Mini-EUSO on board the ISS: mission status and prospects

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(INFN, Structure of Rome Tor Vergata, Italy)

ASAPP 2023 Conference – Perugia, June 19-23, 2023

The JEM-EUSO program

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

2. EUSO-BALLOONS:

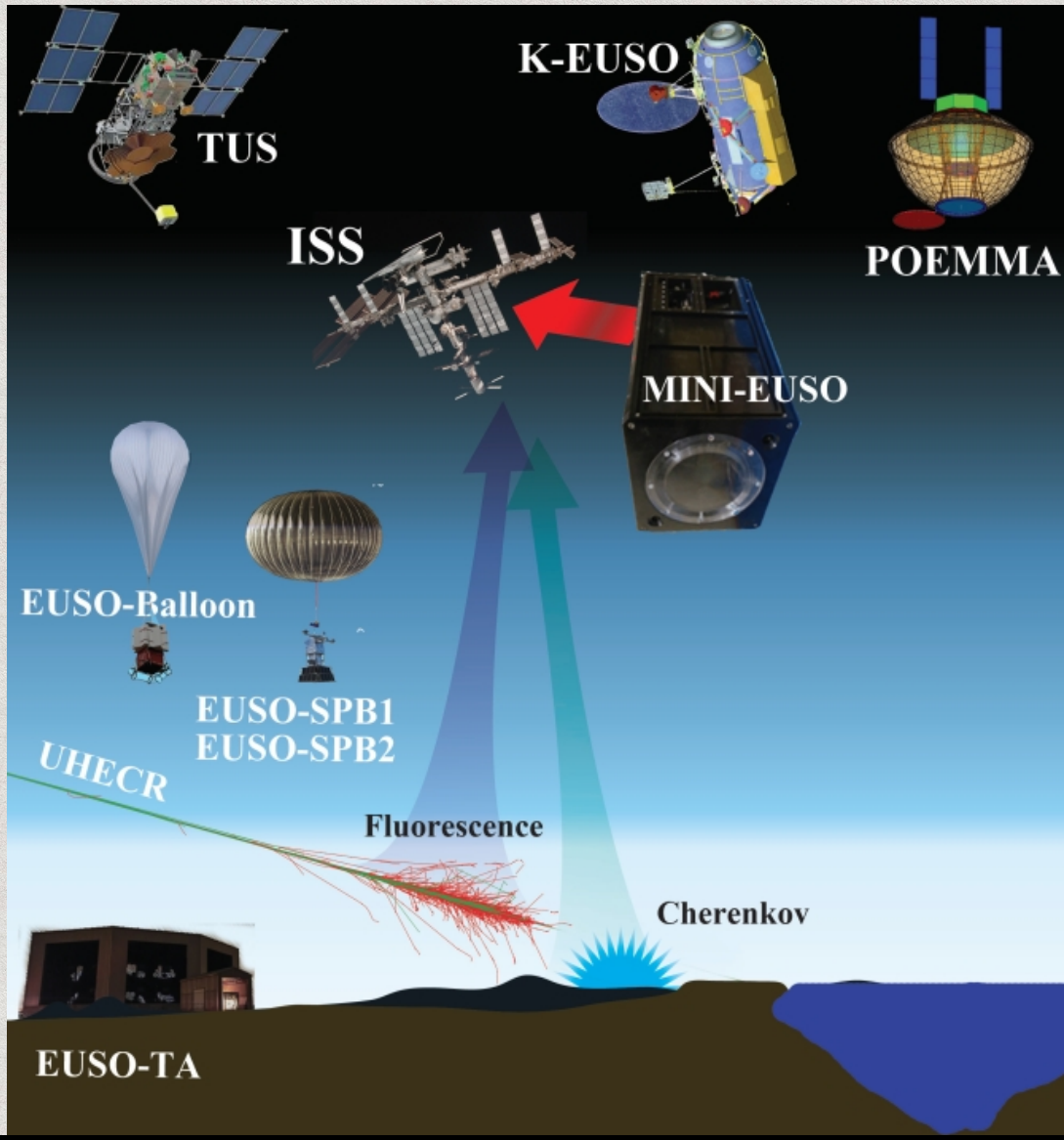
- *2014: EUSO-Balloon Timmins, Canada*
- *2017: EUSO-SPB, NASA, Ultra long duration flight*
- *2023: EUSO-SPB2, NASA, Ultra long duration flight*

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

4. Mini-EUSO (2019): *ISS, Beyond Mission (L. Parmitano)*

5. K-EUSO (2026+): *ISS, Phase A, Russian Space Agency*

6. POEMMA (2030+): *NASA twin free-flyer*



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

Mini-EUSO / UV-Atmosphere

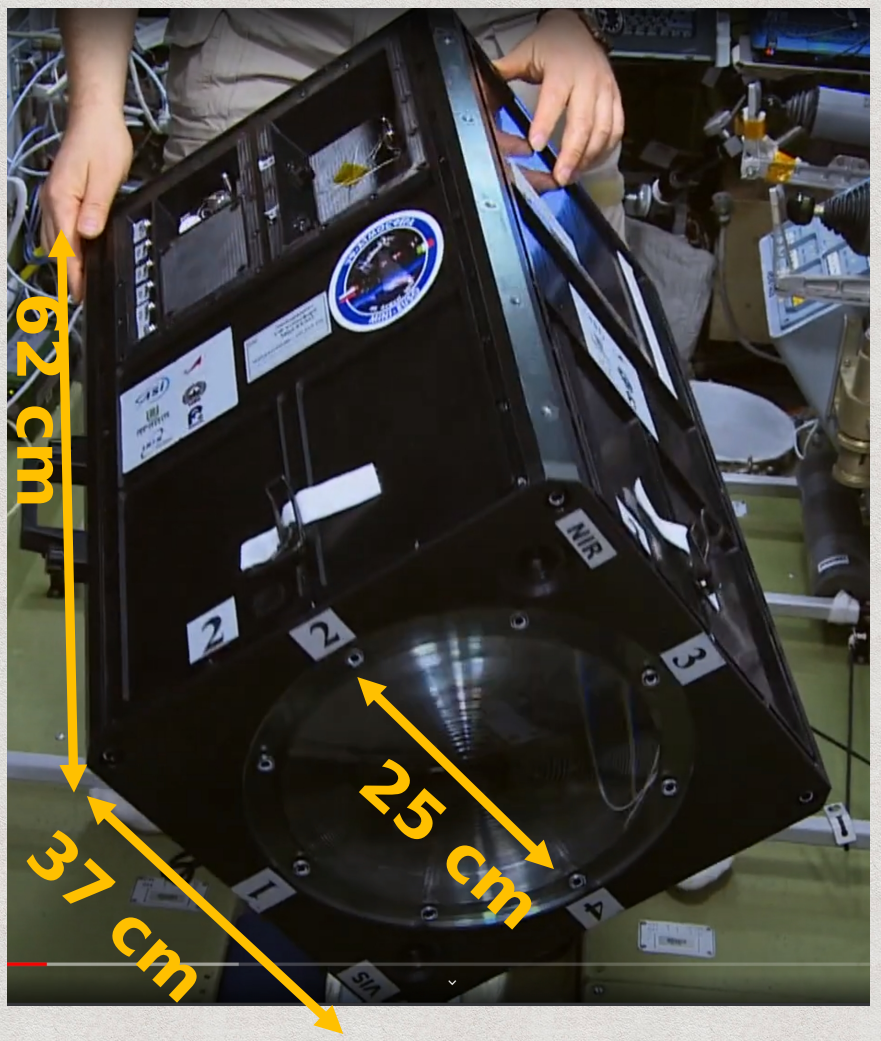
Multiwavelength Imaging New Instrument for the Extreme Universe Space Observatory

Installed on a UV-transparent window on board the ISS

Weight: 35 kg

Power consumption: 60 W

Dimensions: 37x37x62 cm^3



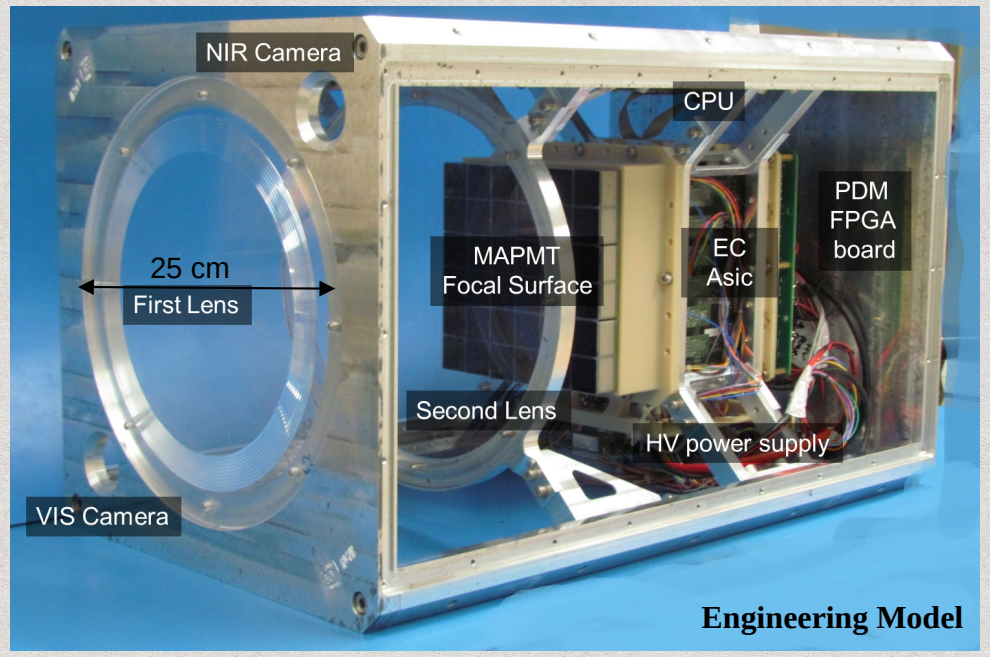
Mini-EUSO Mission to Study Earth UV Emissions on board the ISS
S. Bacholle et al., The Astrophysical Journal Supplement Series, 253:36, 2021

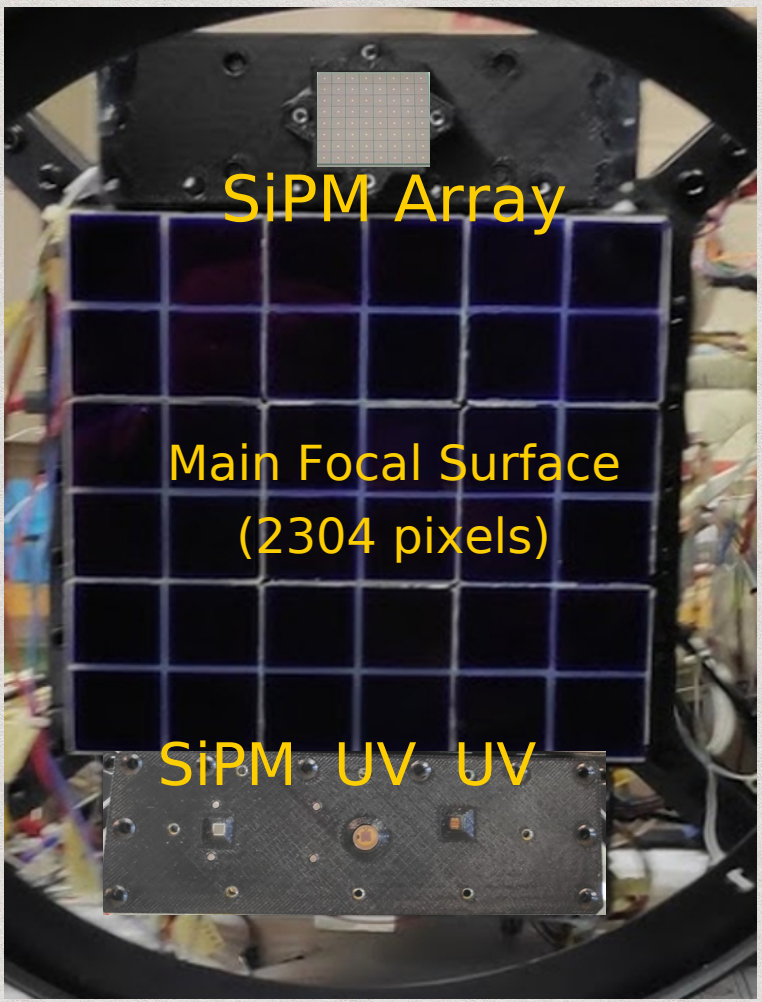
Mini-EUSO / UV-Atmosphere

Multiwavelength Imaging New Instrument for the Extreme Universe Space Observatory

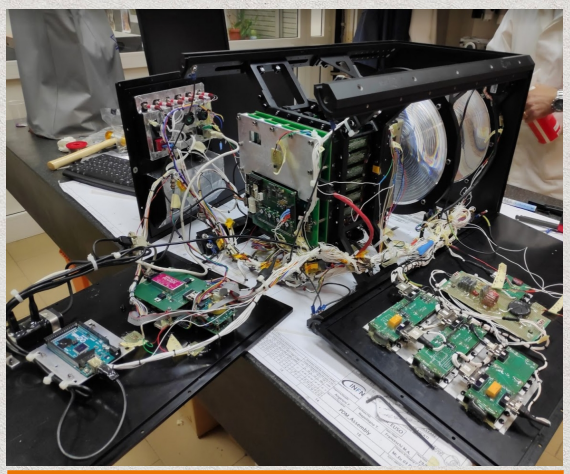
Mini-EUSO main sensors:

- Ultraviolet telescope with Fresnel lenses (48*48 pixels, FoV= 44 deg, ~320x320 km^2, 2.5 μs and above)
- Near Infrared camera (1280*960 pixels, FoV=33.2*24.8 deg, 231*174 km^2, 1s)
- Visible camera (1280*960 pixels, FoV=33.2*24.8 deg, 231*174 km^2, 4s)
- SiPM (8*8 pixels) and UV sensors



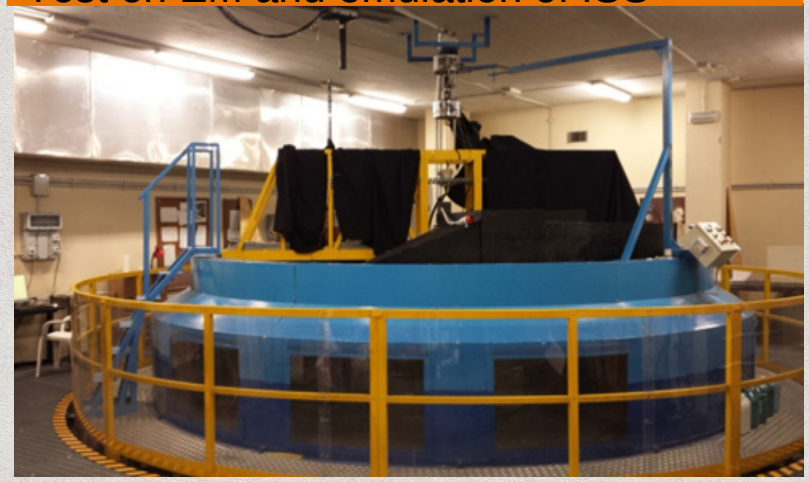


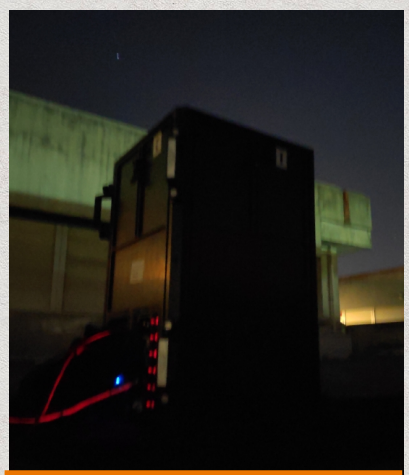
Integration and Tests of EM and FM @ INFN
2017-2019



INFN, Tor Vergata and LNF
Integration & Mechanics

TUR-LAB, Univ and INFN Torino
Test on EM and emulation of ISS



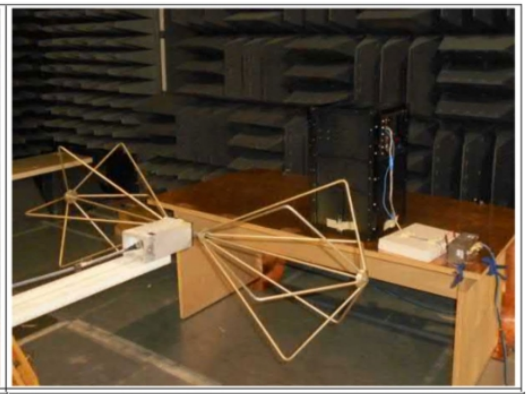


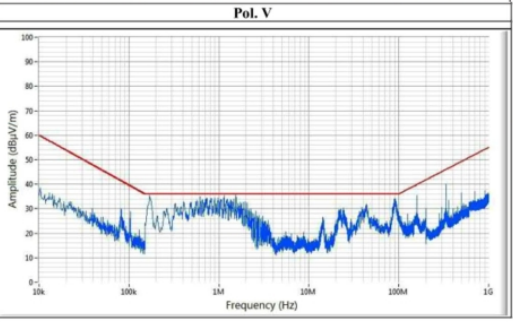
INFN, Tor Vergata
Sky tests (FM)

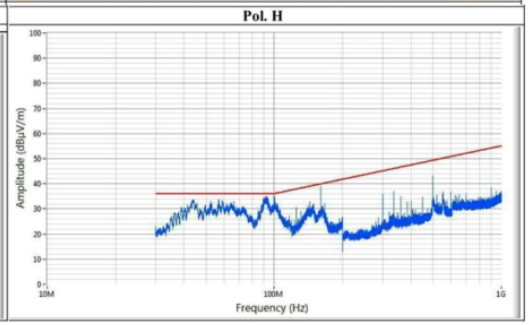
INFN, Tor Vergata
Qualification and
Acceptance tests

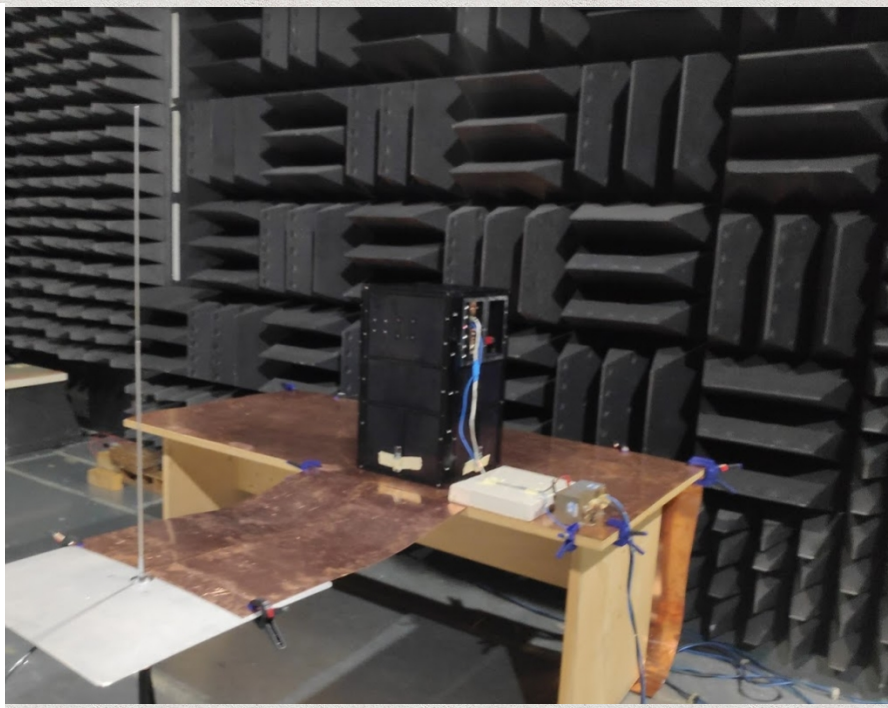
INFN, Tor Vergata
L. Parmitano & Mini-EUSO in the black box

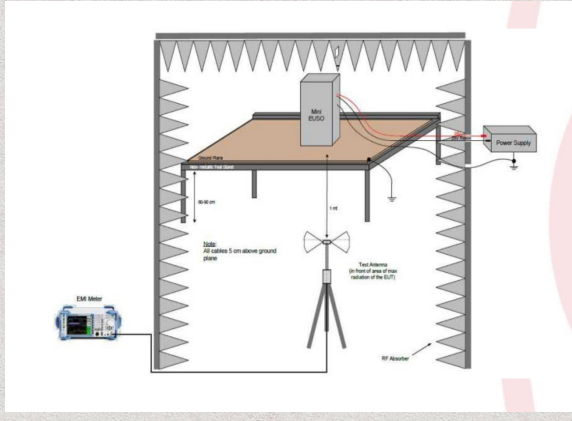
EMI/EMC tests in Pisa (GSD Laboratories) - 14/1/2019



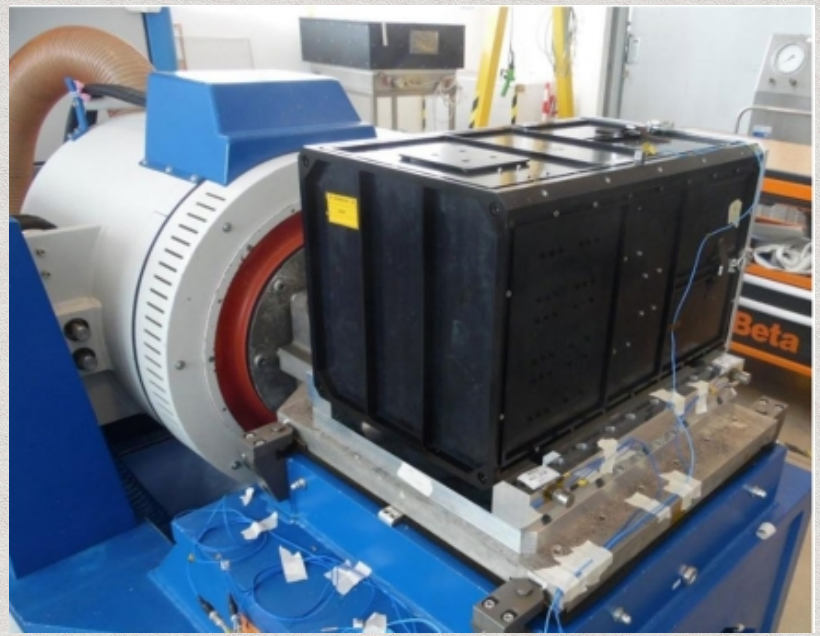


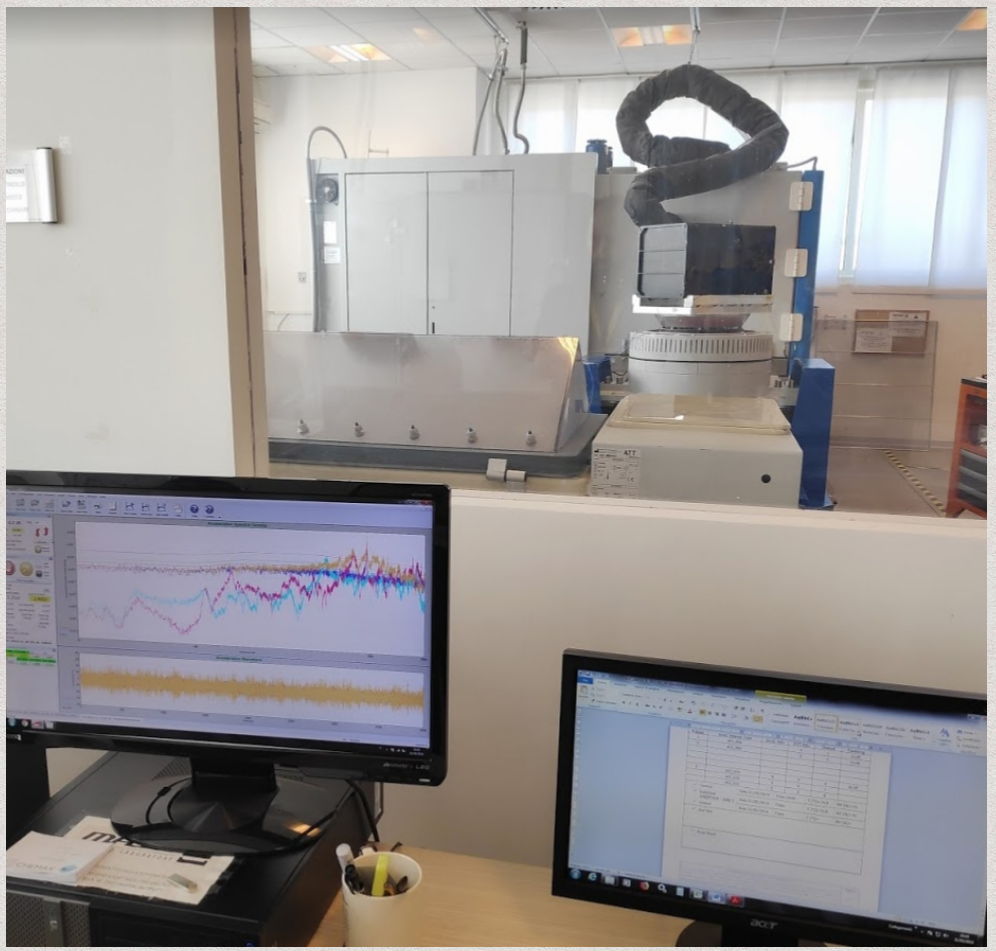


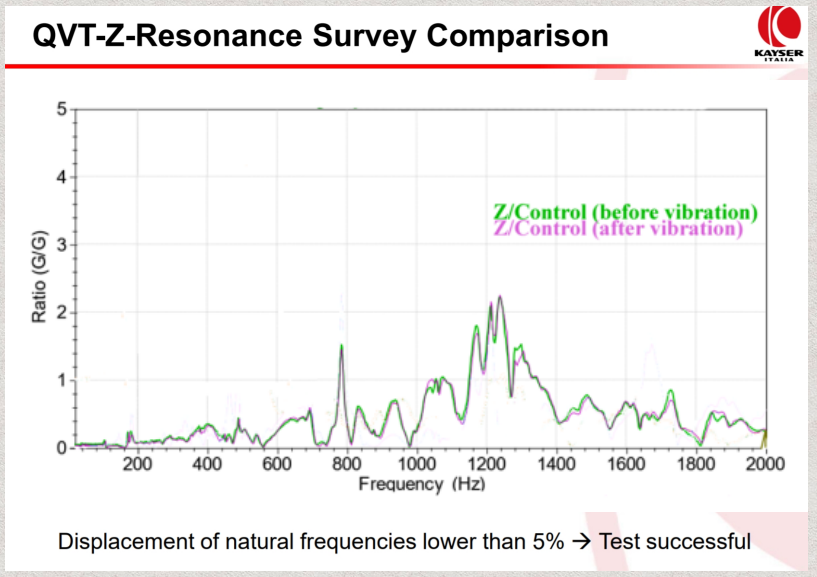




Vibration tests in Torrita di Siena (MATE Laboratories) - 31/5/2019







Integration, qualification, and launch of the Mini-EUSO telescope on board the ISS
L. Marcelli et al., Rendiconti Lincei (2023)

Acceptance tests in Baikonur and integration with Soyuz – August 2019

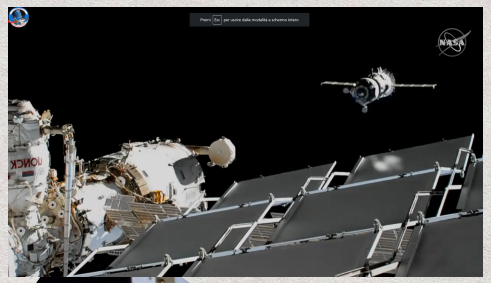
Building 254, assembly of Soyuz/Progress

Roll-out of Soyuz MS-14, 19/8/2019

Launch, 22/8/2019

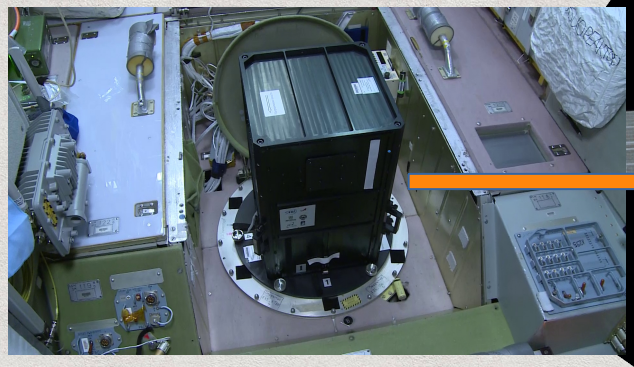
First docking, 24/8/2019 unsuccessful

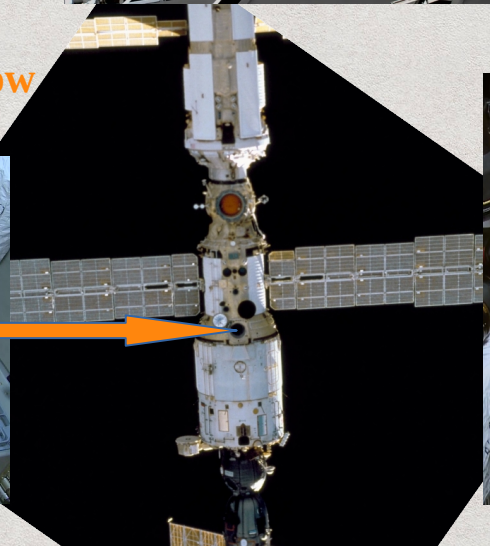
Relocation of MS-13 from Zvezda to Poisk

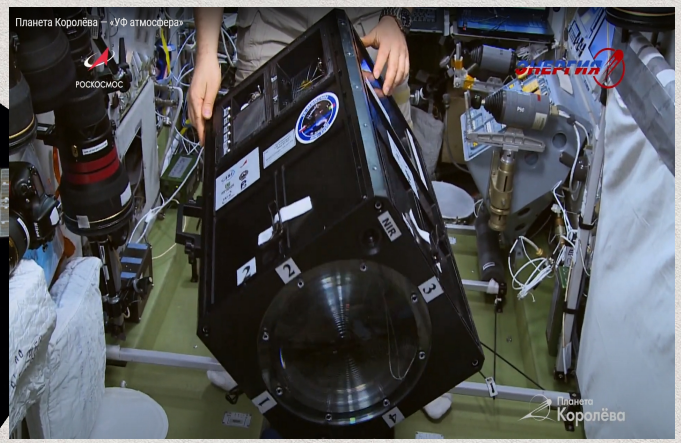


Second docking, 27/8/2019 successful

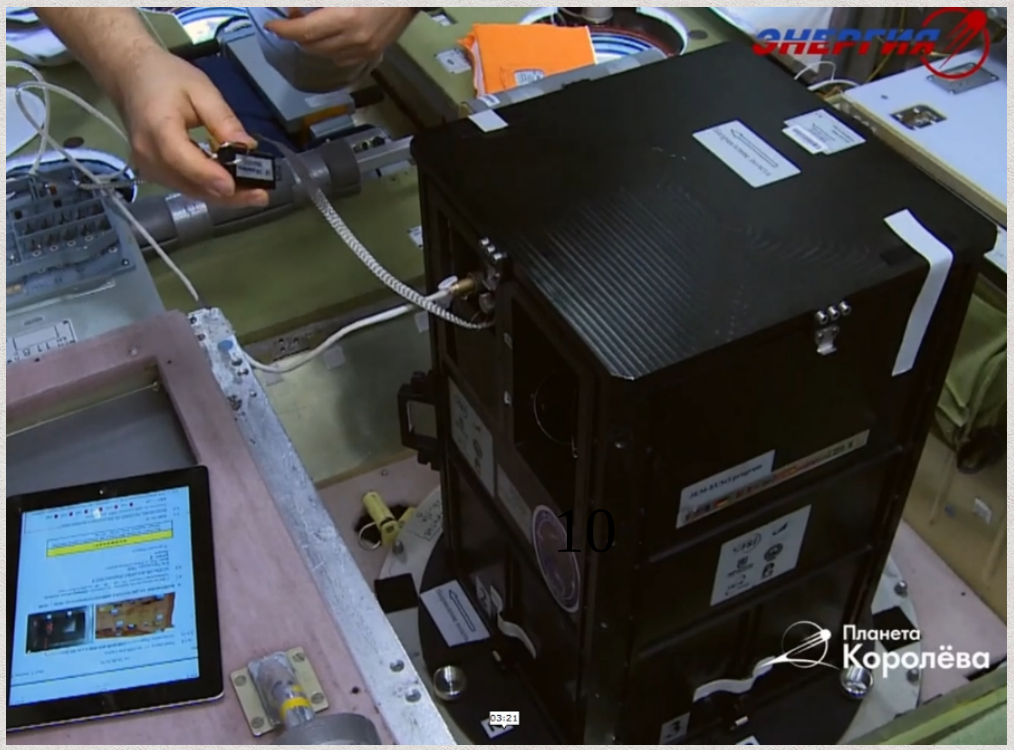
Installation - UV transparent window Zvezda module, 07/10/2019

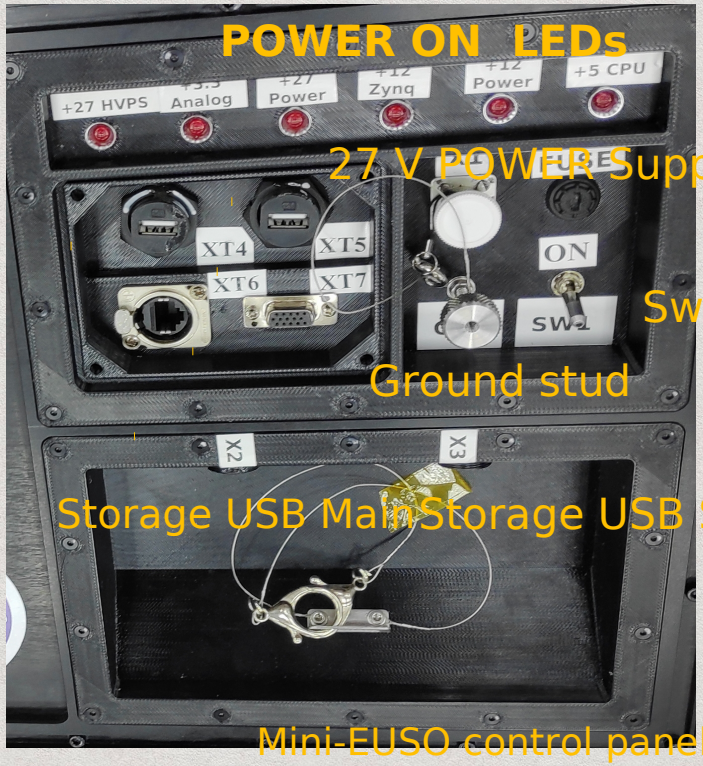






Mini-EUSO in-flight operations





START OF SESSION

- Latch on the UV-trasparent window
- Connect 27V power supply cable
- Connect grounding cable
- Insert and latch the USB stick
- Turn on the switch

END OF SESSION

- Turn off the switch
- Remove and store USB stick
- Periodically copy of selectet files on
- station computer for later downlink
- Unlatch and store the instrument

Mini-EUSO in-flight operations

Launch: August 2019

Pouch003: sessions 1-14
Returned in April 2020

Pouch004: sessions 15-44
Returned in October 2021

Pouch003_v2: sessions 45-(?)
Currently in use

Pouch004_v2:
Ready to be launched!

~3 sessions/month
~12 hours/session

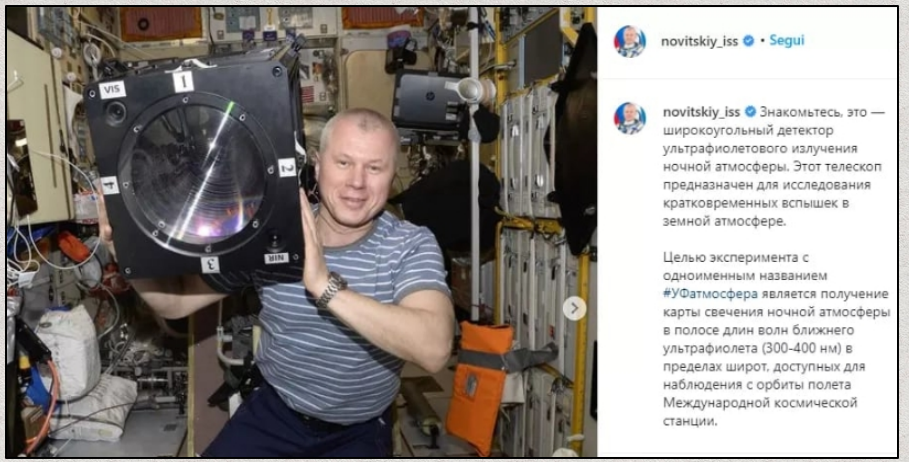
~20 GB stored each session
(data subset downlinked
via telemetry channel)

Mini-EUSO on the ISS

Sergei Kud-Sverchkov

Twitter from I. Vagner

Oleg Artemyev



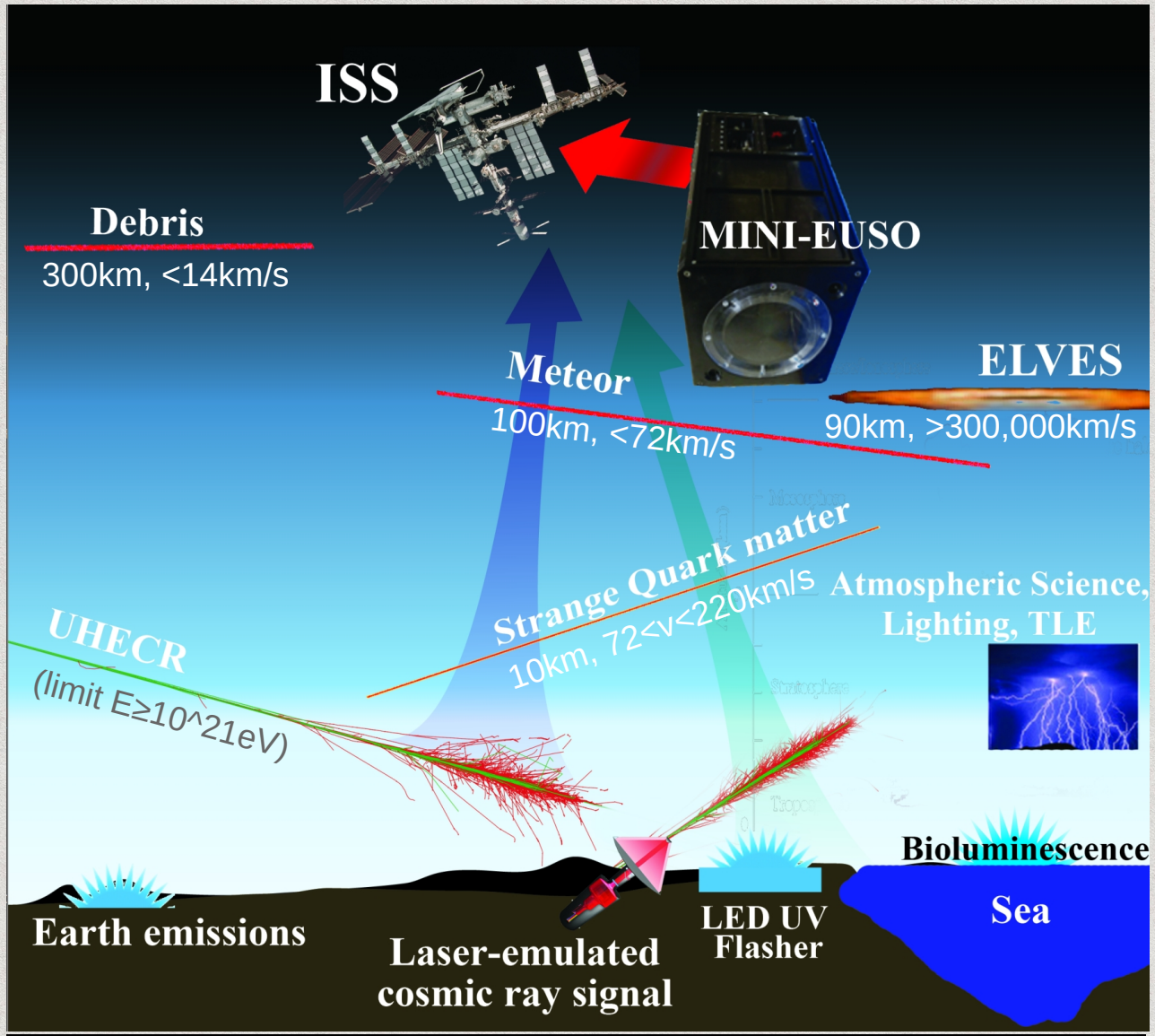
Twitter from O. Novitskiy

O. Skripocka: outreach video from ISS
https://www.youtube.com/watch v=lXedBGVHc4o&t=62s

85 sessions performed

>150 crew hours

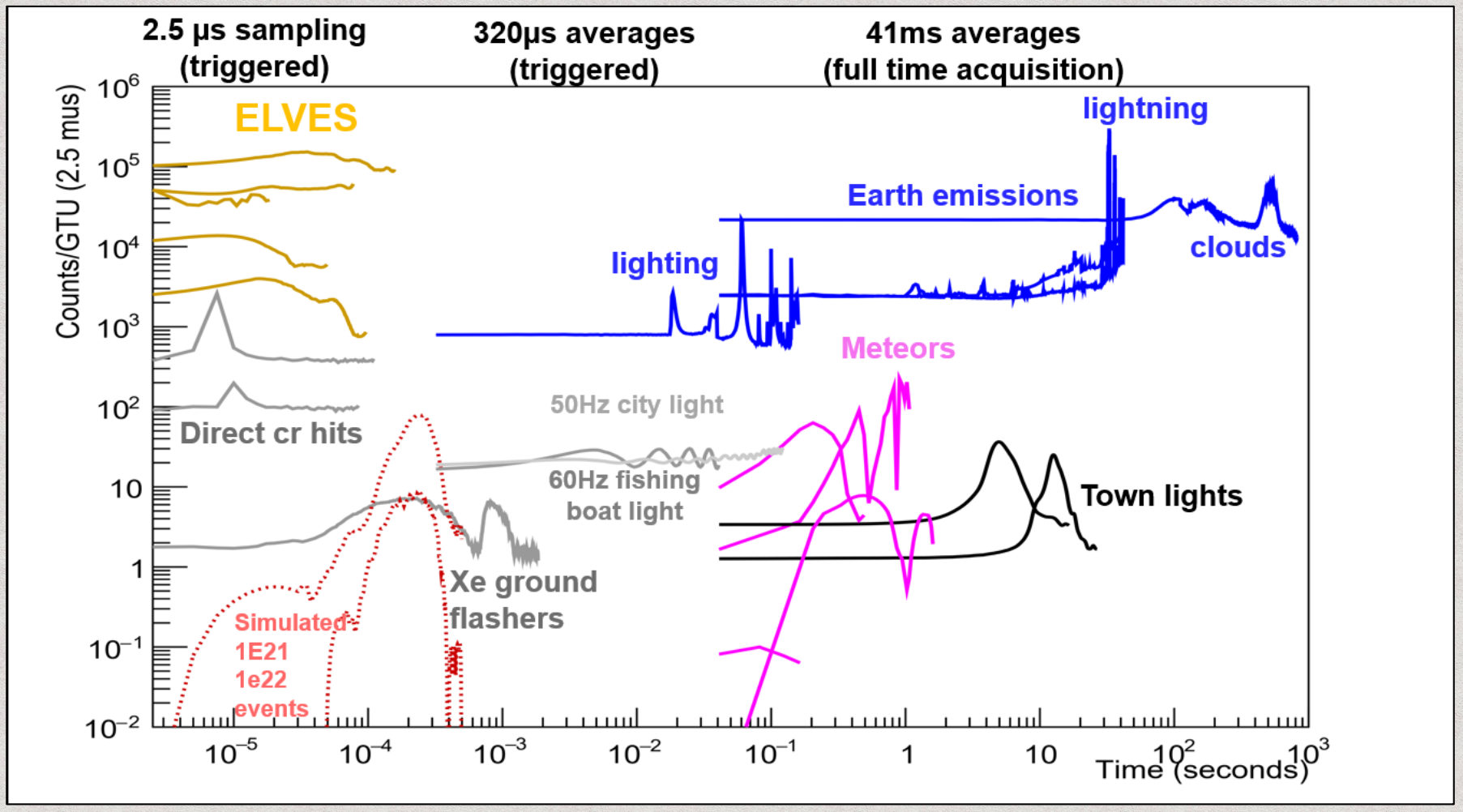
Scientific Objectives



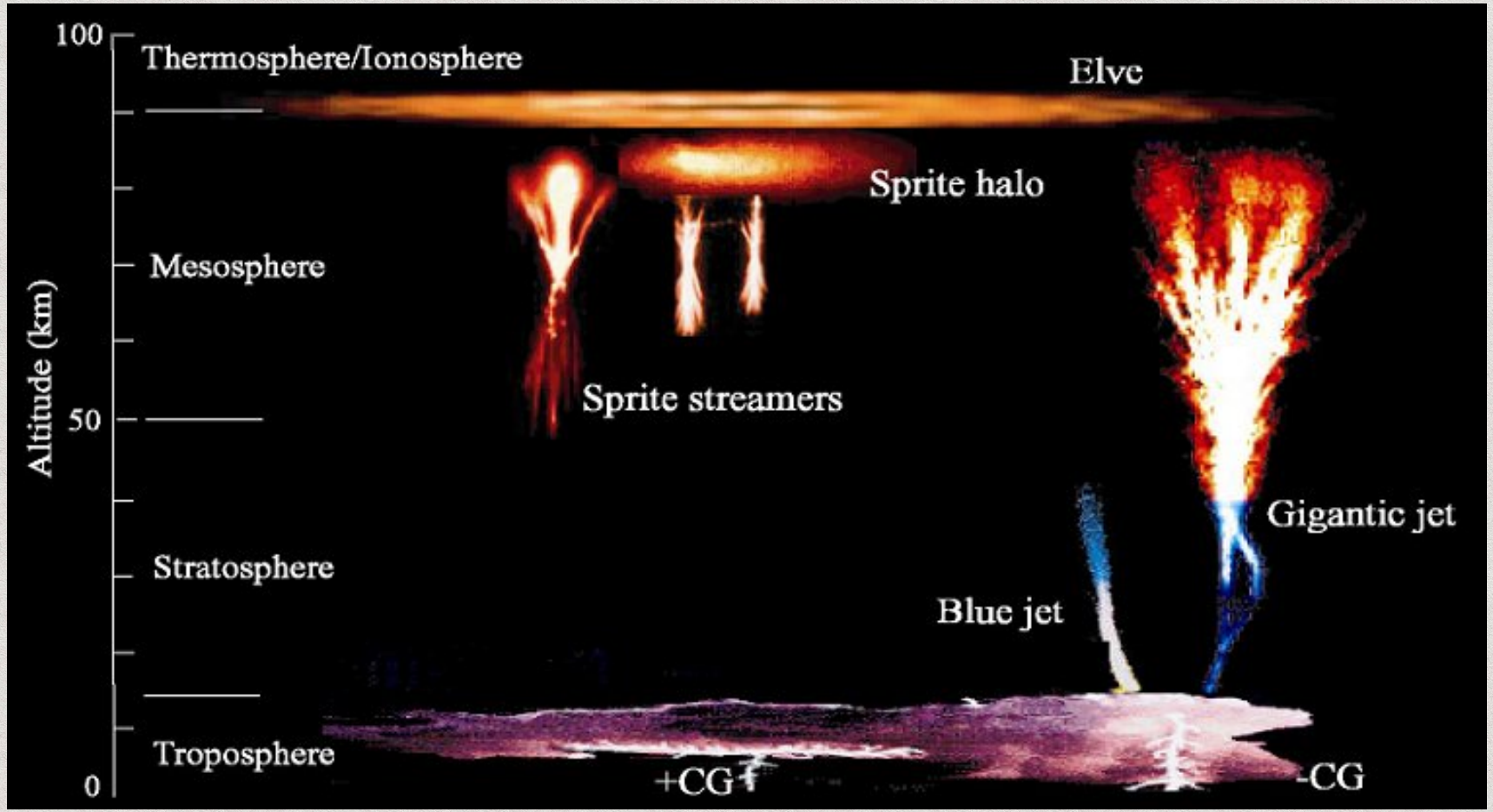
Time profile of various events

2.5 µs X 128 — 320 µs X 128

D1 acq. mode → D2 acq. mode → D3 acq. mode



ELVES

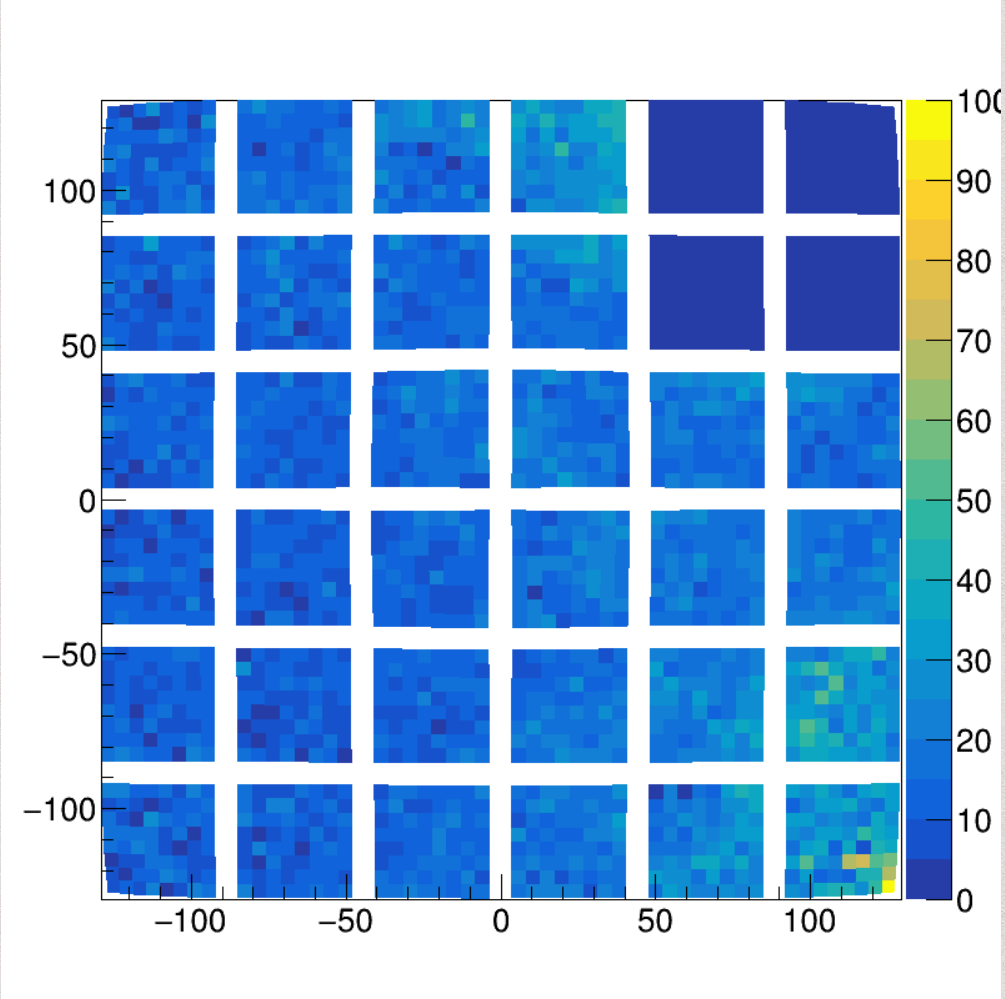


Apparently superluminal rings

Upper atmospheric lighting releases e.m. wave which heats the ionosphere

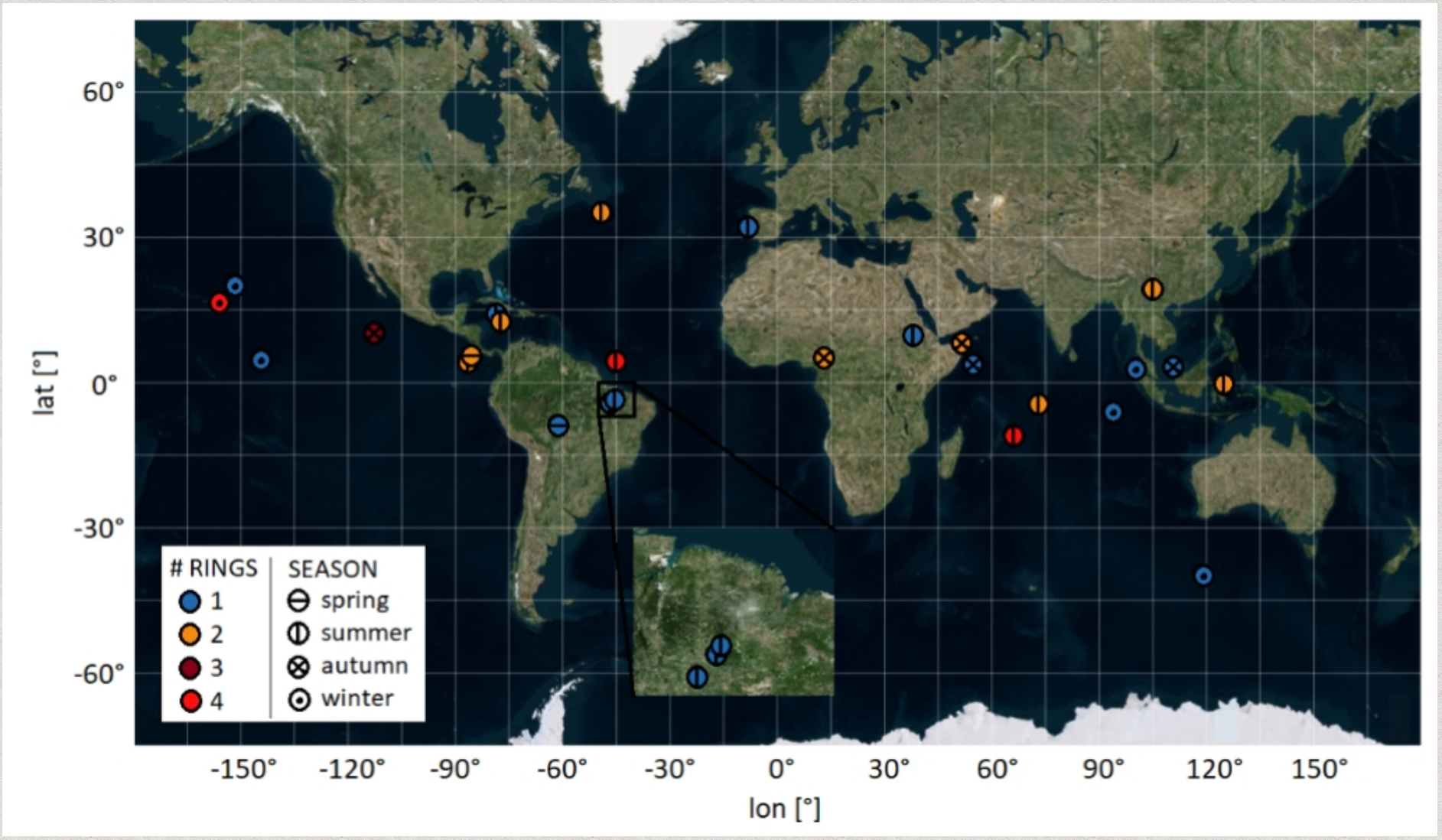
ELVES

Time sampling: 2.5 µs
Pixel size: 5x5 km² (@ 90 km)
Elve lifetime: about 400µs



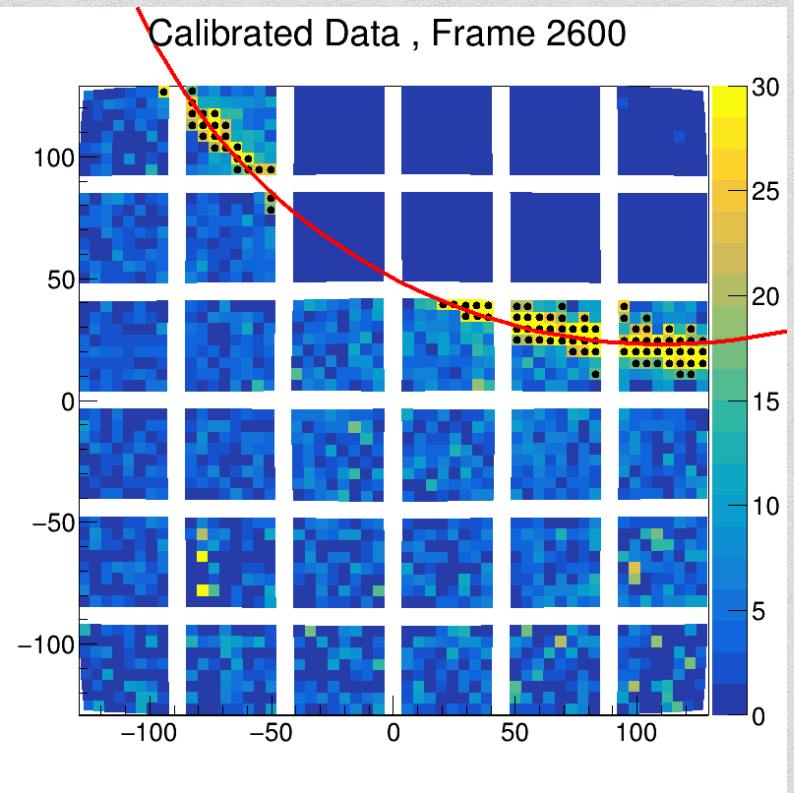
ELVES

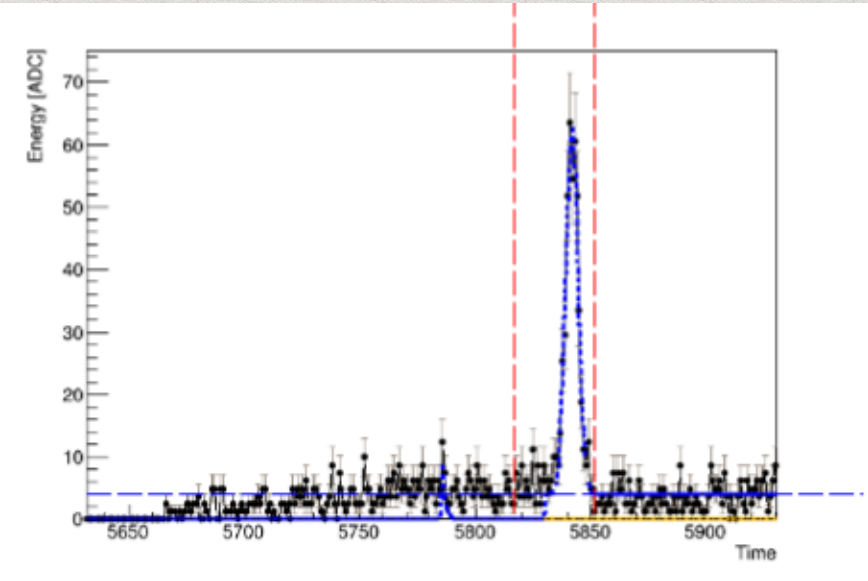
30 ELVES detected, mostly in the equatorial region



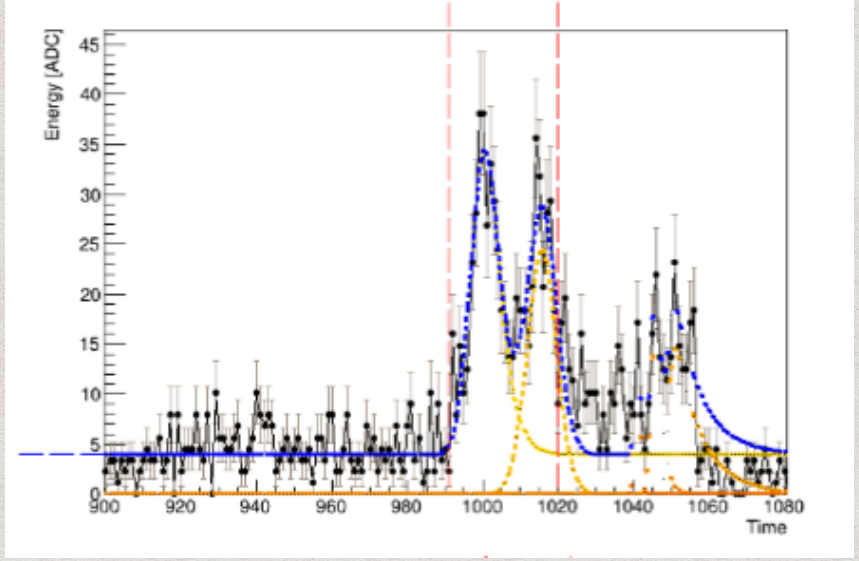
ELVES

From G. Romoli



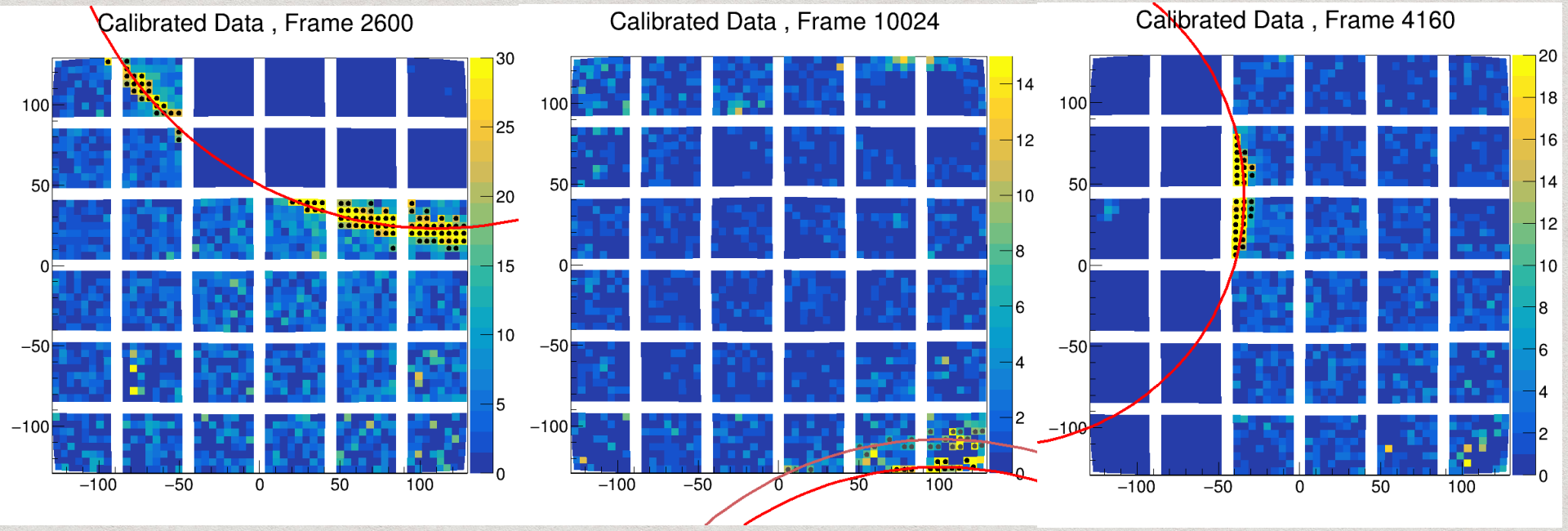


Pixel signal (pixel lightcurve) -> ELVES classification



ELVES

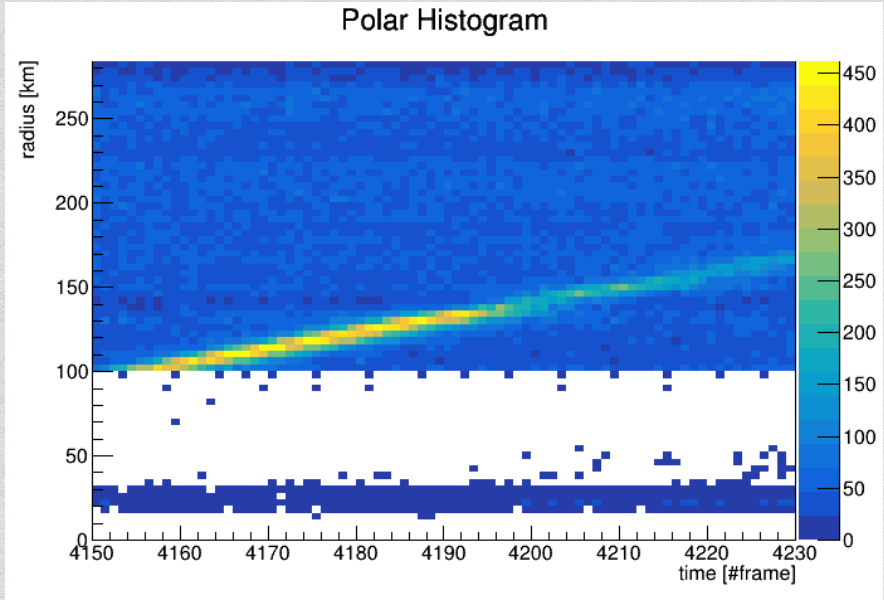
From G. Romoli

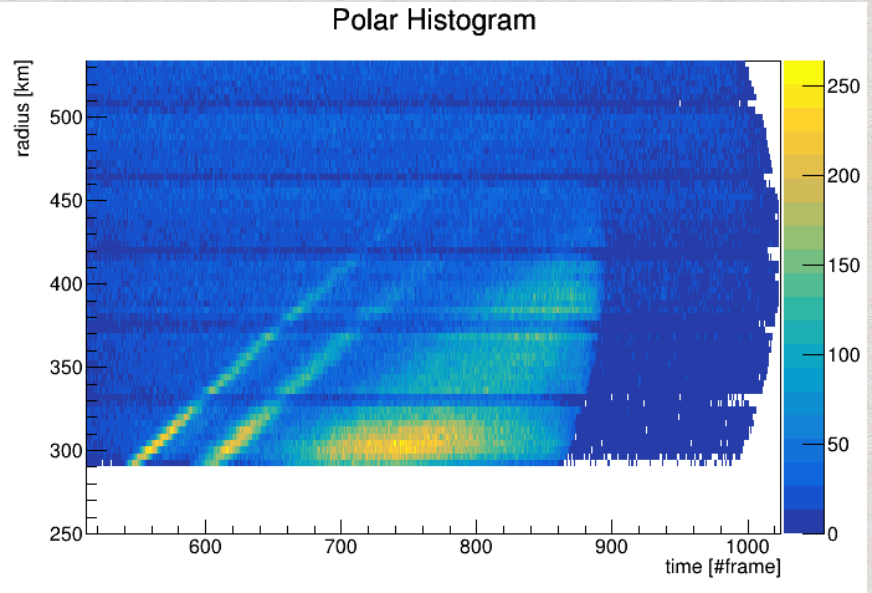


Tracking fitting algorithm -> ELVES centre

ELVES

From G. Romoli / Z. Plebaniak

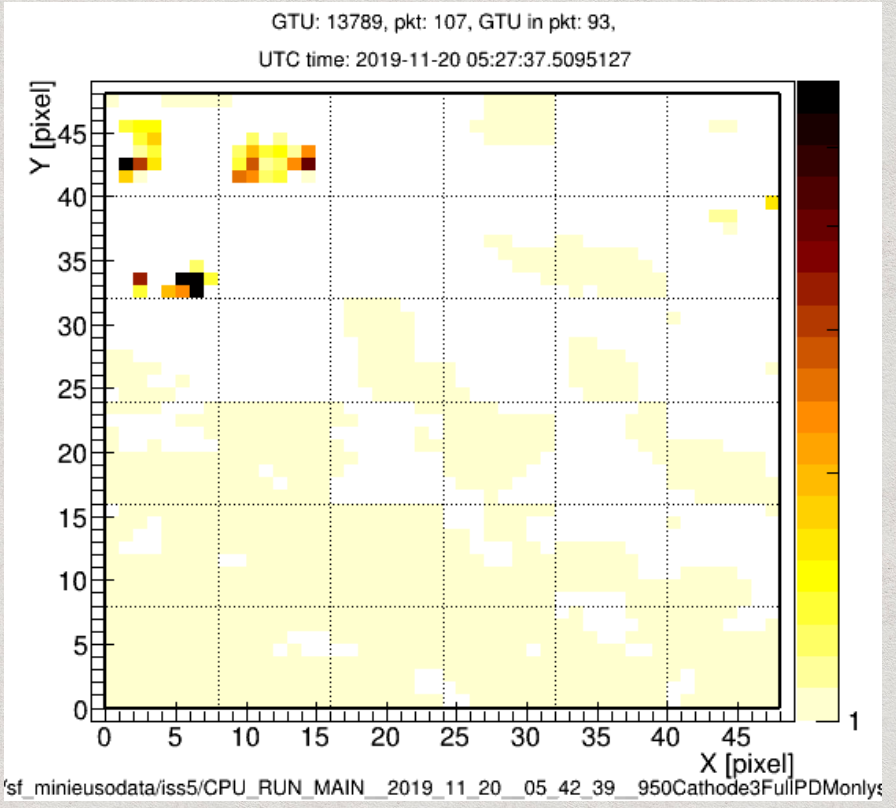


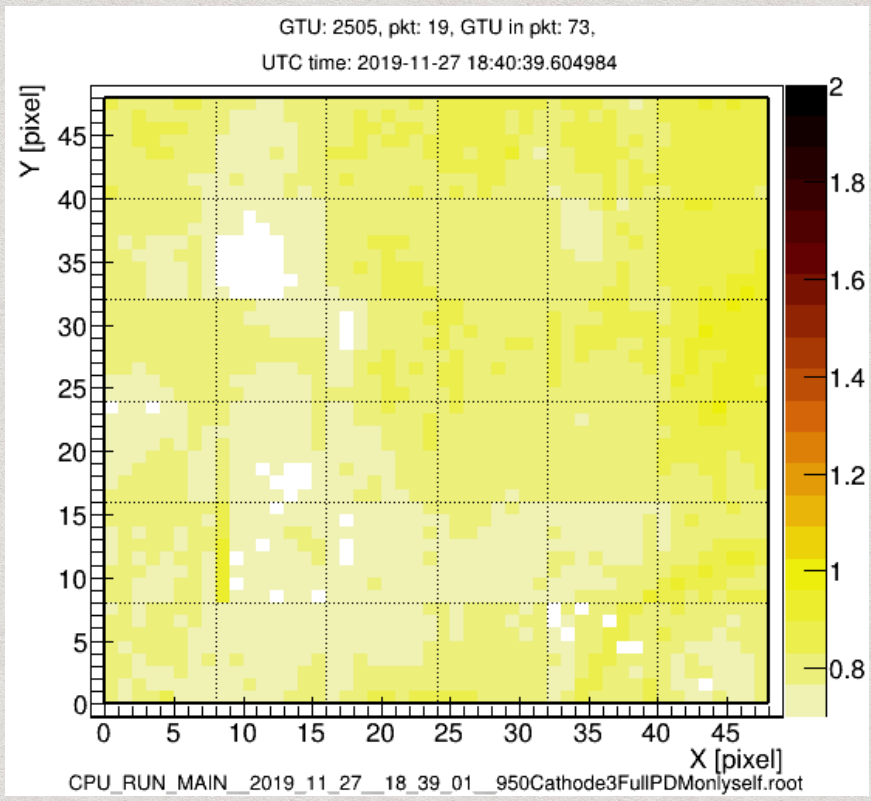


Polar histogram - > ELVES speed and classification

Meteors

Time sampling: 40.96 ms

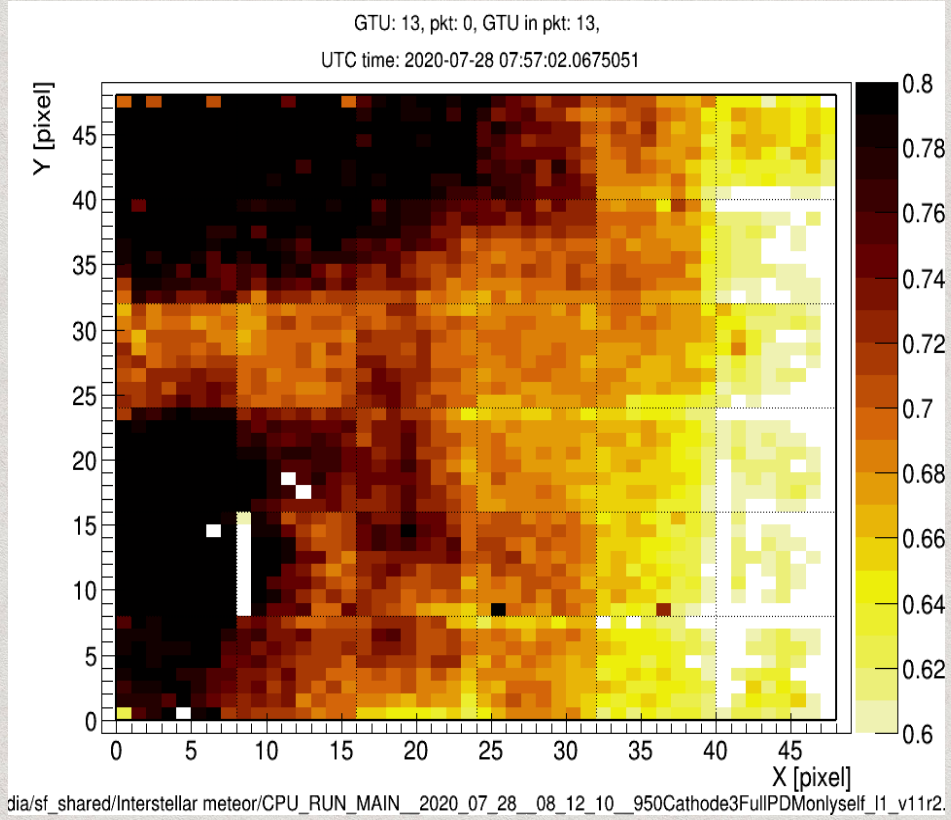


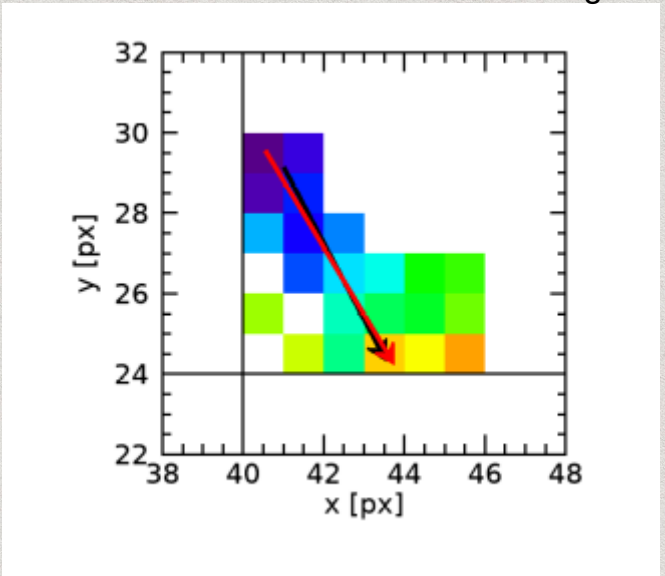


Mini-EUSO meteor dataset: 24k

Meteor tracking algorithm

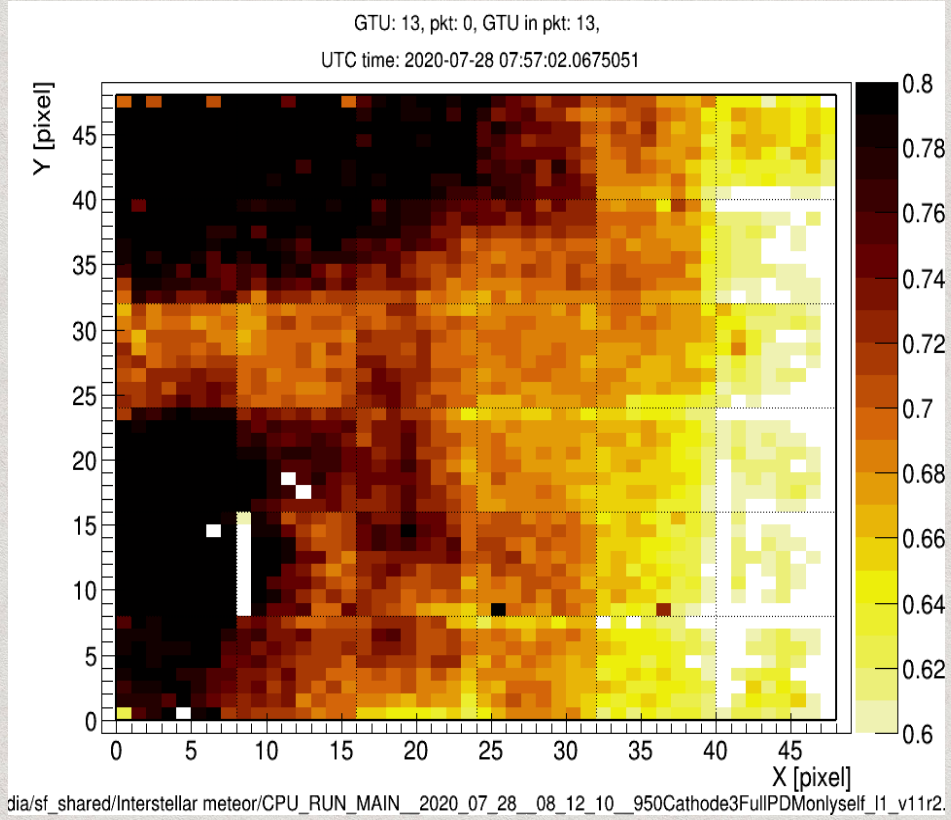
From D. Barghini

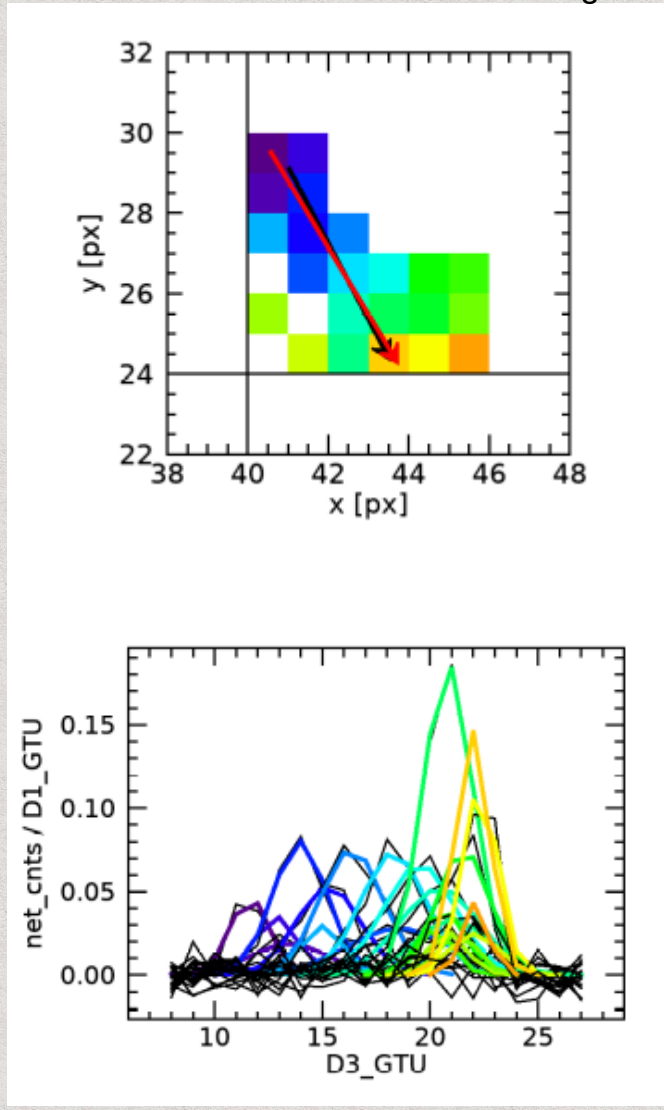




Meteor tracking algorithm

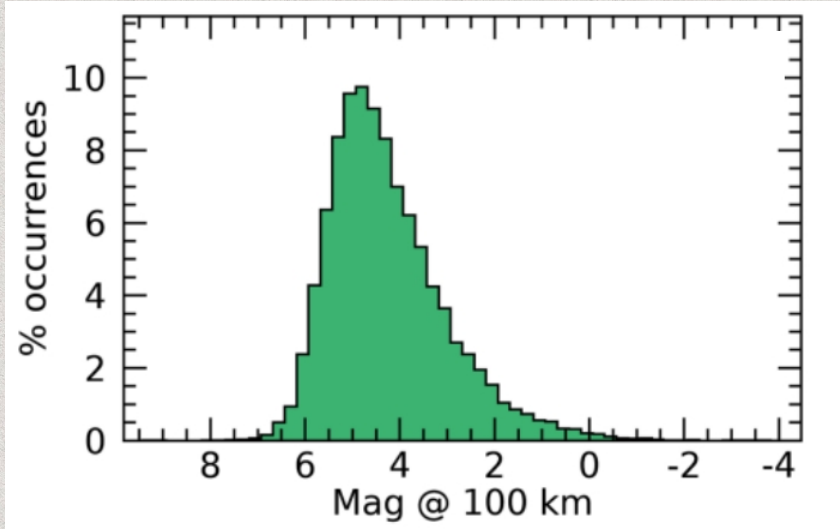
From D. Barghini

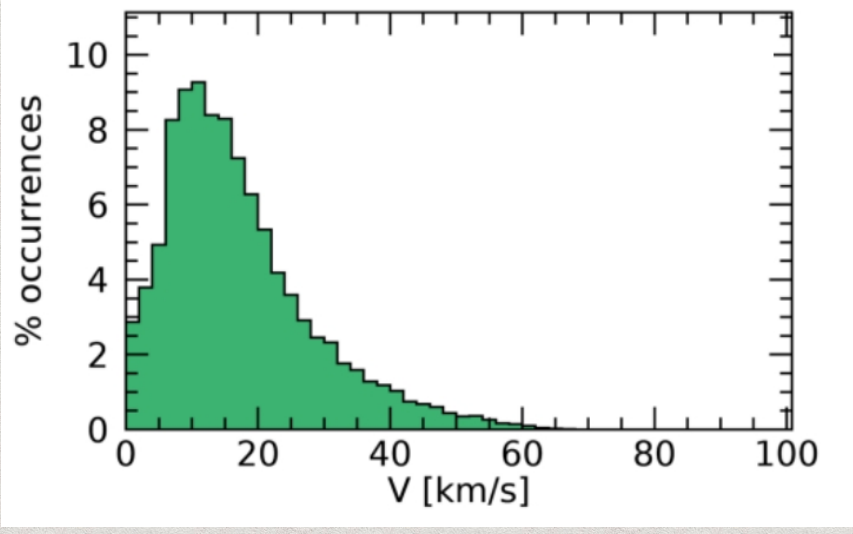




Meteors

From D. Barghini

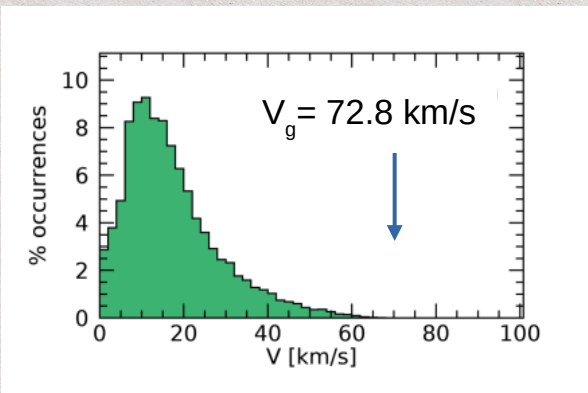




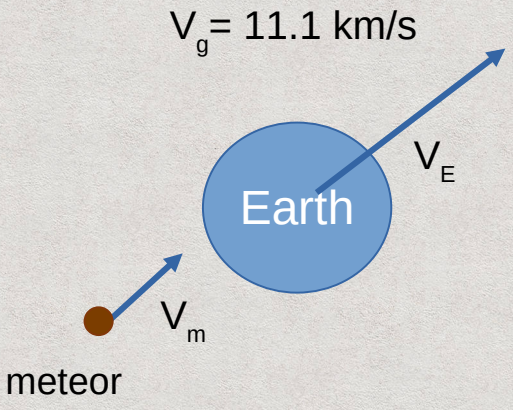
Mag 7 → ~ 2 mg
Mag 5 → ~ 10 mg
Mag 0 → ~ 0.1 g

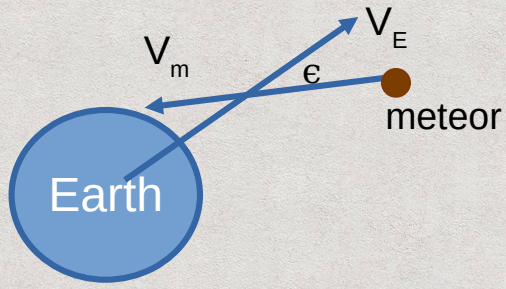
Mini-EUSO meteor dataset: 24k

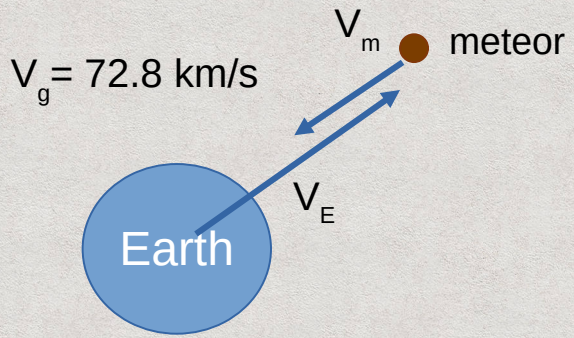
Interstellar meteors



Solar system meteors: 11.1 km/s < v_g < 72.8 km/s

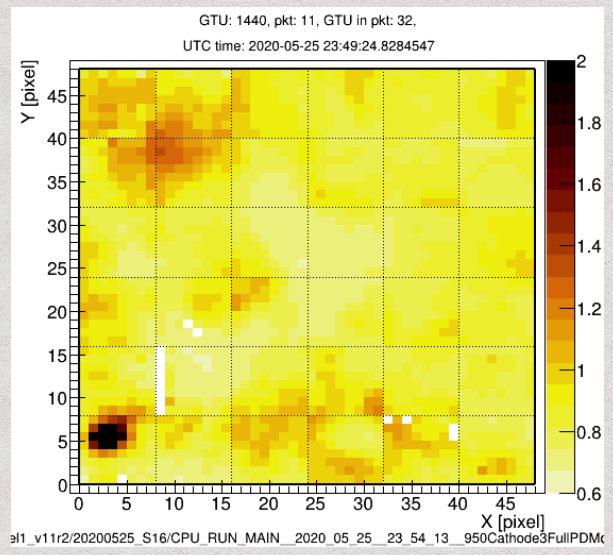




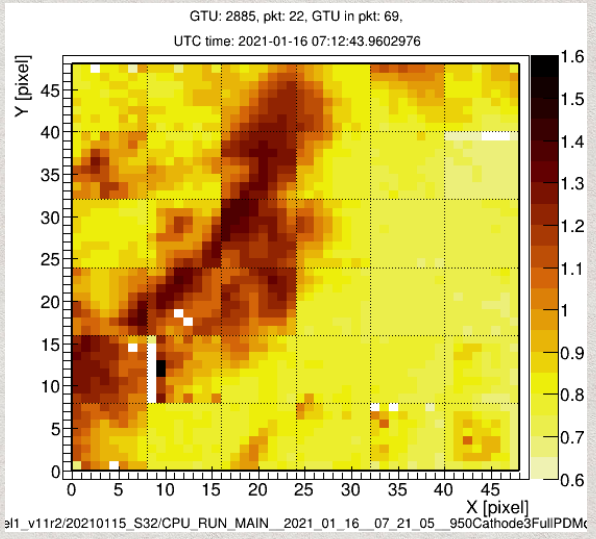


Interstellar meteors: meteor speed above solar system allowed speed

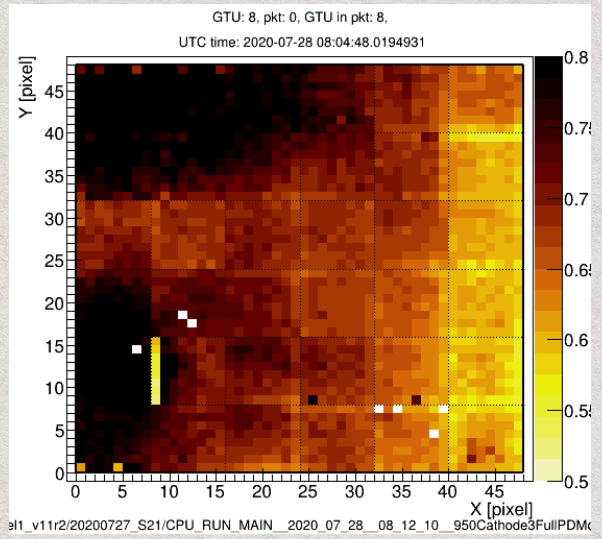
Interstellar meteors: three candidates



V_{hor} = 33 ± 2 km/s
M= 2.7 ± 0.1
N_{pix} = 9
ΔT = 0.70 s



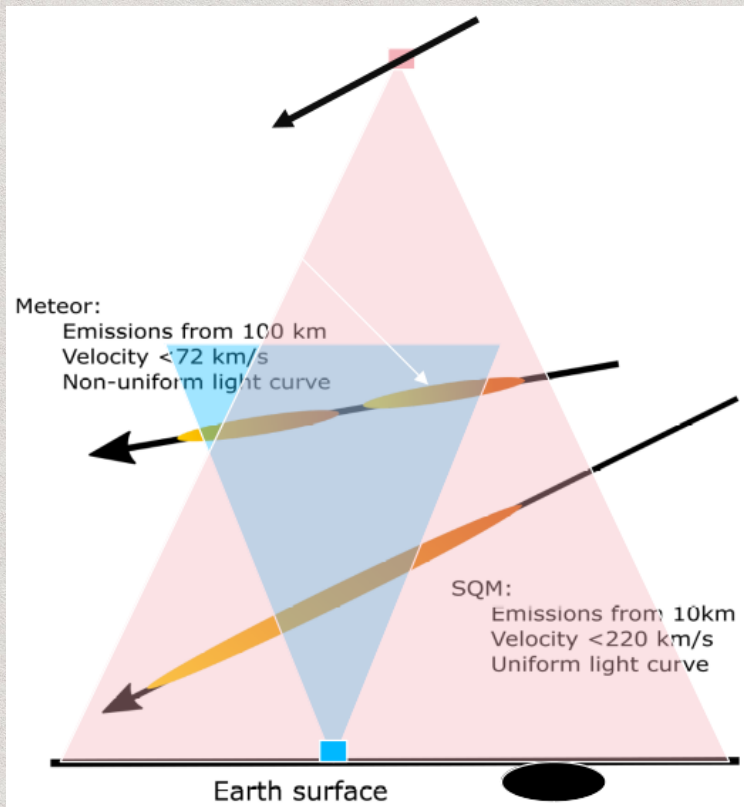
V_{hor} = 42 ± 4 km/s
M= 3.3 ± 0.1
N_{pix} = 22
ΔT = 0.82 s

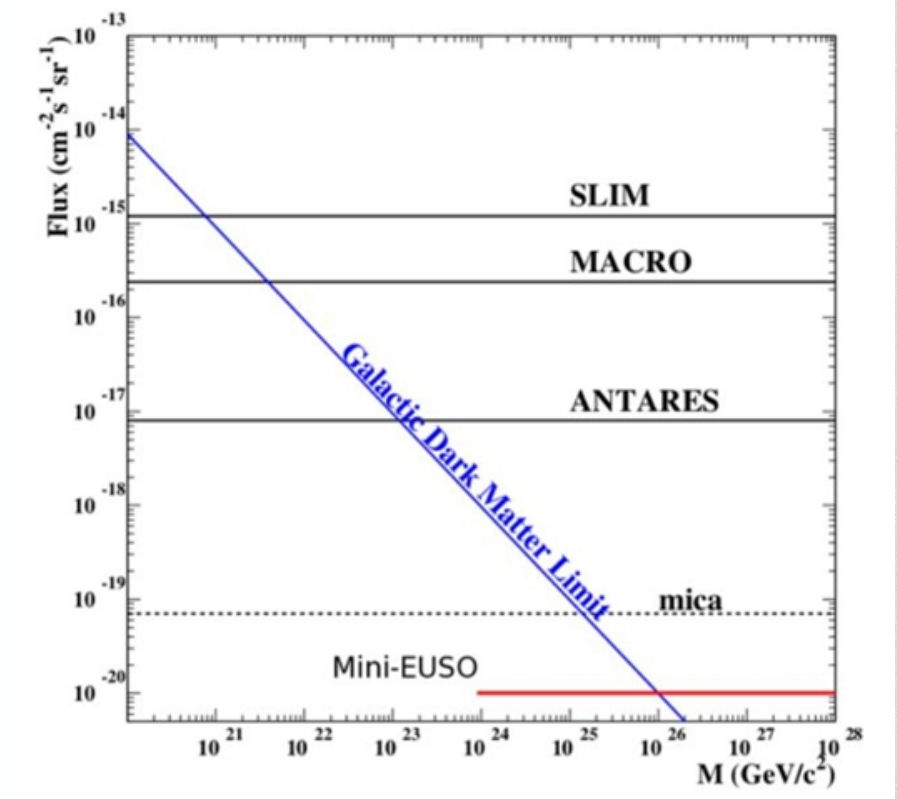


V_{hor} = 37 ± 3 km/s
M= 2.9 ± 0.1
N_{pix} = 10
ΔT = 0.78 s

Selection: robust track reconstruction (n. pixel, magnitude, ...)
correct estimation of uncertainty on velocity measurement
(trajectory inclination missing)

Search for Strange Quark Matter



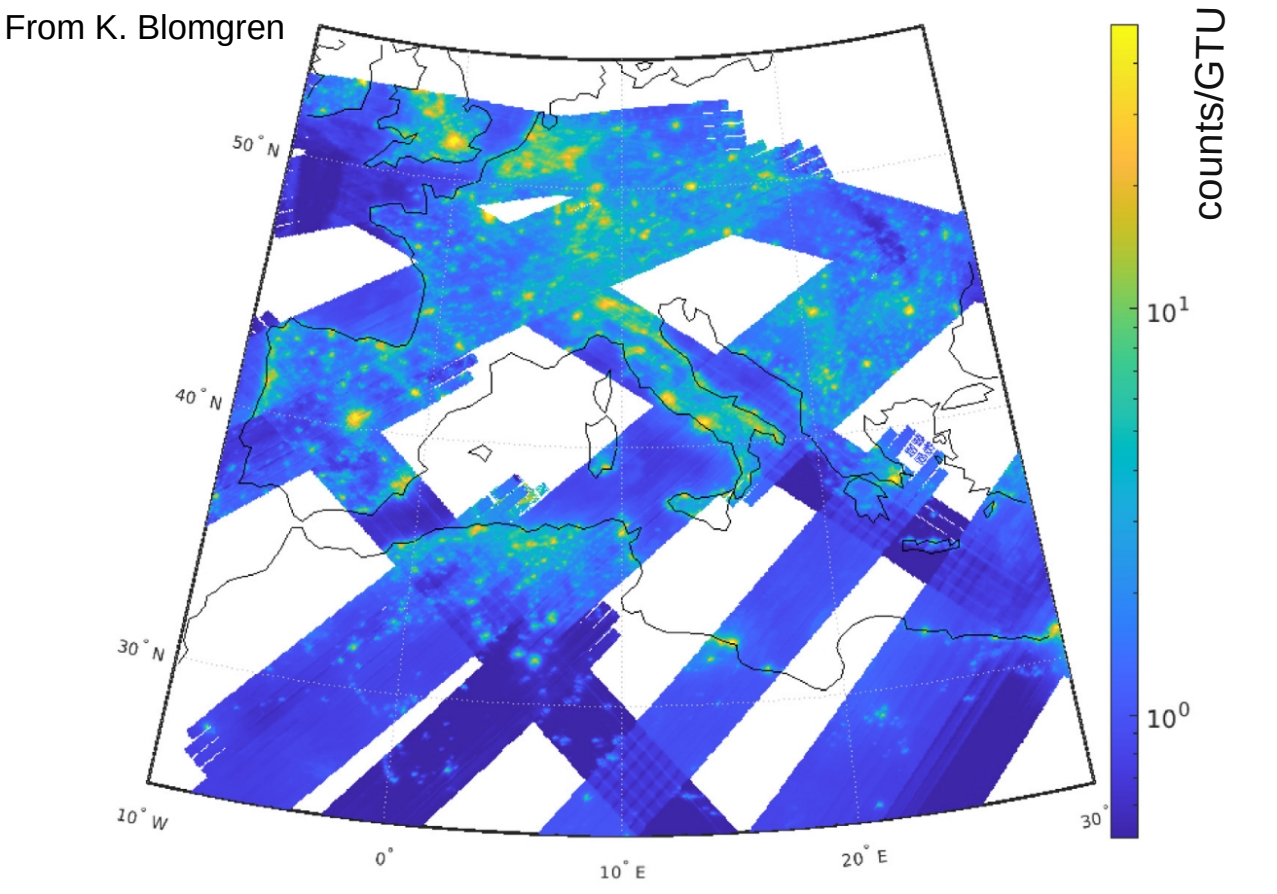


Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245-255, 2017.

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

Night-time Earth Emissions

Time sampling: 40.96 ms



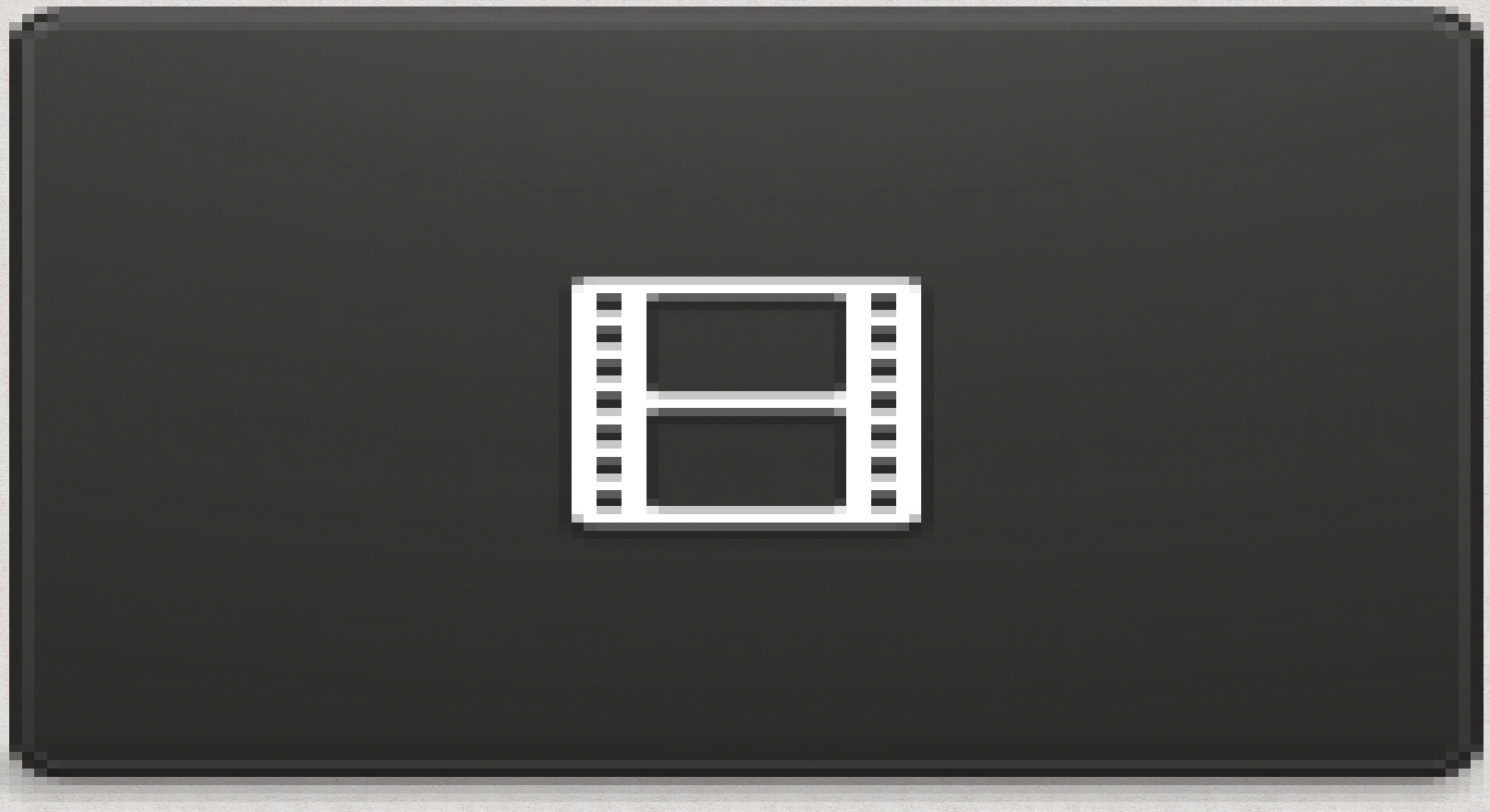
Observation of night-time emissions of the Earth in the near UV range from the International Space Station with the Mini-EUSO detector
M. Casolino et al., Remote Sensing of Environment 284 (2023) 113336

Dataset of night-time emissions of the Earth in the near UV range (290-430 nm), with 6.3 km resolution in the latitude range -51.6<L<+51.6 degrees, acquired on board the International Space Station with the Mini-EUSO detector
L. Marcelli et al., Data in Brief, Volume 48, June 2023, 109105

Mendeley database: https://data.mendeley.com/datasets/57fmn7th4n/4

Youtube video: https://youtu.be/X_QATtf38Og

Night-time Earth Emissions



UHECR detection efficiency

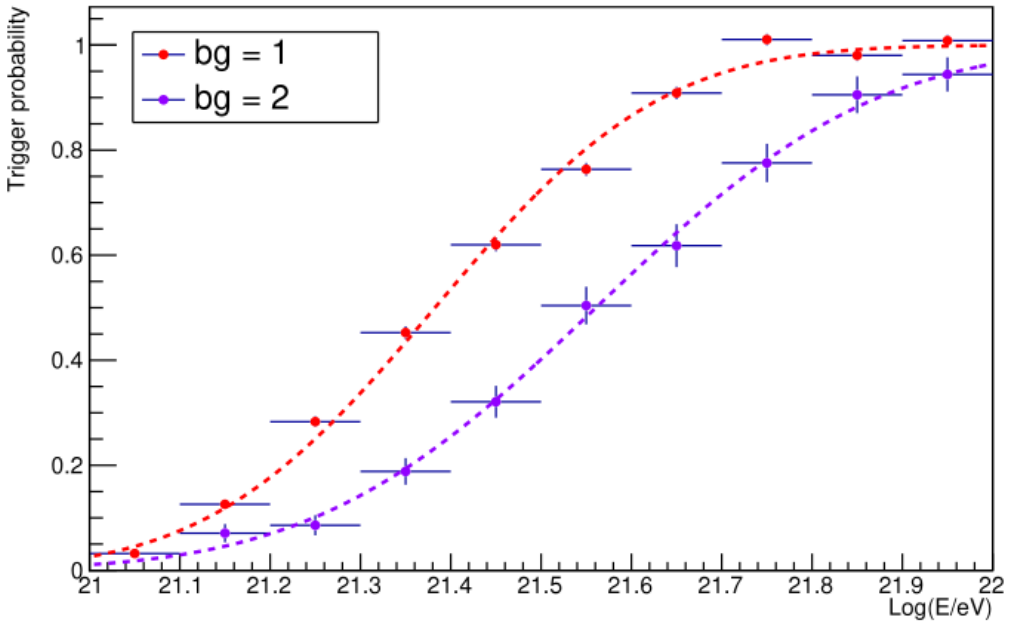


Fig. 27. UHECR efficiency curve as a function of energy for the Mini-EUSO detector in two different background conditions (bg = 1 and bg = 2 counts/GTU) (Bianciotto, 2020). Trigger threshold (the energy where trigger efficiency is 50%) is $10^{21.38}$ eV and $10^{21.56}$ eV for bg = 1 count/GTU and bg = 2 counts/GTU, respectively.

Detection thresholds (trigger efficiency = 50%): $10^{21.38}$ eV for bg = 1 count/pixel/GTU
$10^{21.56}$ eV for bg = 2 counts/pixel/GTU

Observation of night-time emissions of the Earth in the near UV range from the International Space Station with the Mini-EUSO detector M. Casolino et al., Remote Sensing of Environment 284 (2023) 113336

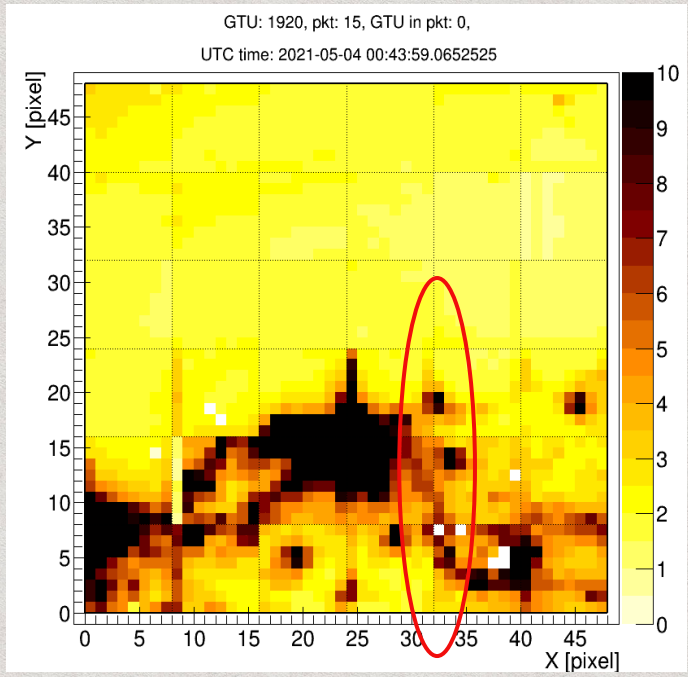
End-to-end Calibration with UV flashers

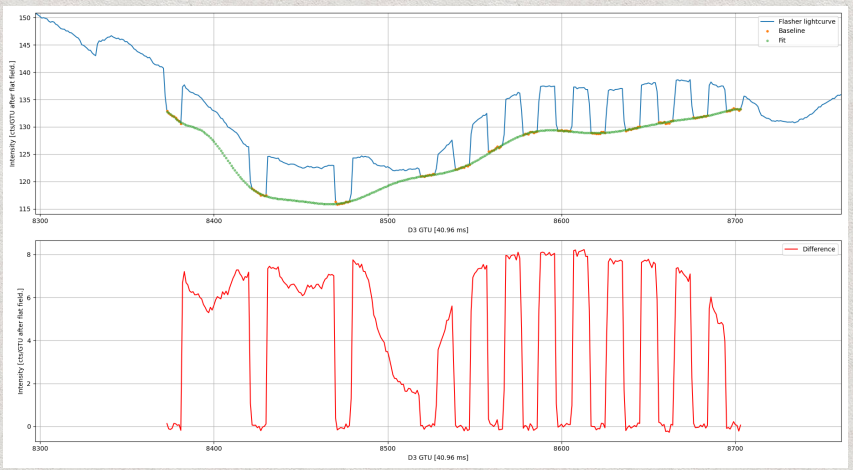
2-3 kW pulsed UV LED portable arrays

- Calibration from ground
- Shoot when in field of view
- Pulsed and coded shots

- Many flasher campaigns performed

- Partial results published, waiting for new data





An end-to-end in-flight calibration of Mini-EUSO detector
H. Miyamoto, EPJ Web of Conference 283, 06017 (2023)

Selected publications

Dataset of night-time emissions of the earth in the near uv range (290-430 nm), with 6.3 km resolution in the latitude range -51.6<L<+51.6 degrees, acquired on board the international space station with the mini-euso detector.
Data in Brief, 48, 2023.

Observation of night-time emissions of the earth in the near uv range from the international space station with the mini-euso detector.
Remote Sensing Of Environment, 284, 2023.

Onboard performance of the level 1 trigger of the mini-euso telescope.
Advances in Space Research, 70(9):2750–2766, 2022.

Pre-flight qualification tests of the mini-euso telescope engineering model.
Experimental Astronomy, 53(1):133–158, 2022.

Mini-EUSO Mission to Study Earth UV Emissions on board the ISS
The Astrophysical Journal Supplement Series, 253, 2 , 36, 2021.

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, 2018.

Secondary cameras onboard the Mini-EUSO experiment: Control software and calibration.
Advances in Space Research, 64(5):1188-1198, 2019.

Mini-EUSO data acquisition and control software.
Journal of Astronomical Telescopes Instruments and Systems, 5(4), 2019.

The integration and testing of the Mini-EUSO multi-level trigger system,
Advances in Space Research, 62(10), 2966-2976 , 2018

Conclusions

After 85 sessions Mini-EUSO works nominally

Mini-EUSO is a multisciplinary experiment (ELVES, UV Earth maps, SQM...)

UHECR detection efficiency estimation validated for future missions

SPB2 + Mini-EUSO results pave the way for UHECR detection from space