JEM-EUSO: Joint Experiment Missions for Extreme Universe Space Observatory

L'osservazione di meteore con l'esperimento Mini-EUSO a bordo della Stazione Spaziale Internazionale

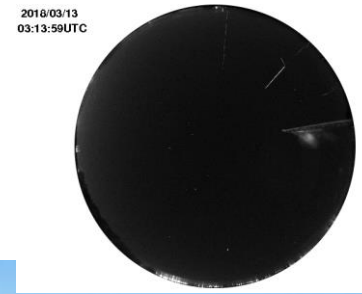
e le sinergie con la rete PRISMA...

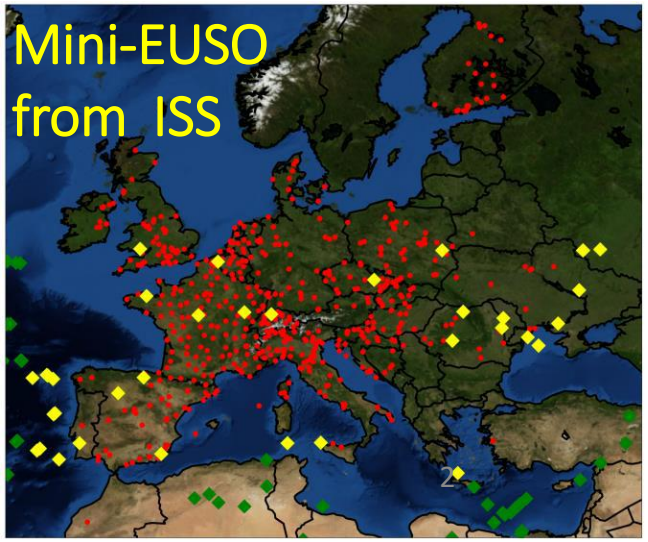
D. Barghini, M. Bertaina, S. Bertone, F. Bisconti, A. Cellino, D. Gardiol, H. Miyamoto, F. Reynaud
(Univ. Torino & INAF-OATo)
on behalf of the JEM-EUSO Collaboration
PRISMA day 10-11 Dicembre 2020

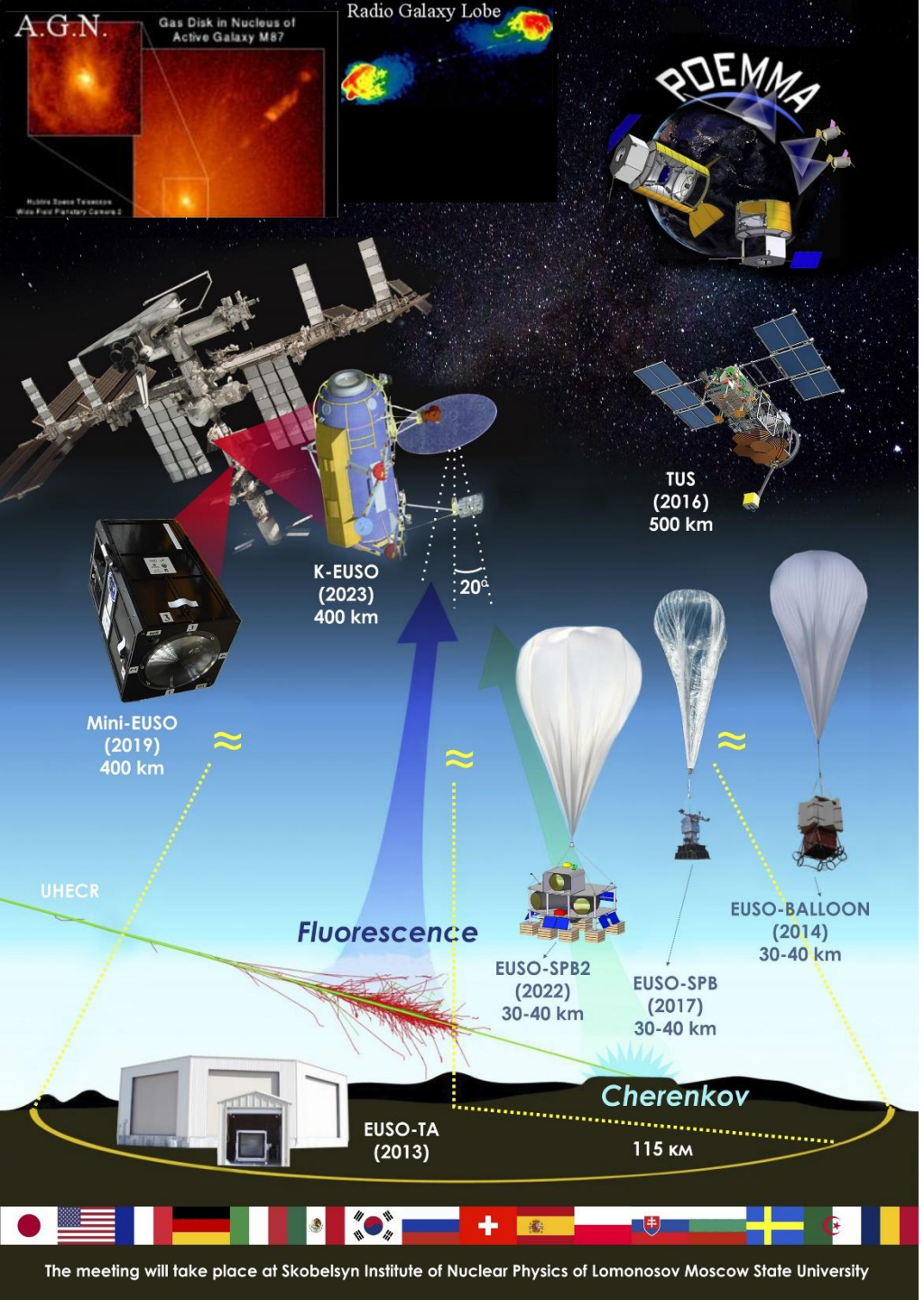
Mini-EUSO & PRISMA
a sinergy from the beginning

- PRISMA Day – Firenze 2016: M. Bertaina «Mini-EUSO e attivita' correlate all'osservazione di Meteore e Space Debris in associazione con PRISMA»
- PRISMA Day – Bologna 2018: F. Bisconti «Osservazioni con l'Engineering model di Mini-EUSO e la camera PRISMA all'INAF-OATo»
- PRISMA DAY – 2020: M. Bertaina «L'osservazione di meteore con l'esperimento Mini-EUSO a bordo della Stazione Spaziale Internazionale

PRISMA camera
@INAF-OATo

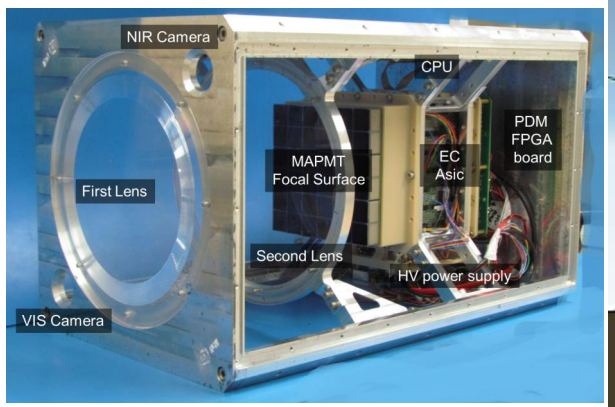


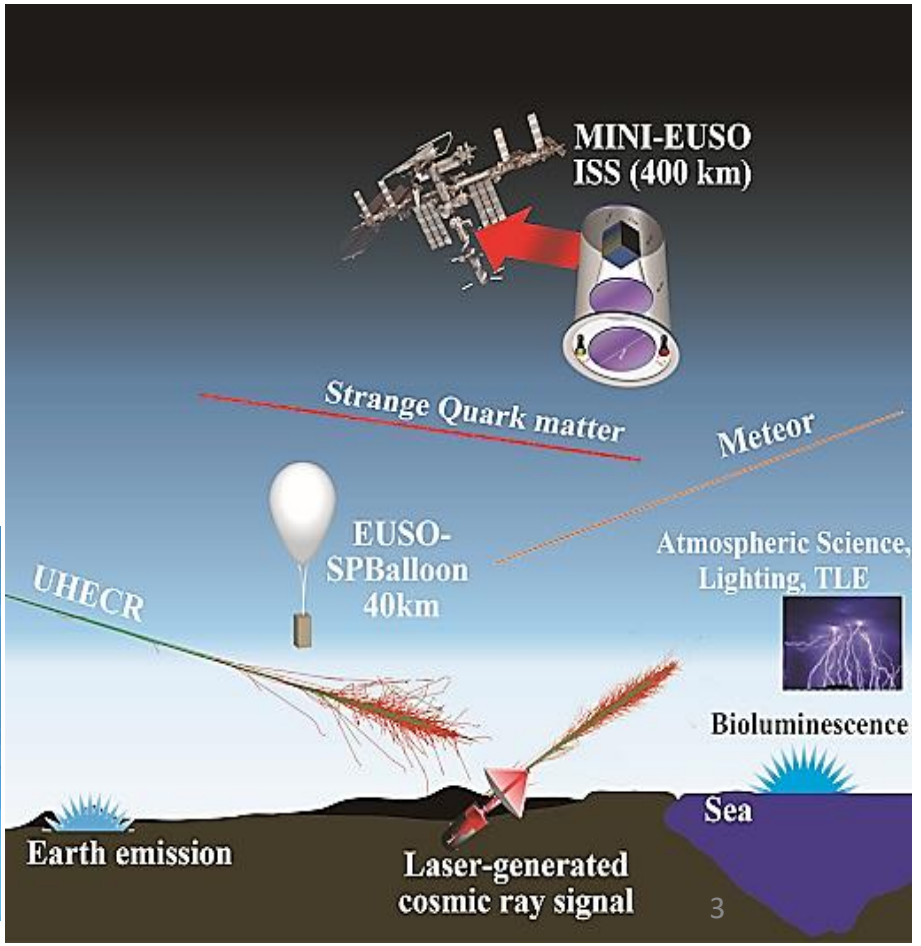




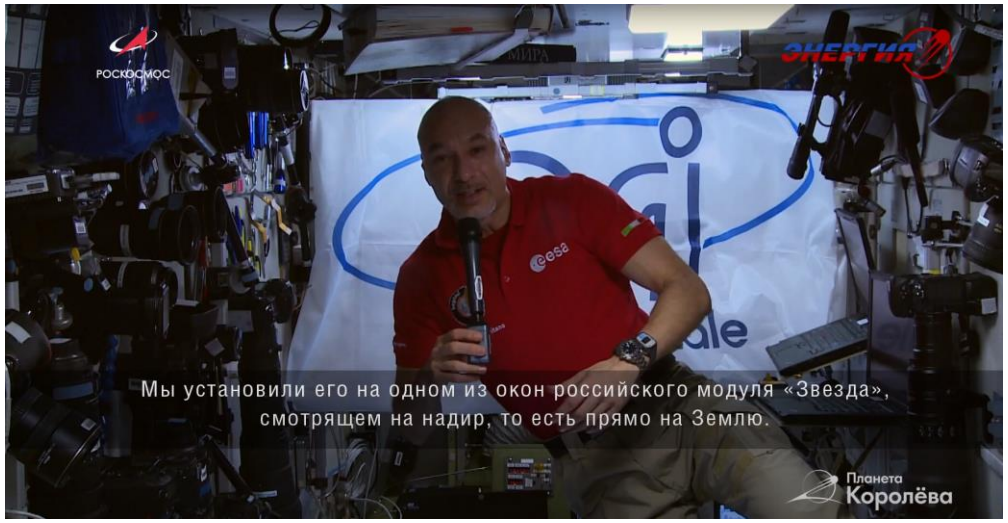
JEM-EUSO Program: observation of Extreme Energy Cosmic Rays ($E>5x10^{19}$ eV) from space

Mini-EUSO: precursor mission with several scientific objectives

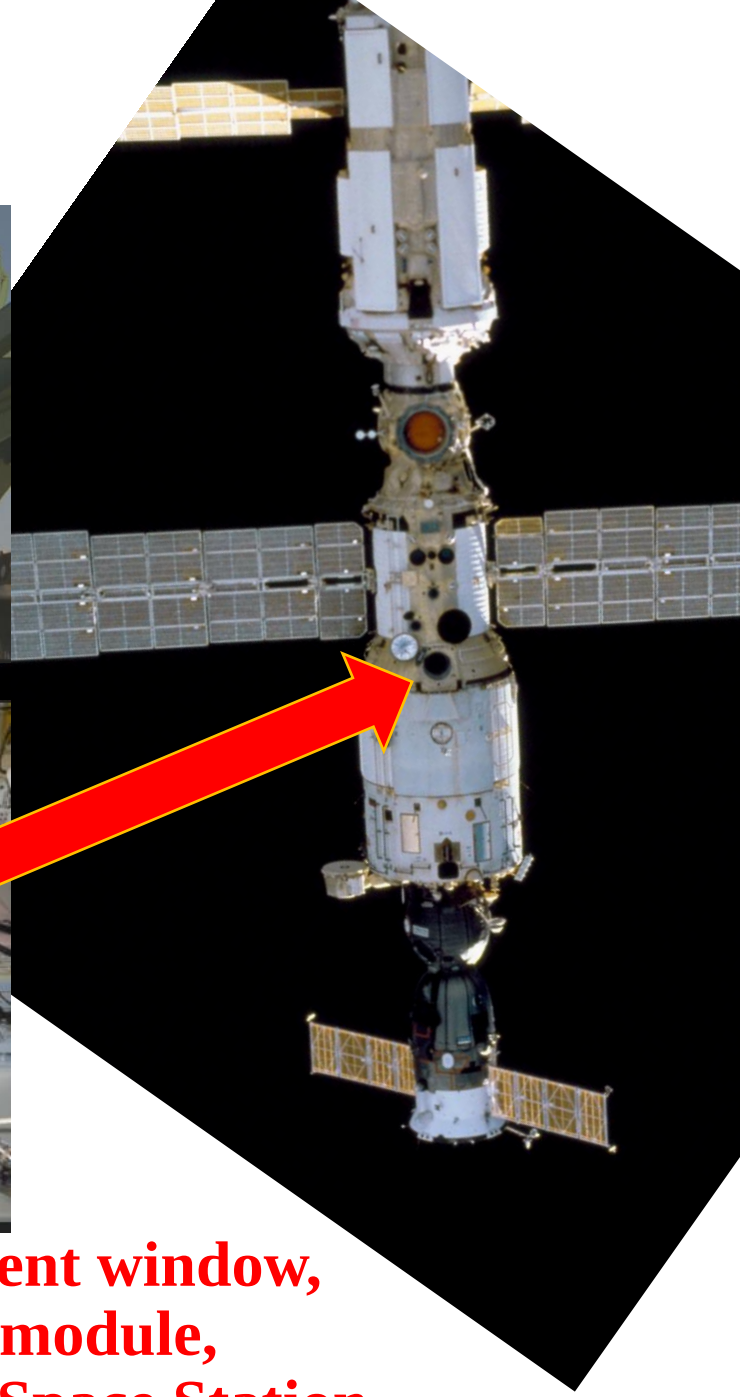




Mini-EUSO on the ISS



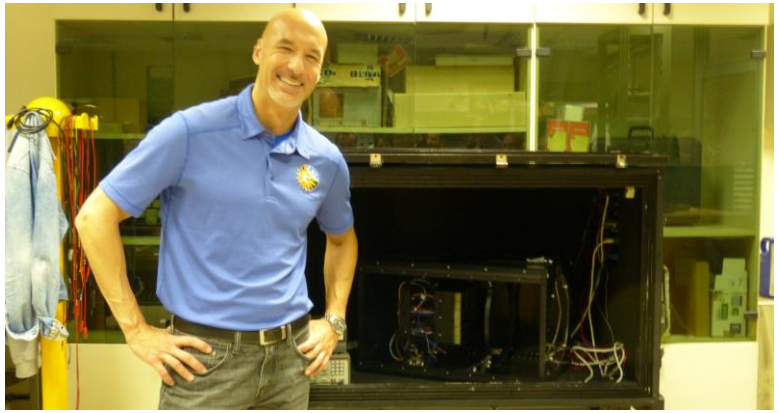
Launch 22/08/2019



Mini-EUSO operated ~2/month for ~12h.
Data are transferred to ground with ISS crew **once/year.**
At the moment ~30h of night data available for analysis.

Uv transparent window,
Zvezda module,
International Space Station

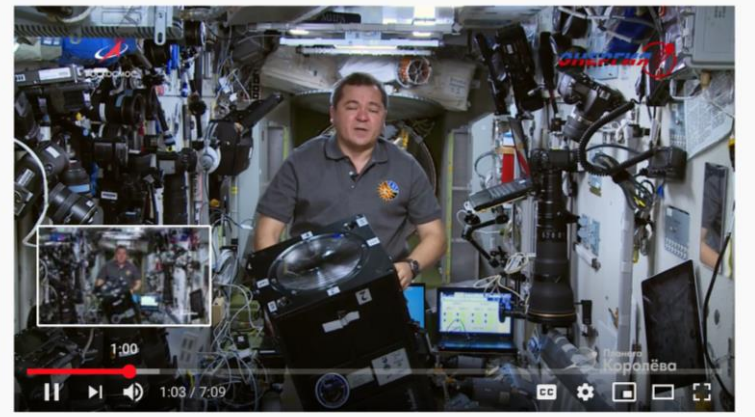
Beyond mission & outreach



@ Tor Vergata with FM Mini-EUSO

Video of Outreach from ISS
https://www.youtube.com/watch?v=QincAp4V-SM&t=1s

Also in Russia a certain success:

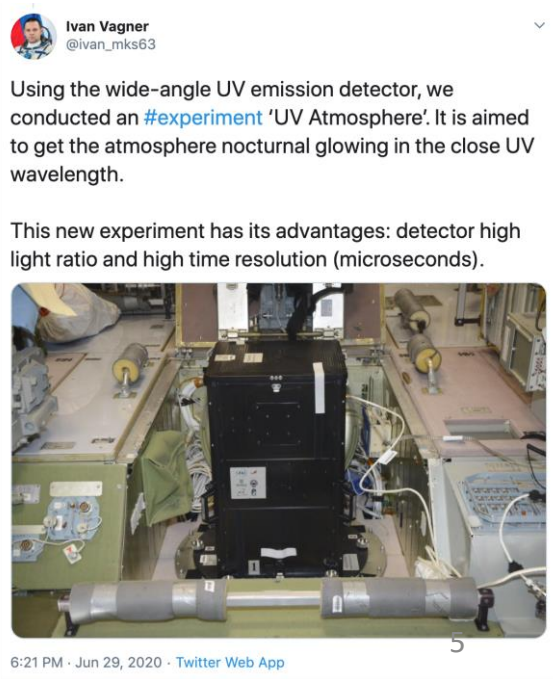


https://www.youtube.com/watch?v=lXedBGVHc4o&t=62s

Video ofioutreach on Corriere della sera

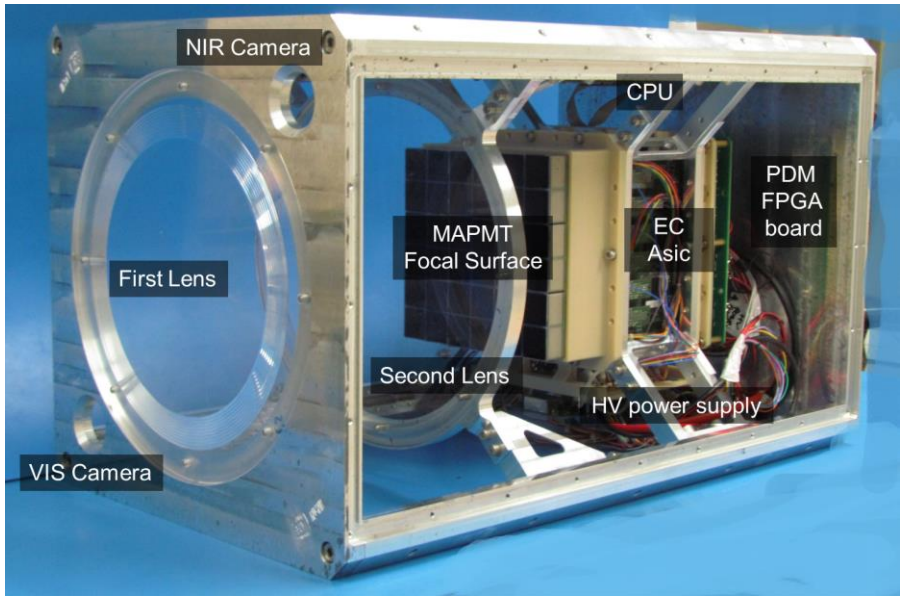
https://video.corriere.it/cronaca/mini-euso-luca-parmitano-protagonista-web-serie-beyond/2582bd90-aa06-11e9-a88c-fde1fa123548

Mentioned in the teleconference with Presid. Mattarella
https://www.youtube.com/watch?v=NMTTSB6BVaw (min 5:15-6:30)
and Prime Minister Conte:
https://www.youtube.com/watch?v=4GDgpyAsz94 (min 16:51 – 19:15)



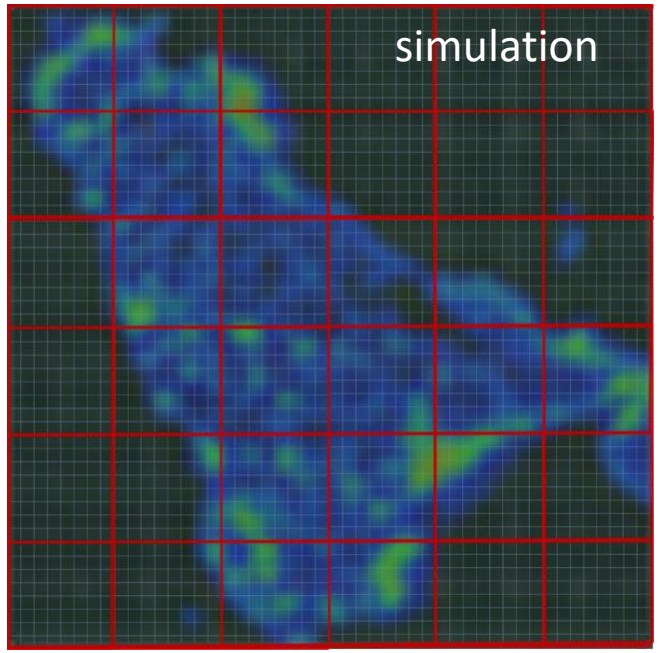
MINI-EUSO / UV-Atmosfera

Multiwavelength Imaging New Instrument for the Extreme Universe Space Observatory



- Detector: dimensions of 36 x 36 x 62 cm^3, two Fresnel lenses (25 cm of diameter)
- The light focuses on 36 multi-anode photomultiplier tubes (MAPMTs)
- Focal surface of 2304 pixels
- Field of view of 44°
- Spatial resolution on ground ~ 6.5 km/pixel
- Bandwidth: 300 – 400 nm

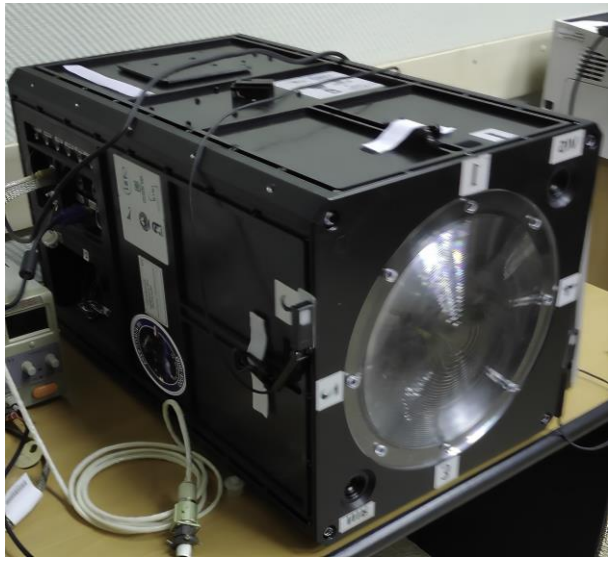
Instantaneous FoV

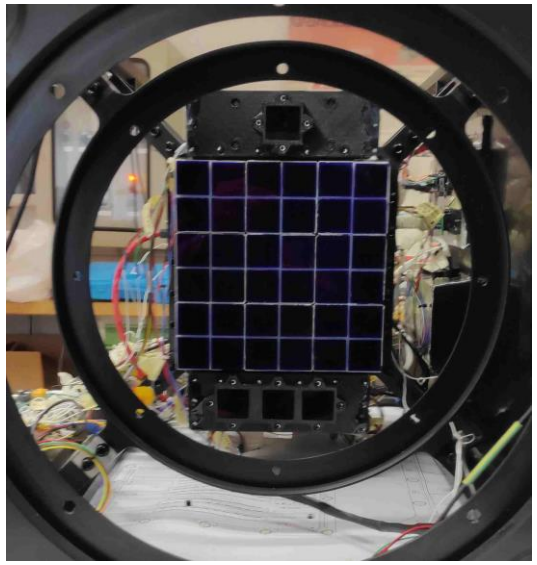


- **Acquisition logic with 3 times resolutions**:
- D1= 2.5 µs, D2=320 µs and D3 =41 ms ,
- 1 packet = 128 frames or Gate Time Unit (GTU)
- D1 and D2 are self triggered (4 packets/5.24s), D3 is a continuous video stream.

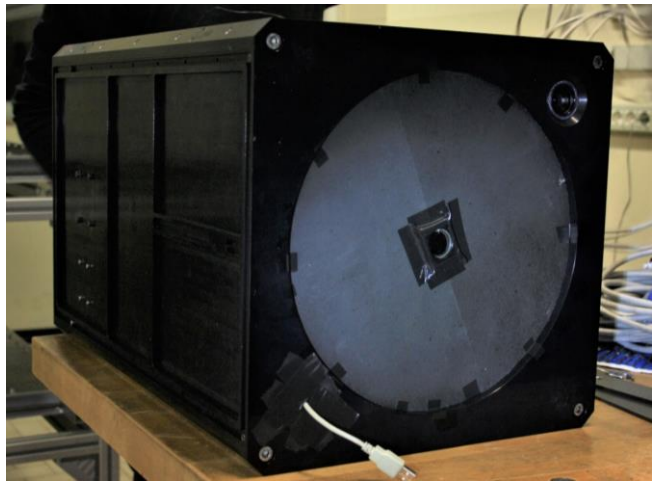
Mini-EUSO Flight & Engineer Models

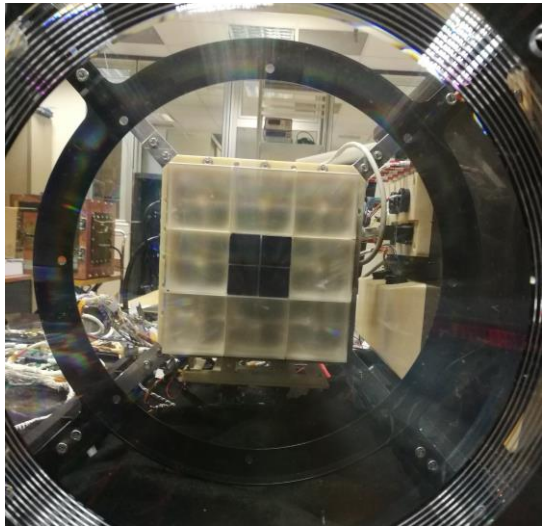
FM





EM





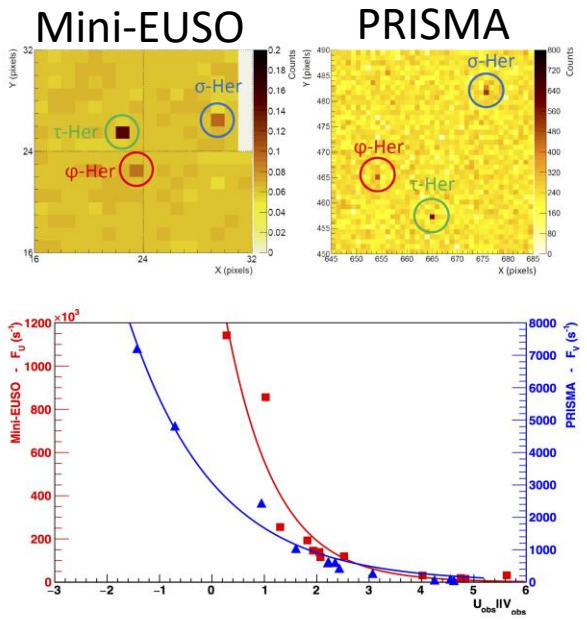
	Mini-EUSO *EM*	Mini-EUSO
Focal Surface	2×2 MAPMTs $16 \times 16 = 256$ pixels	6×6 MAPMTs $48 \times 48 = 2304$ pixels
Optical system	1 plano-convex lens	2 Fresnel lenses
Diameter lens(-es)	2.5 cm	25 cm
Focal length	30 cm	20.5 cm
Focal ratio	$f/12$	$f/1.2$
Field of view	square	square
Total	$\sim 10°$	$\sim 44°$
Per pixel (no gaps)	$\sim 0.6°$	$\sim 0.8°$

Table 1: Comparison of the key specifications of Mini-EUSO*EM* and Mini-EUSO.

Integration tests of Mini-EUSO EM in 2017 @ Univ. Torino to mimic ISS orbits & @ INAF-OATo for sky tests

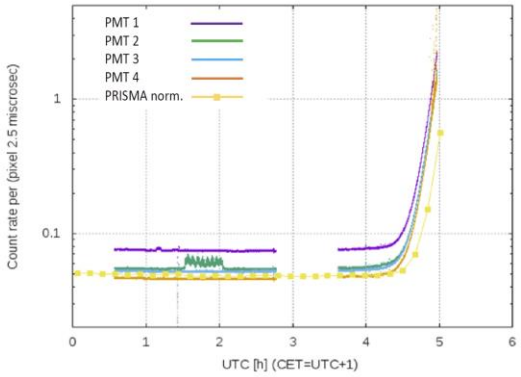
TurLab @ UNITO

Tests at INAF-OATo



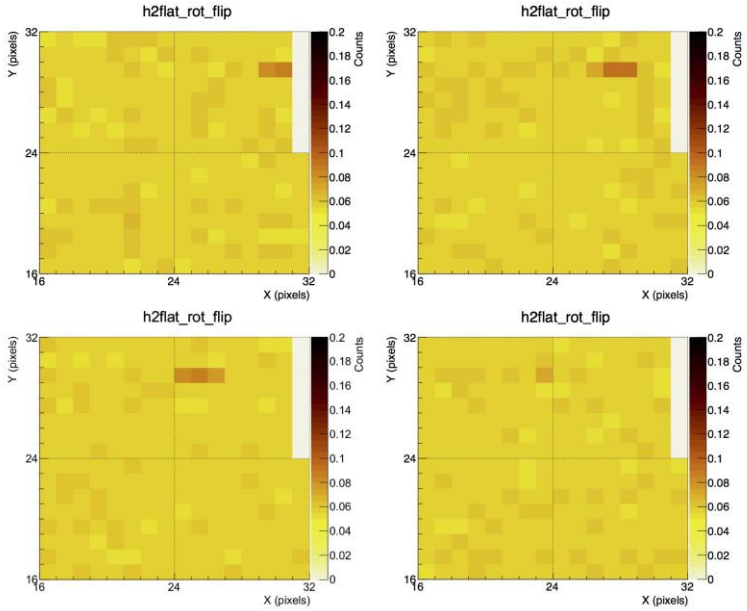
Stars

Figure 8: Three stars of the Hercules constellation. Stars in a Mini-EUSO *EM* data frame, integrated over 40.96 ms (top-left). Same stars in an image of the PRISMA camera, integrated over 5 s (top-right). The images have to be mirrored and rotated by a few degrees to have the same orientation. Flux of counts from stars and Jupiter for the Mini-EUSO *EM* (left y-axis) and for the PRISMA camera (right y-axis), with respect to the U (for the Mini-EUSO *EM*) and V (for PRISMA) apparent magnitudes (bottom).



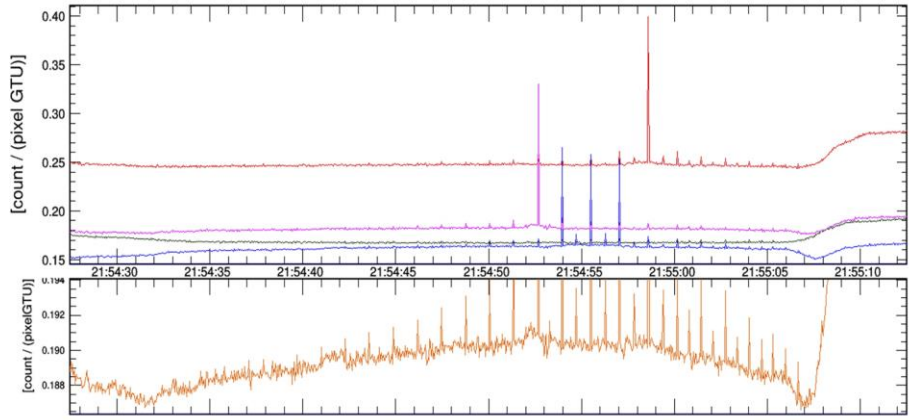
UV light

Figure 10: Background count rate over time of the four MAPMTs of the Mini-EUSO *EM* and of the PRISMA camera, normalized to the mean value of the three MAPMTs with lower counts.



Meteors

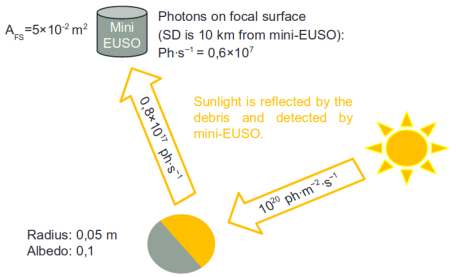
Figure 9: Example of meteor event shown in four consecutive D3 data frames, each integrated over 40.96 ms.

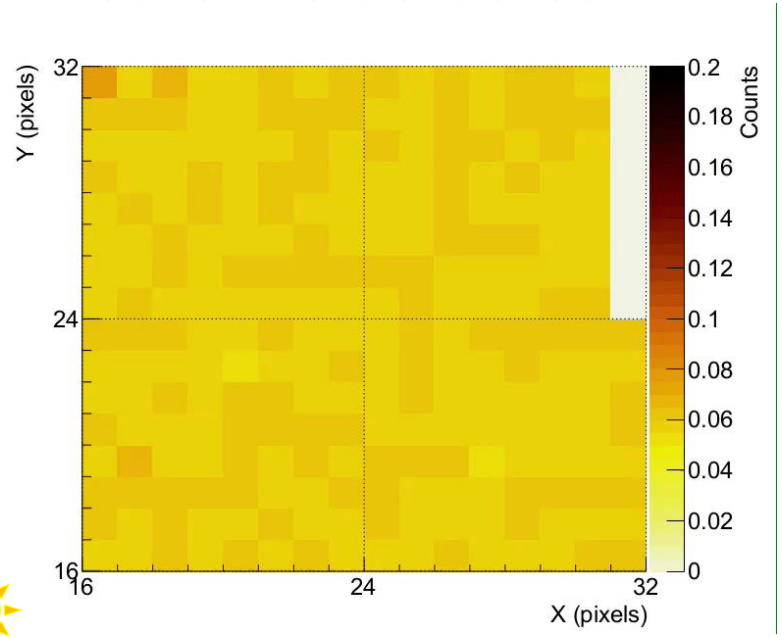


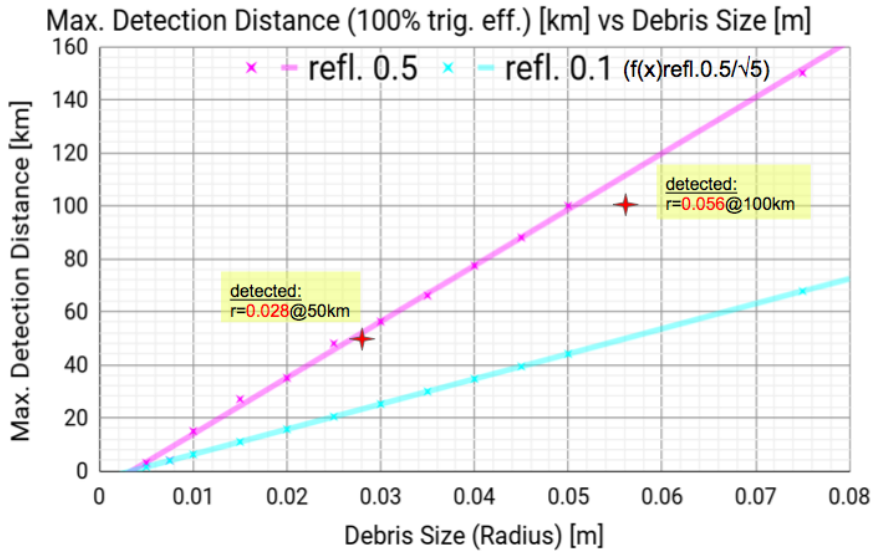
Airplane

Figure 13: Airplane for the flight LH1902 detected on March 12, 2018 in the time interval 21:54:27-21:55:12 UTC. In the top panel, peaks from four separate MAPMTs are shown. In the bottom panel, peaks from the whole EC are shown: the frequency of the visible flashes changes over the time due to the turning of the airplane while approaching the runway.

Satellite detected!







- In the animation: 1 frame every 10 D3 GTUs (409.6 ms)
- In the FOV for 400 GTUs (182 D3 GTUs in the first PMT, 173 D3 GTUs in the second PMT, 45 D3 GTUs not visible), for a total of 16.4s.
- Consistent with a satellite

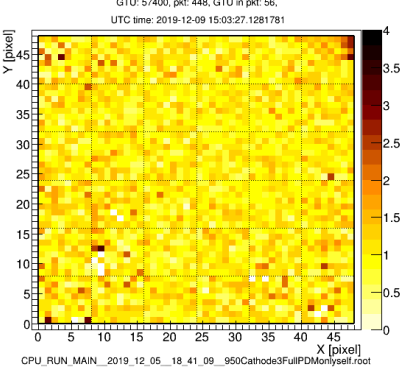
→ **Identified as Meteor 1-31 rocket**, also known as SL-3 R/B, NORAD: 12586.

```
Name:           Meteor 1-31 Rocket
Dimensions:     2.8 m x 2.6 m, cylindrical
Brightness:      5.0 mag (at 1000 km, 50% illuminated)
                 2.8 mag (at perigee, full illumination)
                Mean magnitude from visual observations
RCS:            7.1m2 (Radar cross section)
USSPACECOM Nr: 12586  Internat. Designator: 1981-065B
Orbit:          519.4 x 545.5 km, 95.3min  Inclination: 97.5°
Age Elements:   0 days
```

Rescaling satellite to Mini-EUSO sensitivity plot

	Sat. Meteor 1-31 Rocket	scale to SD	scale to SD + lens 2.5cm → 25cm	scale to SD	scale to SD + lens 2.5cm → 25cm
distance[km]	530	50	50	100	100
Dimension [mxm]	2.8 x 2.6	0.27 x 0.25	0.085 x 0.08	0.53 x 0.49	0.17 x 0.16
RCS[m^2]	7.1	0.063	0.02011	0.25	0.08
corr. SD radius[m]	1.50	0.14	**0.028**	0.28	**0.056**
magnitude/ full	5/2.8				

Mini-EUSO on ISS:

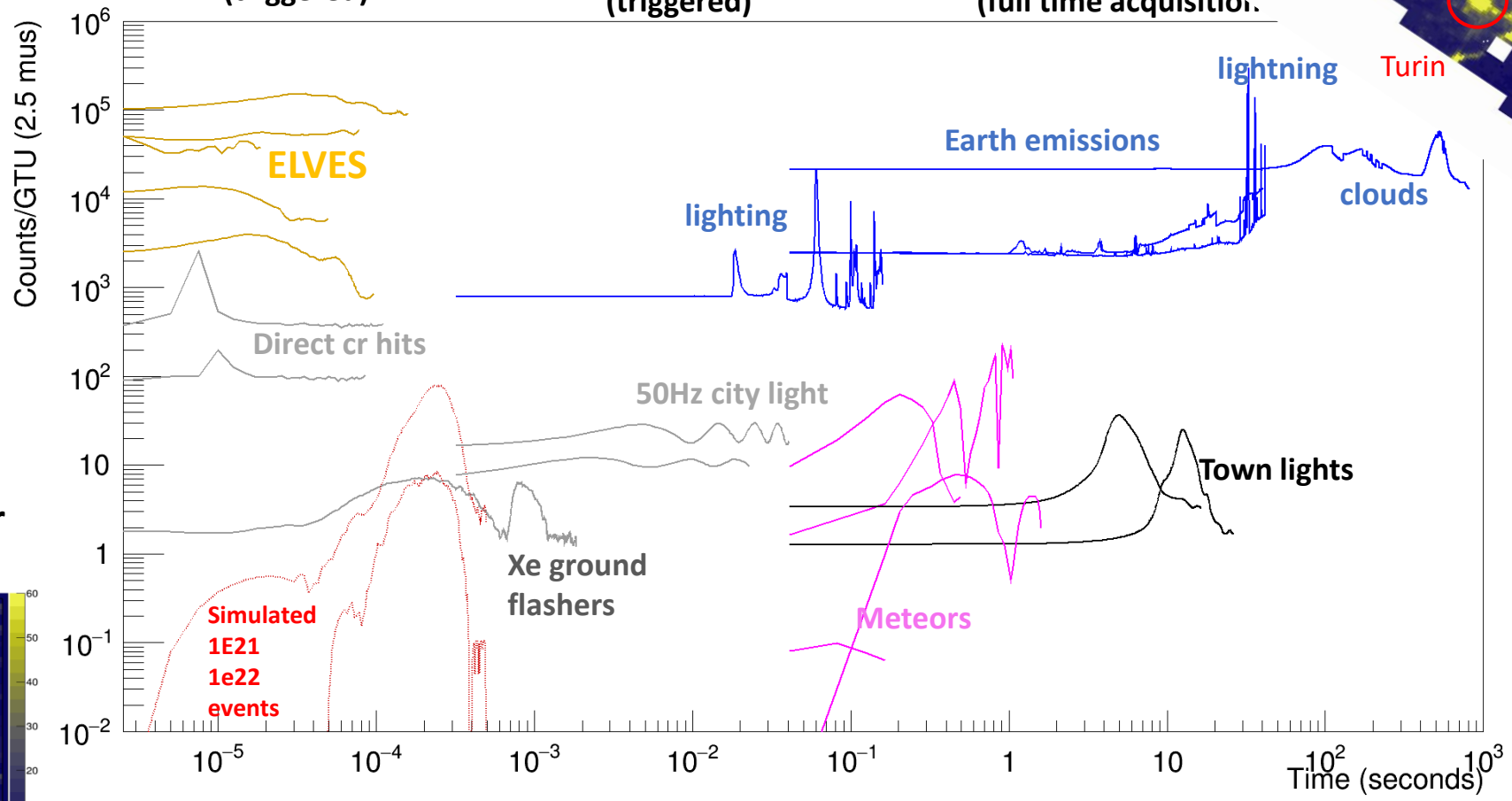


Elve

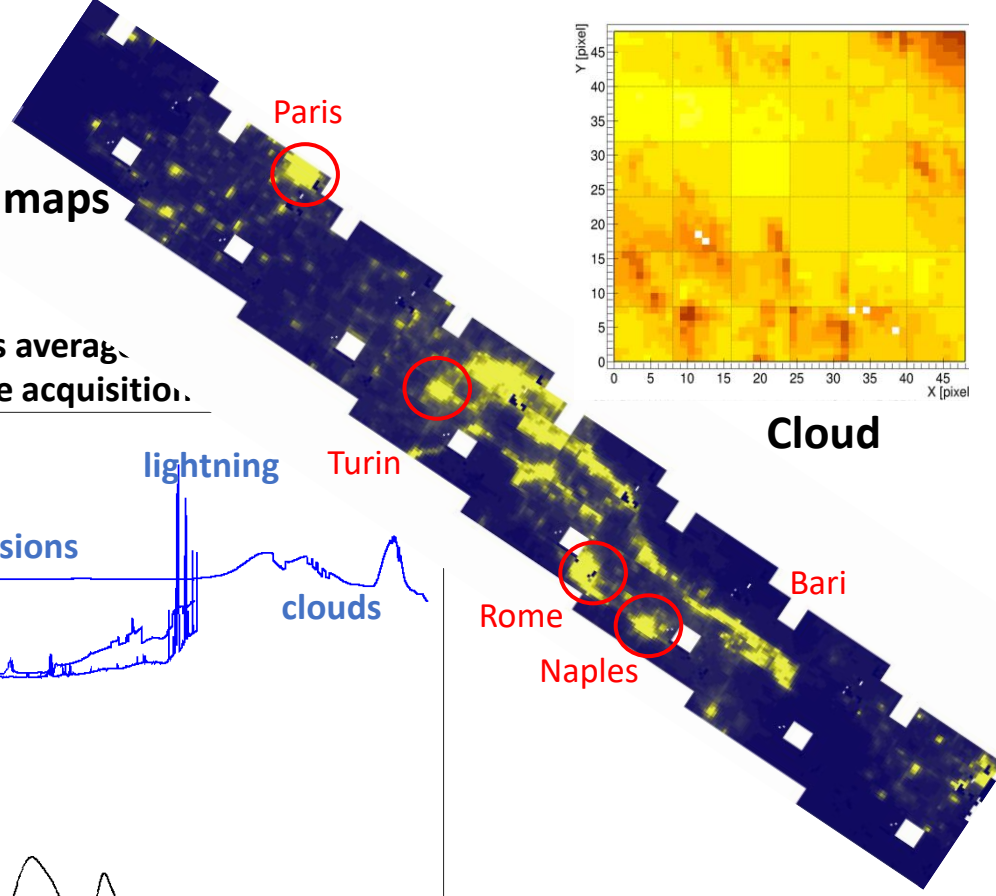
2.5 µs sampling (triggered)

320µs averages (triggered)

41ms averag… (full time acquisitio…

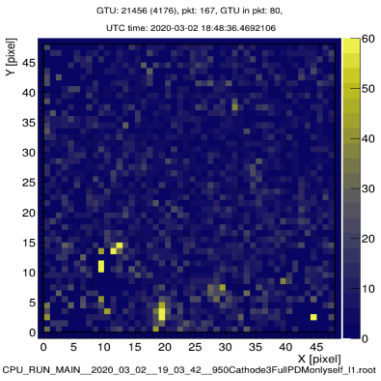


UV maps

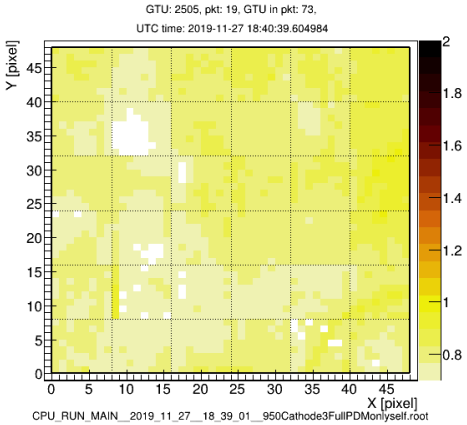


Cloud

Ground flasher

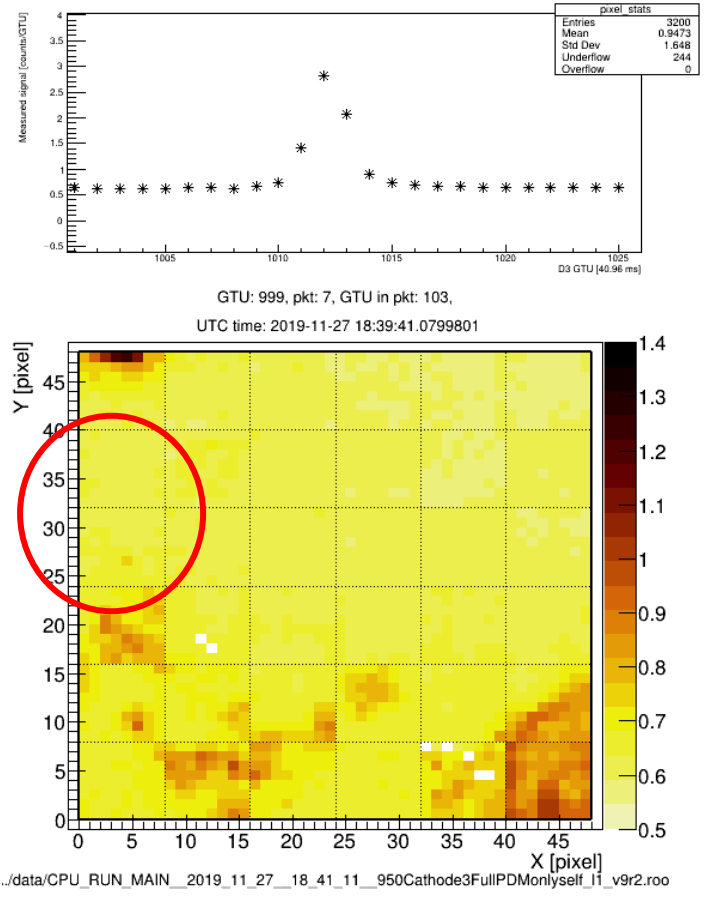


Meteor

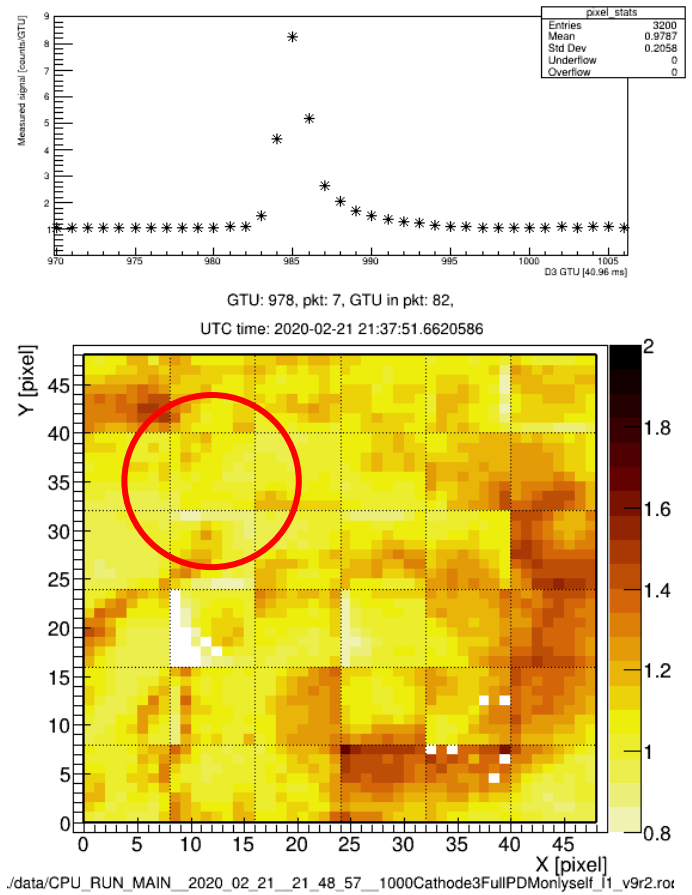


Meteors in Mini-EUSO:

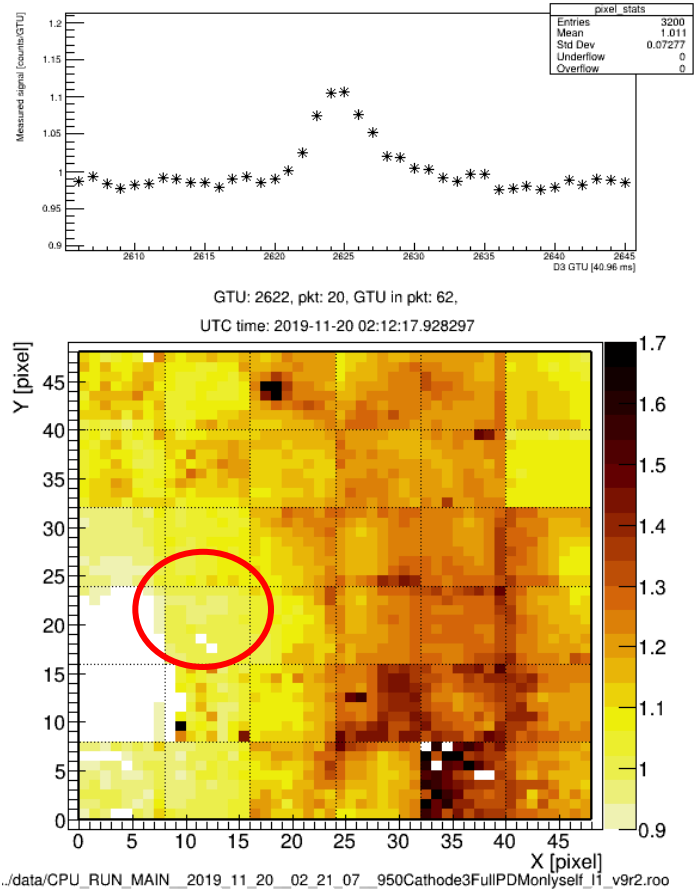
- automatic offline search & analysis: 1152 events
- offline trigger & visual inspection: 1545 M + 819 M? in 1967 min. of analysis



Session 06, 27/11/2019, 18:41:11 UTC
Andaman sea (near Thailand)



Session 11, 21/02/2020, 21:48:57 UTC
Indian Ocean

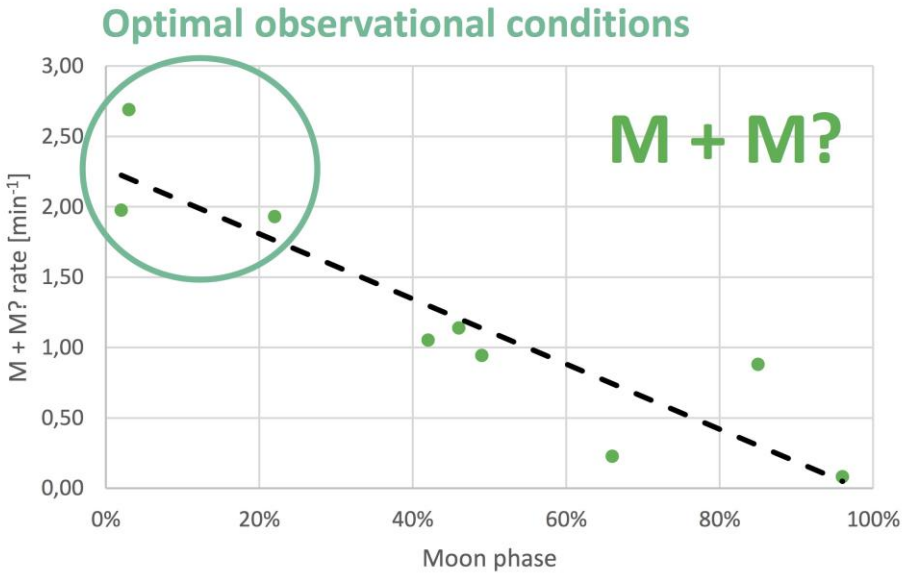


Session 05, 19/11/2019, 02:21:07 UTC
North Atlantic Ocean

Work led by D. Barghini

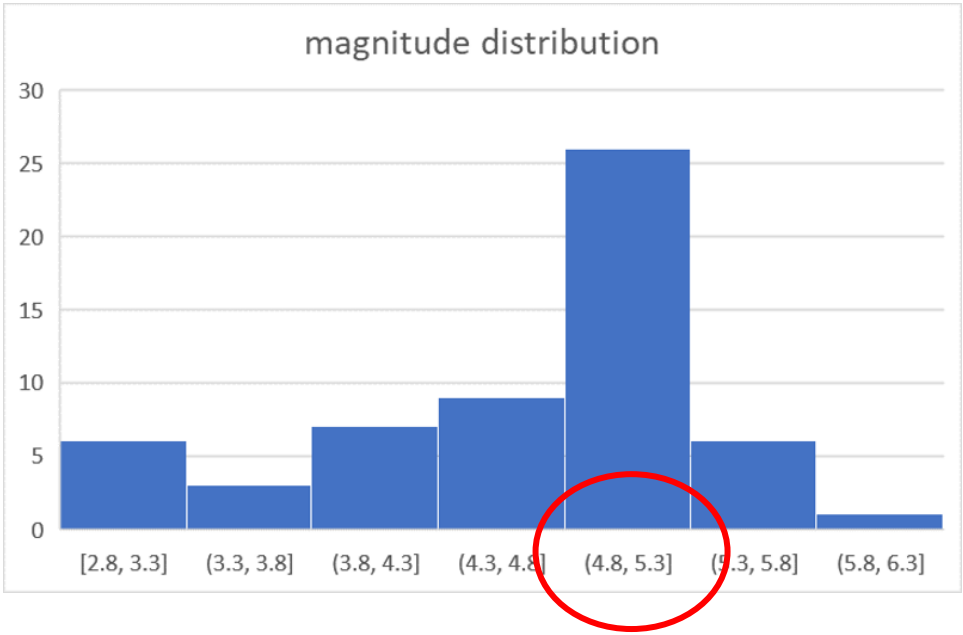
Flux and Limiting magnitude

PRELIMINARY



Observed rate at best conditions: **2.0 – 2.5 ev/min**

Expected rate at +5 absolute magnitude: **2.4 ev/min**



G. Abdellaoui et al. (JEM-EUSO Coll.)
Planetary and Space Science 143 (2017) 245–255

Table 1
For different values of absolute magnitude in visible light, the Table lists the corresponding flux in the *U*-band (according to the Flux Density Converter of the Spitzer Science Center available at web site http://ssc.spitzer.caltech.edu/warmmission/propkit/pet/magtojy/index.html), the corresponding numbers of photons per second (assuming that the meteor is located at a height of 100 km and is observed by the ISS in the nadir direction), and the corresponding number of photo-electrons per GTU, for the cases of JEM-EUSO and Mini-Euso, respectively. The corresponding typical mass of the meteor, and the number of events expected to be observed by JEM-EUSO (by assuming a duty cycle of 0.2) and by Mini-EUSO are also shown. The relationship between mass and magnitude has been obtained following Robertson and Ayers (1968).

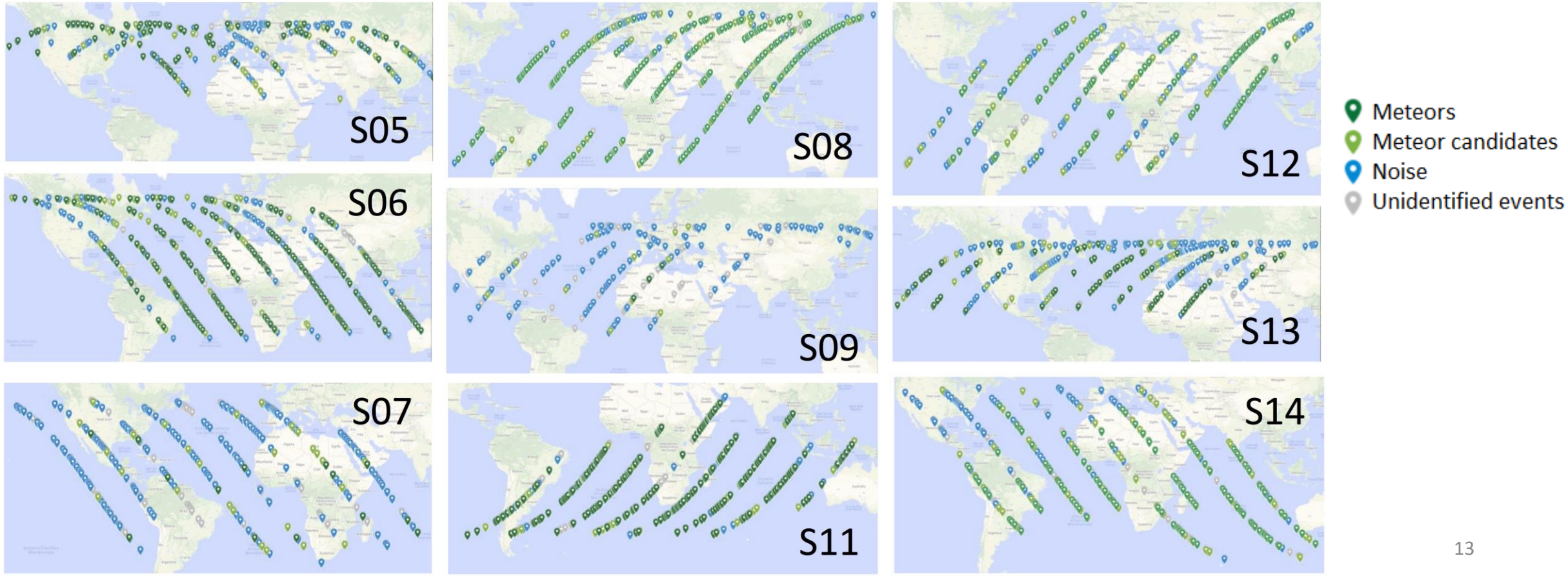
Abs. mag	U-band flux (erg/s/cm^2/A)	photons (s^{-1})	photo-e$^-$ GTU^{-1} (JEM)	photo-e$^-$ GTU^{-1} (Mini)	mass (g)	event rate (JEM)	event rate (Mini)
+7	$6.7{\cdot}10^{-12}$	$4.3{\cdot}10^{7}$	4	0.04	$2{\cdot}10^{-3}$	1/s	0.4/s
+5	$4.2{\cdot}10^{-11}$	$2.7{\cdot}10^{8}$	23	0.23	10^{-2}	6/min	2.4/min
0	$4.2{\cdot}10^{-9}$	$2.7{\cdot}10^{10}$	2300	23	1	0.27/orbit	0.11/orbit
−5	$4.2{\cdot}10^{-7}$	$2.7{\cdot}10^{12}$	$2.3{\cdot}10^{5}$	2300	100	6.3/year	2.5/year

With a crude estimation of Mini-EUSO efficiency of 8%, and by using a subset of faint events the distribution peaks is in a range of magnitude values of [+4.8,+5.3]

Maps:

- Most of the meteors are detected where the background is lower
- The false positives rate is higher over continents

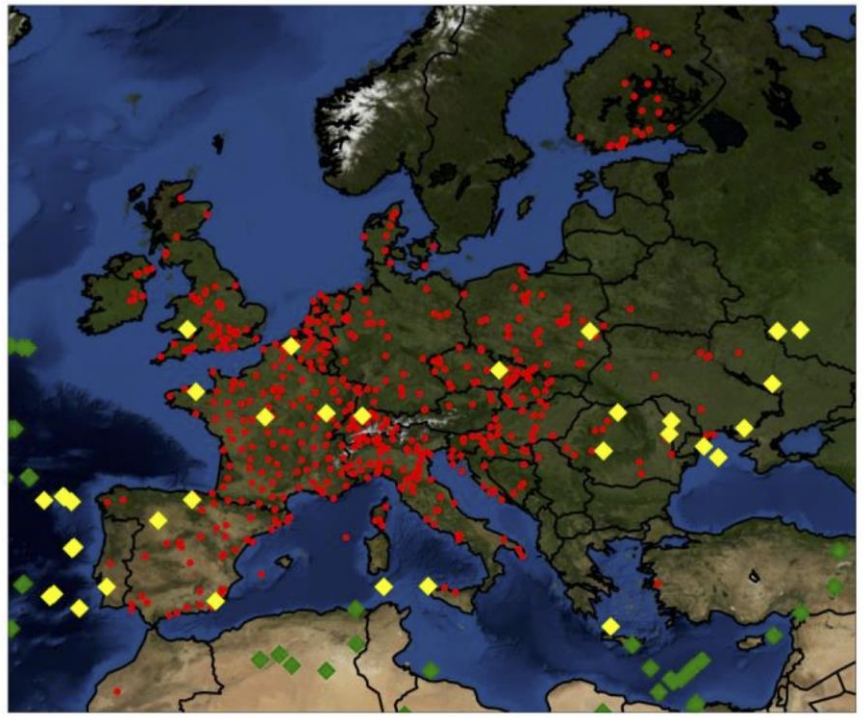
Maps of ISS ground projection for triggered events



Correlation with ground sources

(130 ev. with d < 400 km from a ground station around the world)

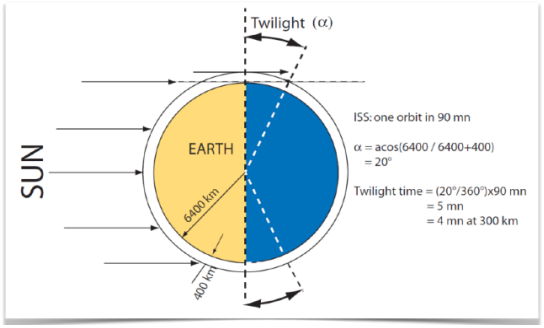
Detail from session 06

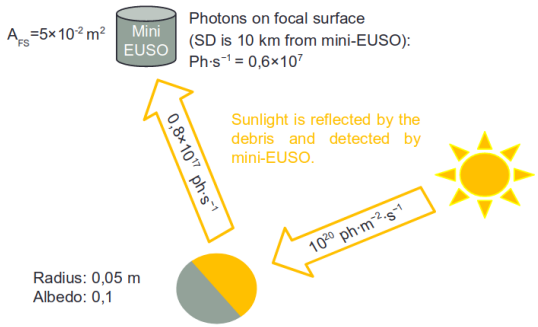


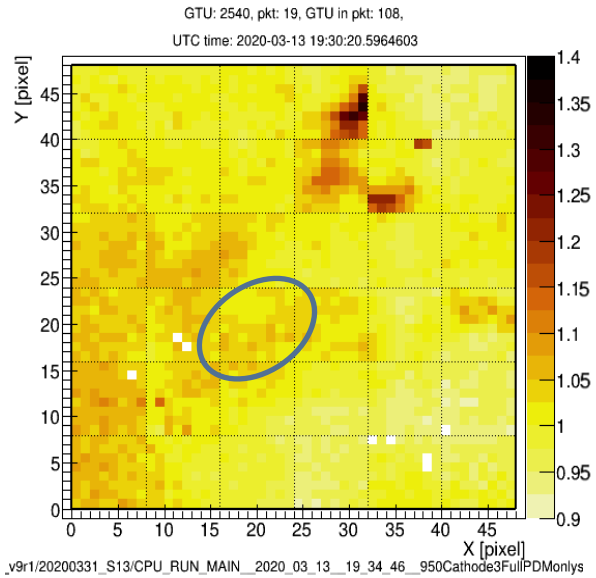
Red dots: ground networks
Yellow diamonds: ISS position at M event
Green diamonds: position of M event

- **2 M in FoV of Palermo PRISMA camera: NO counterpart**
- **3 M in FoV FRIPON network: still to be checked**

Comparison with expected SD signals according to ESAF

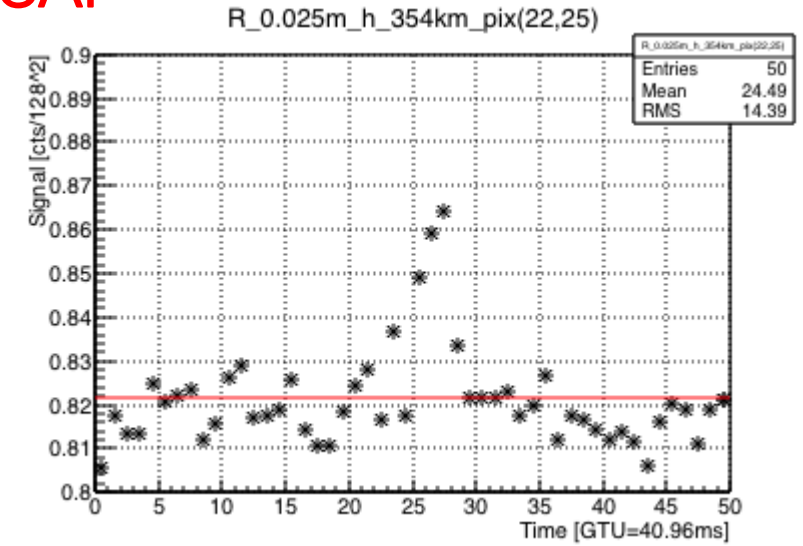




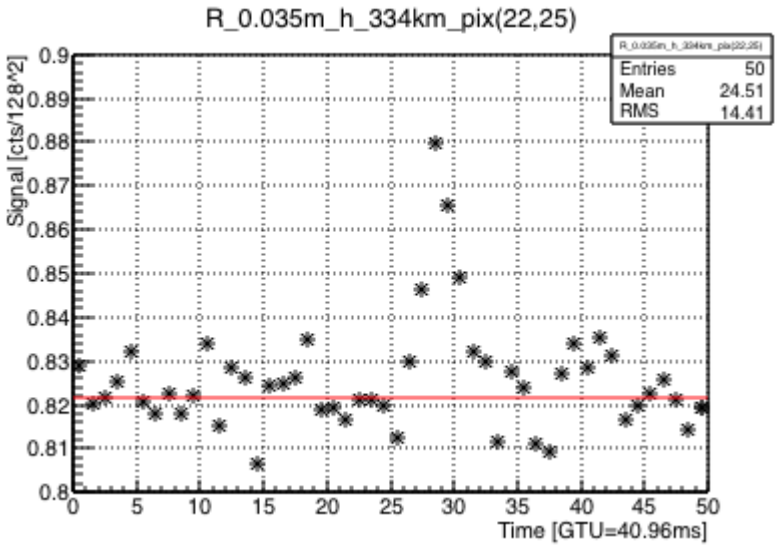


ESAF

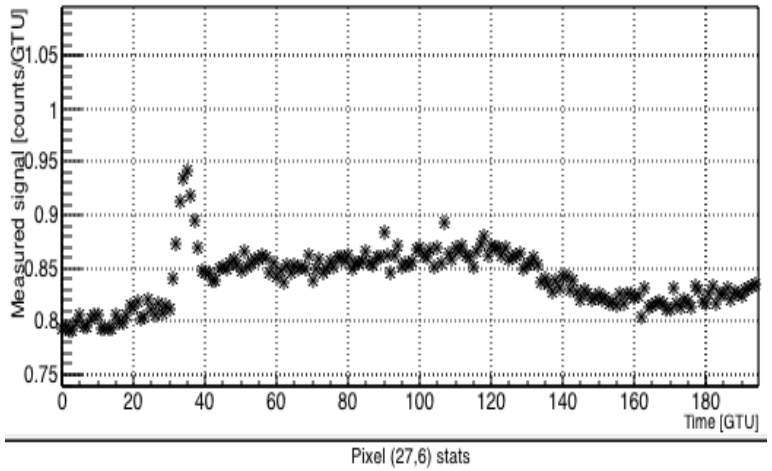
r=0.025m, h=354km, *max 6.1σ*

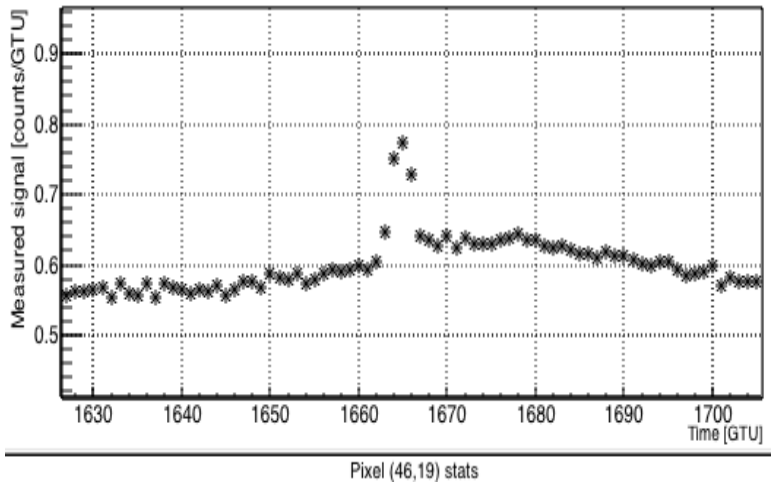


r=0.035m, h=334km, *max 6.2σ*

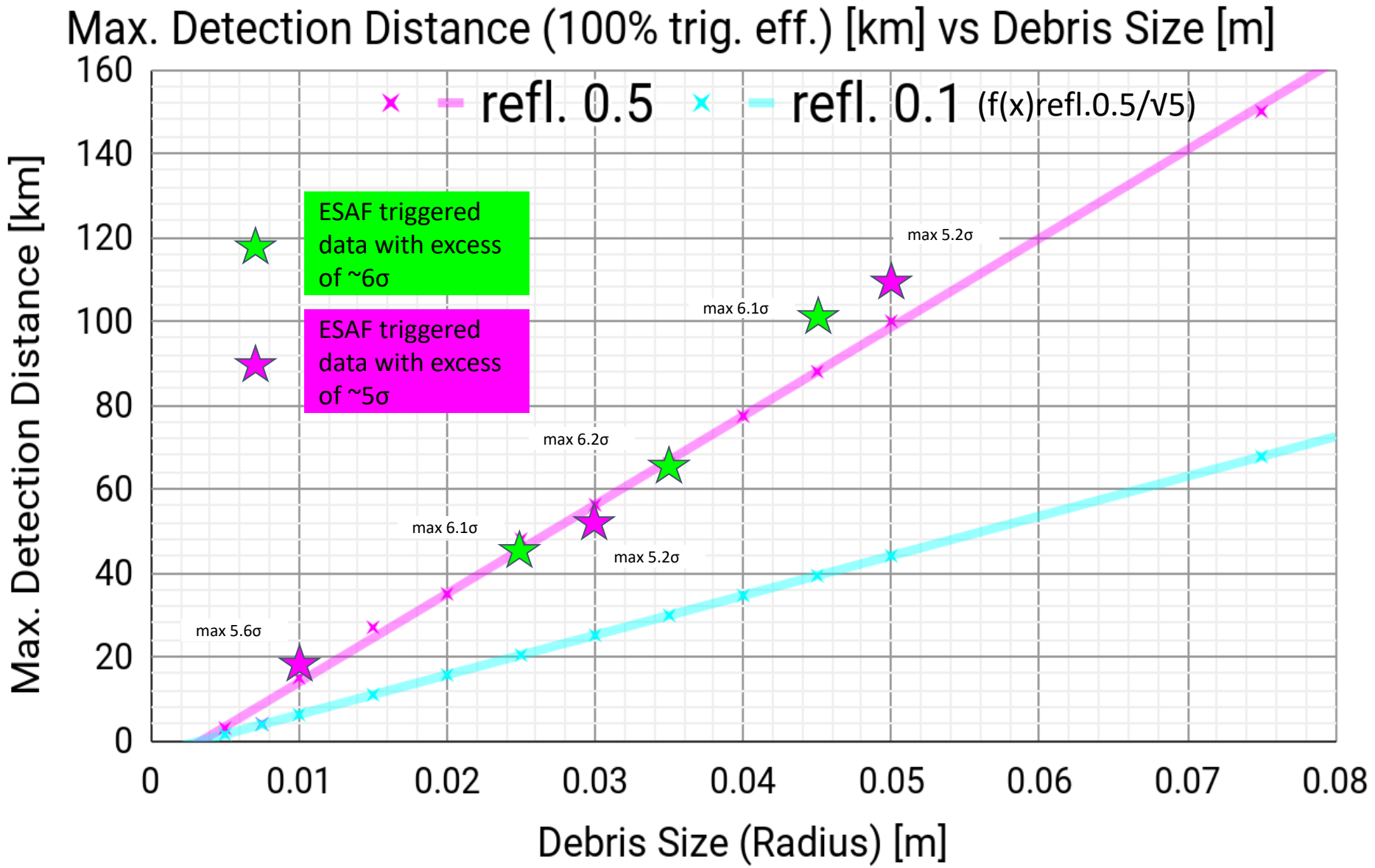


Mini-EUSO meteors





ESAF Simulation results + Mini-EUSO data



CONFIRMATION WITH Mini-EUSO METEOR DATA OF THE EXPECTED SENSITIVITY TO SD

Conclusions:

- Mini-EUSO is on ISS and takes data 2/month.
- Mini-EUSO detects events of different nature according to expectations.
- Thousands of meteor events to be analysed.
- Preliminary estimation of sensitivity to meteors in agreement with simulations.
- Detailed data analysis in process.
- We look forward to have events detected in correlation with PRISMA, we got close but not lucky yet.
- The meteor study is important also for detection of space debris.

THANK YOU