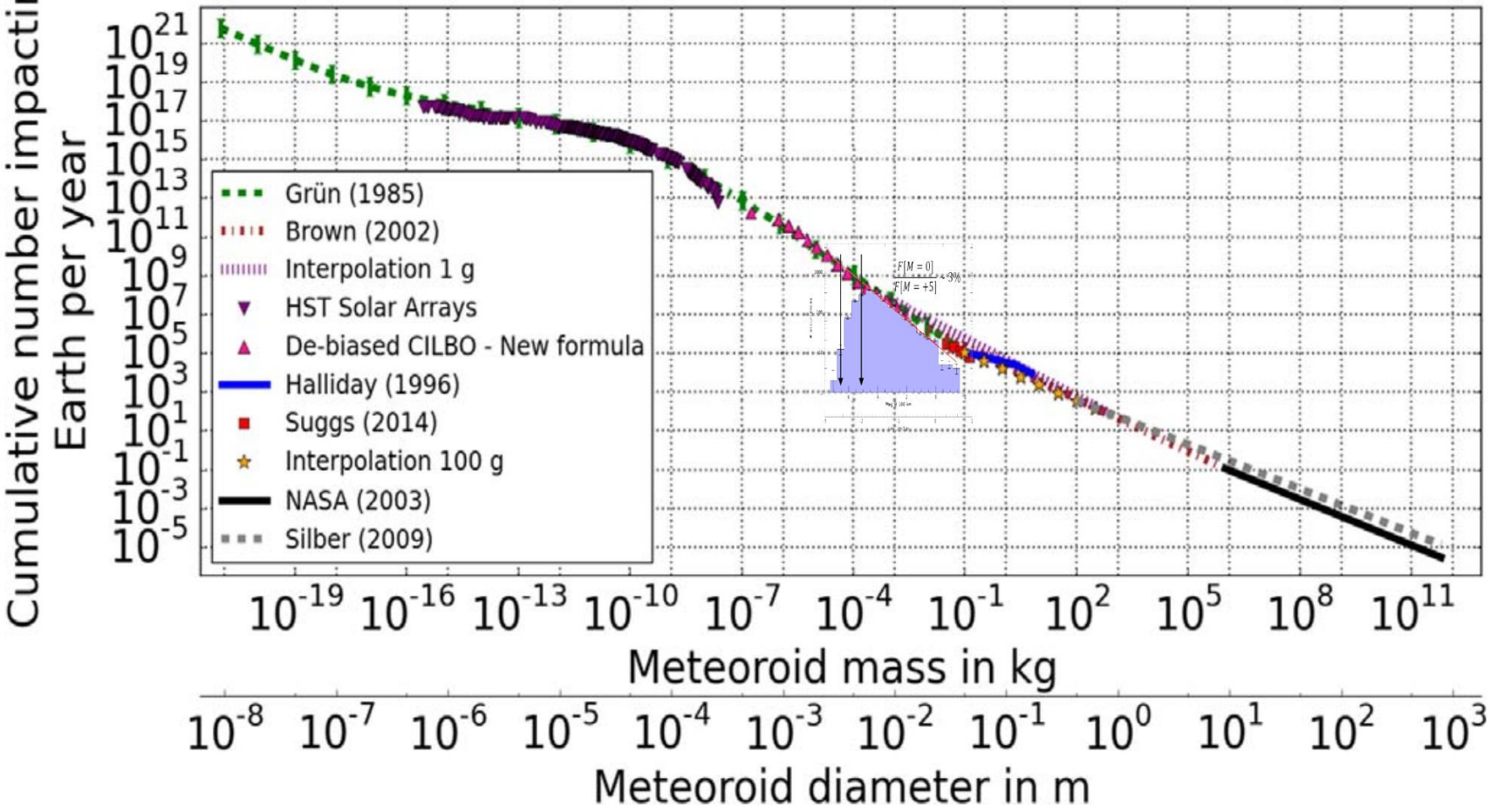




Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245{255, SEP 1 2017.

JEM-EUSO: Meteor and nuclearite observations. Experimental Astronomy, 40:253{279, November 2015.

Solar system meteors

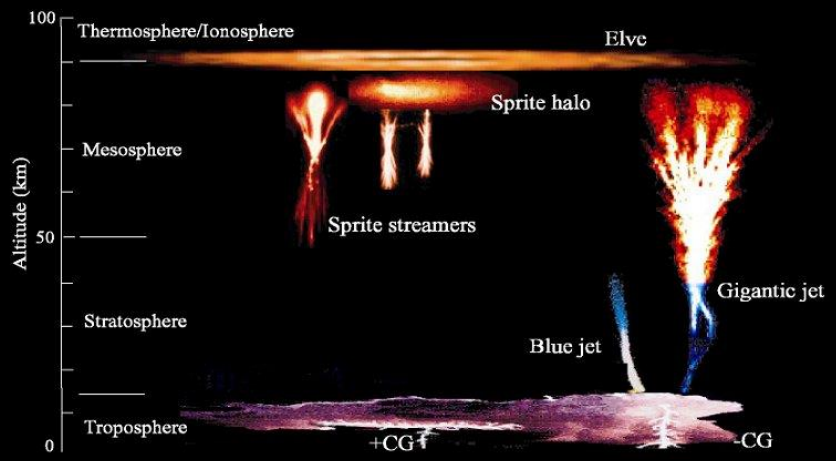


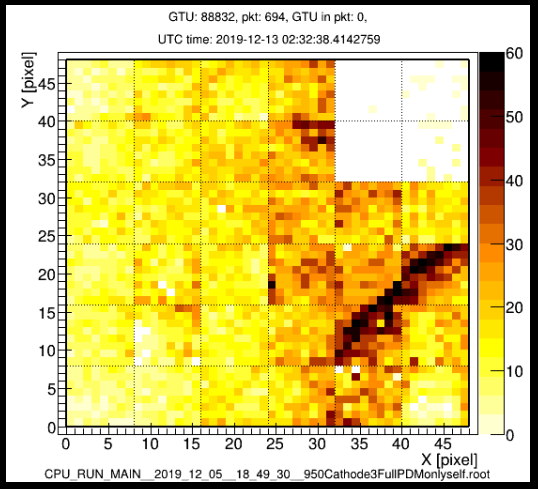
ELVES (transient luminous events)

Superluminal rings
100km+ radius

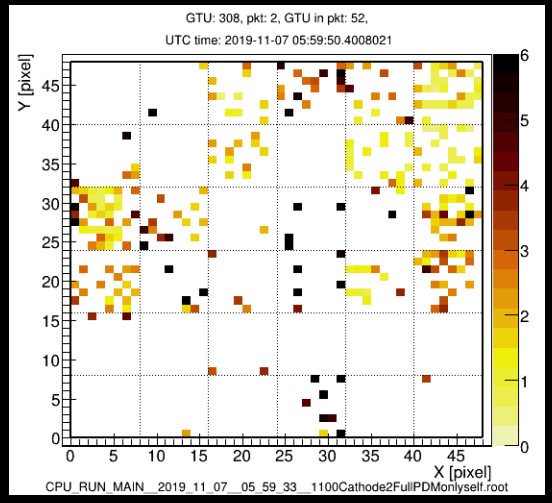
Upper atmospheric lighting releases e.m. wave which heats the ionosphere
Transient Gamma Flash relationship

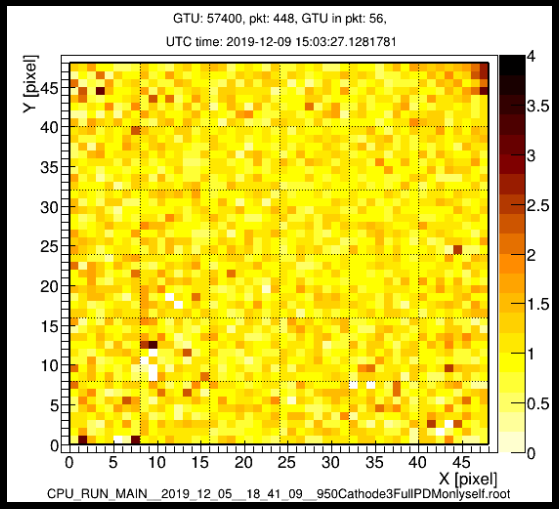
About 400mus
Overall duration



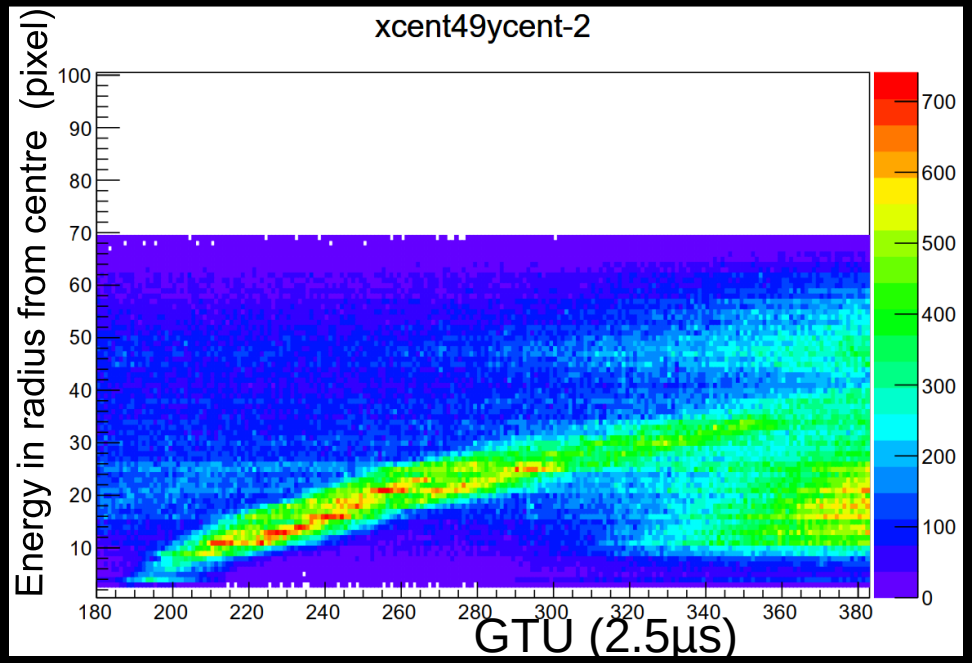


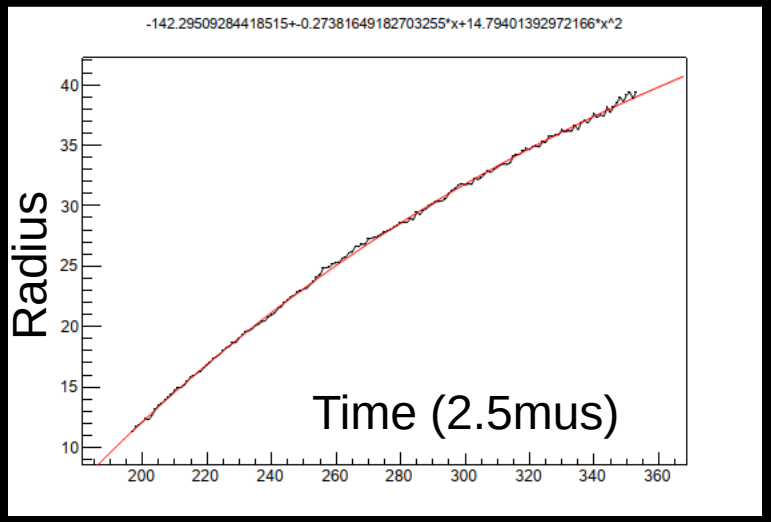
2.5 GTU

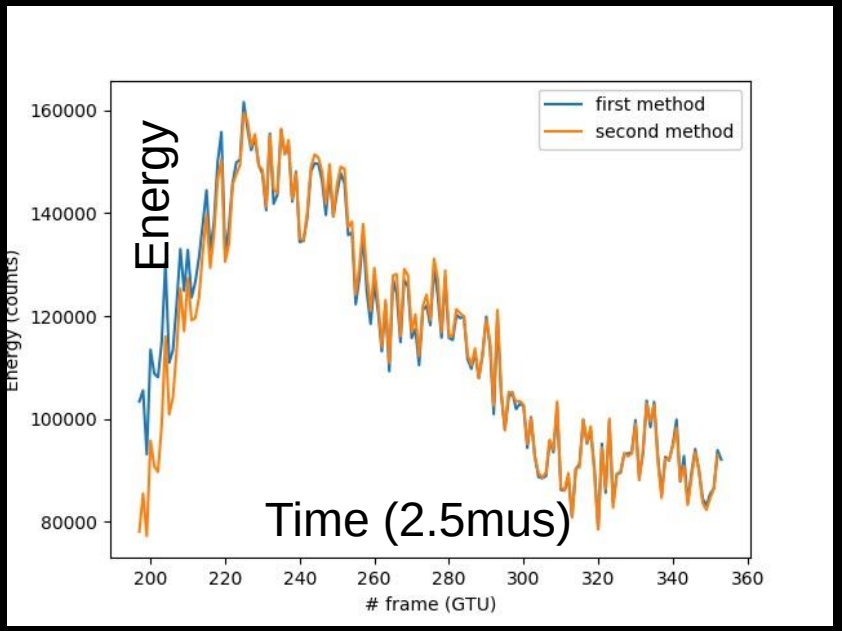




ELVE: 2019-12-05_n1
Polar histogram







Speed ≈ 0.18 pix/GTU ≈ 338 400 km/s

Pixel size:

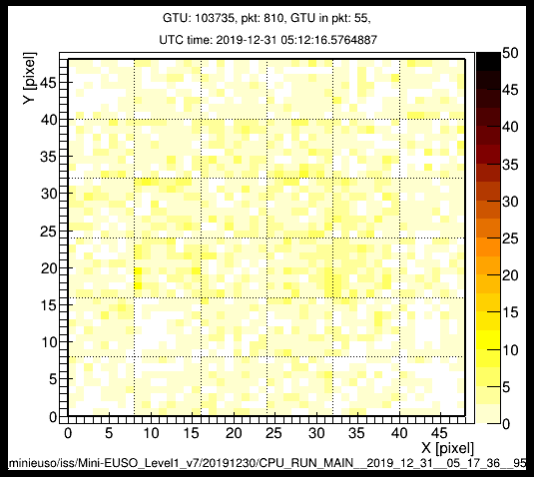
6.1 km on ground

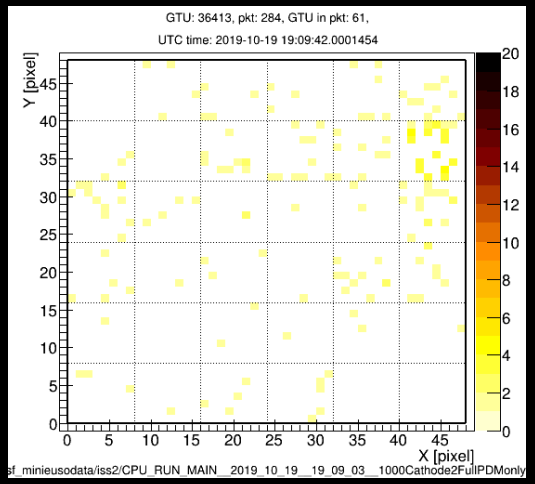
4.7 km at 100 km

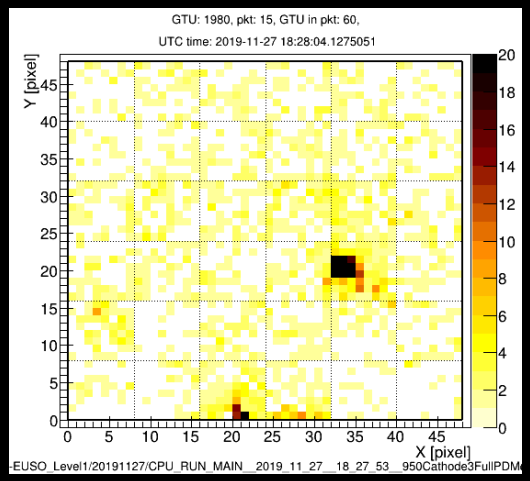
Direct hits on Focal Surface

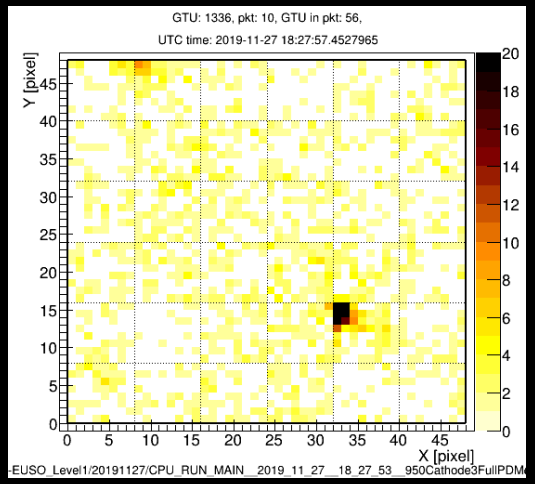
3, 2.5μs frames

Direct particle hitting FS

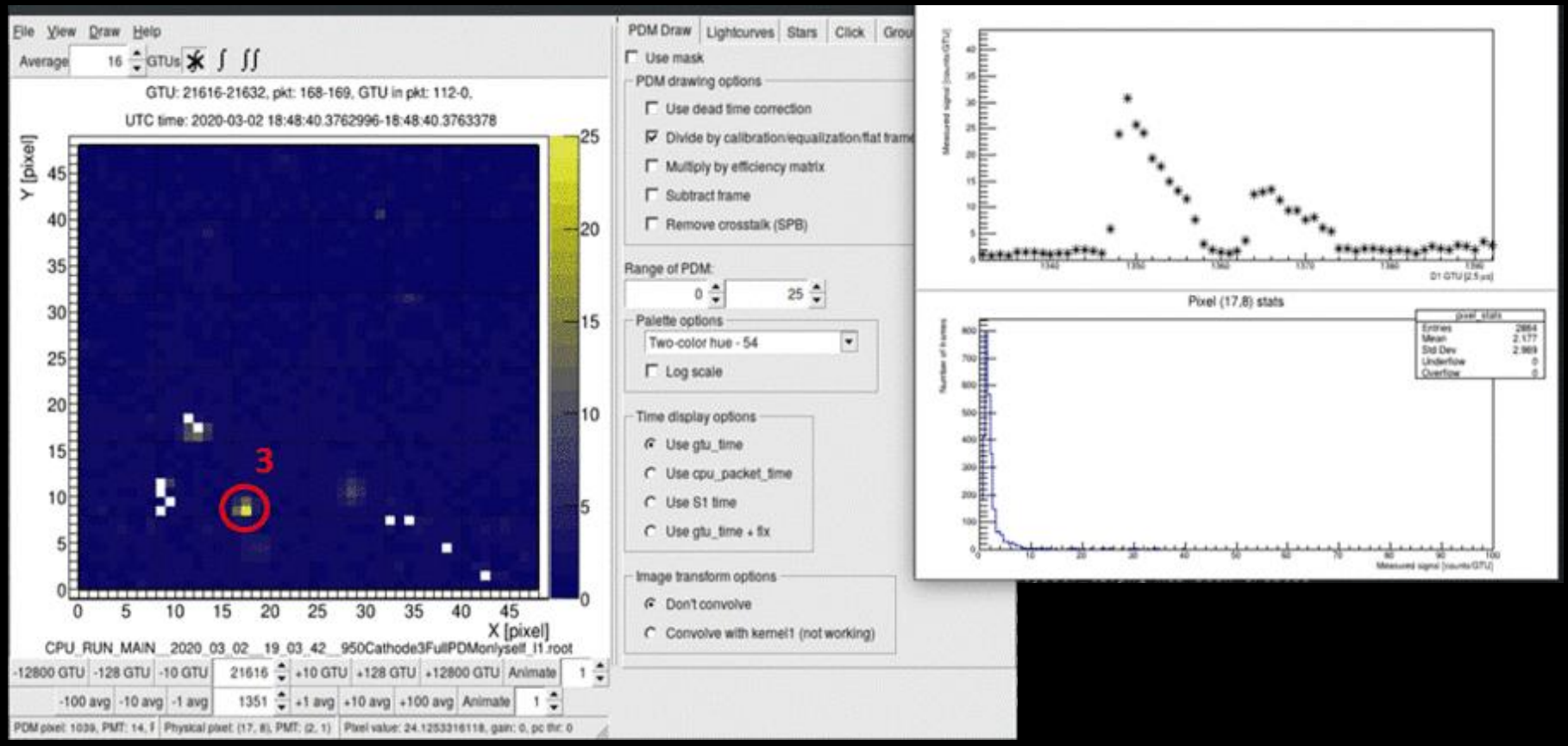








Ground flasher (triggered acquisition)



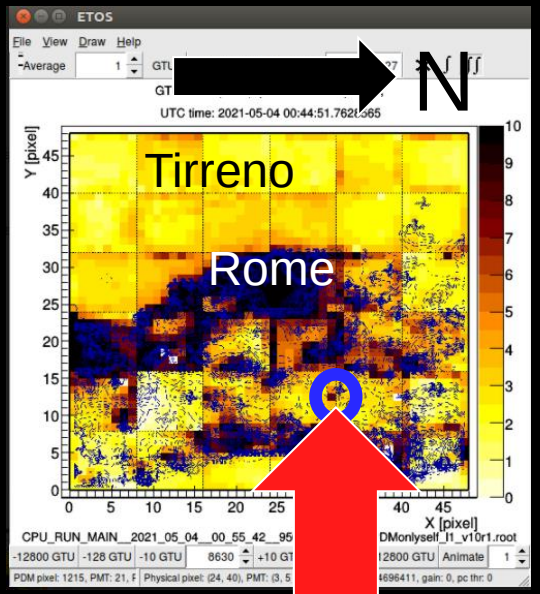
2.5 microsecond GTU, duration 20-100 GTU repeated – shifted - after >second

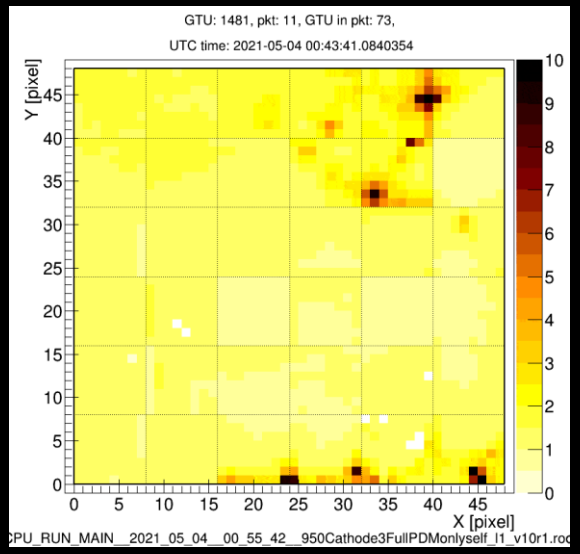
From F. Bisconti

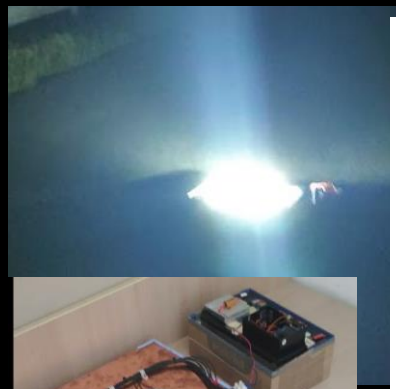
Shower simulation and end-to-end calibration with ground UV laser and UV flasher

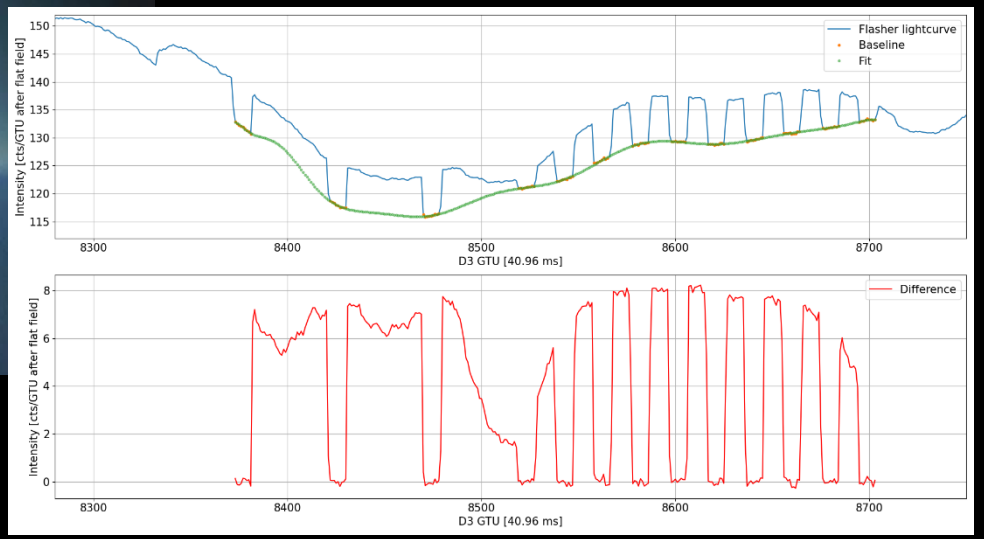
- Riken
- Tor Vergata
- Torino
- Moscow (Laser)
- USA (Laser)

- No trigger yet (Moscow laser)
- Shower emulation



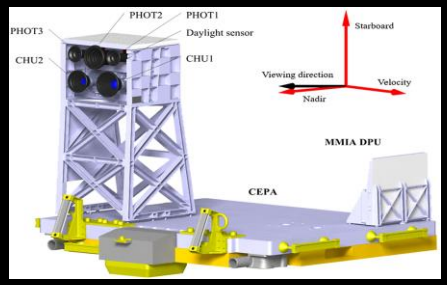






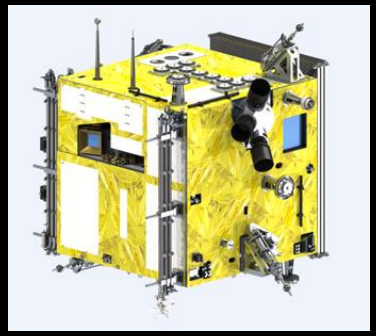
Joint observations with other detectors on the ISS

ASIM:
UV transients and ELVES



ALTEA-LIDAL («our»)
Correlation with radiation environment of cosmic rays 100 Mev – GeV and Transient Luminous Events

CSES-Limadou («our»)
(different orbit)



Financing for 2020 and 2021

紫外線撮像望遠鏡によるTAサイトでの空気シャワー蛍光光の観測、
令和 2年度475万円、
令和 3年度475万円、

…but most important is support and help from Telescope Array collaboration

Mini-EUSO: A high resolution detector for the study of terrestrial and cosmic UV emission from the International Space Station. Advances in Space Research, 62(10):2954{2965, Nov 2018.

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Conclusions

Measurements at TA site are of crucial importance for understanding and calibrating our systems

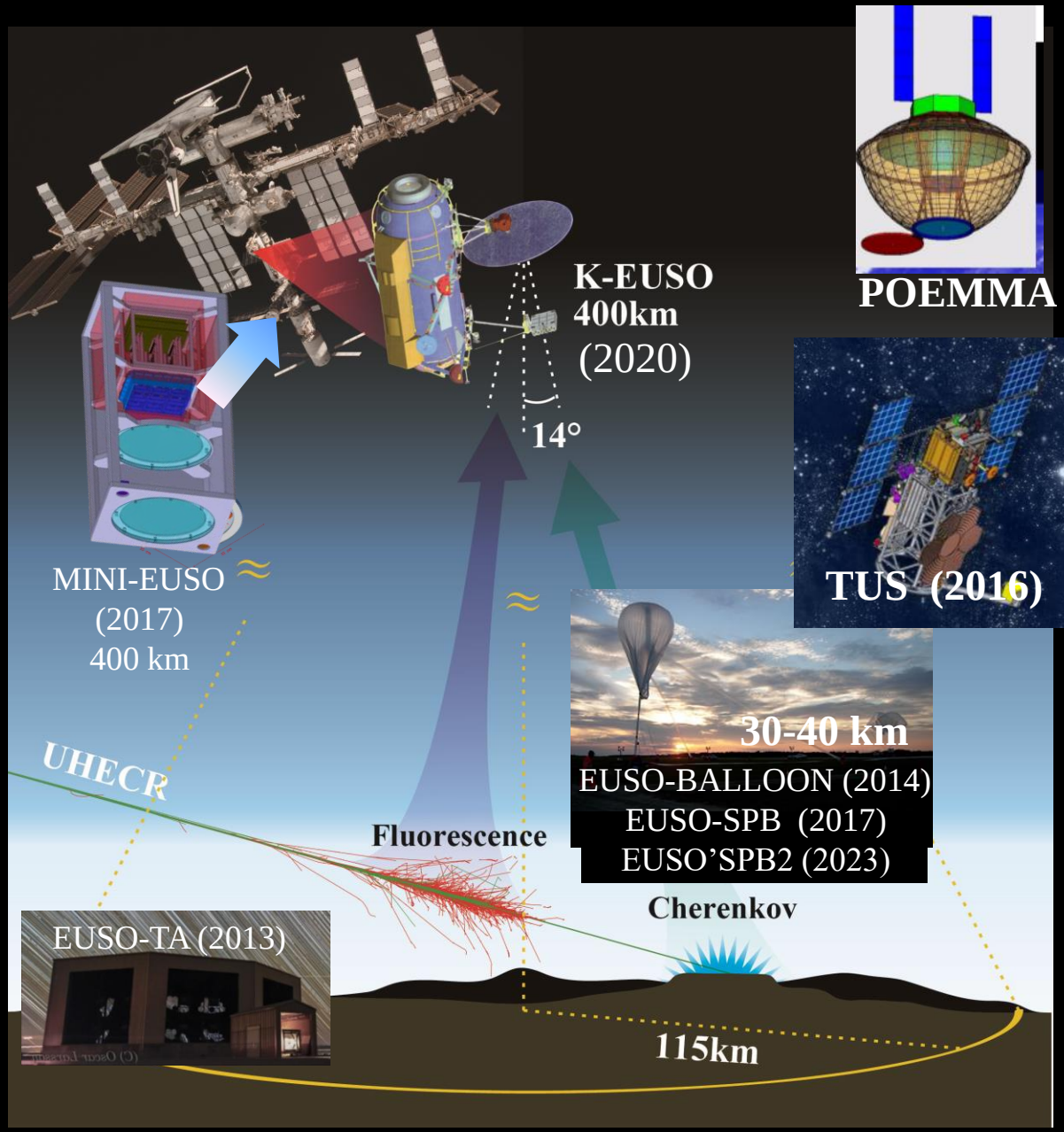
Roadmap to space

Detector development

Mini-EUSO is working correctly on ISS. *It proves that it is possible – with larger detectors – to perform UHECR observation from space, with measurements according to simulations*

EUSO-SPB2 will be launched in 2024

Plan to go to TA in 2022



JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people