Università degli studi di Torino
Corso di Laurea Triennale in Fisica
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A COMPARISON BETWEEN MINI-EUSO DATA FROM ISS AND TURLAB REPRODUCTION OF JEM-EUSO ORBITS

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SUMMARY

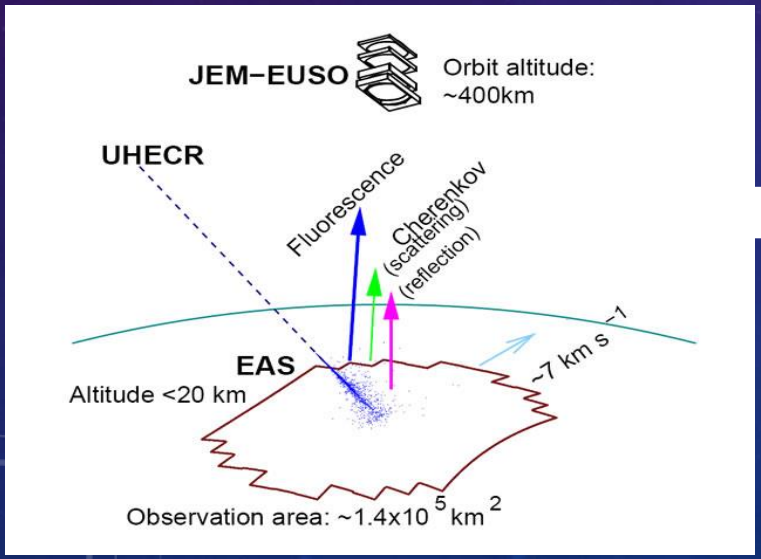
THE JEM-EUSO PROGRAM

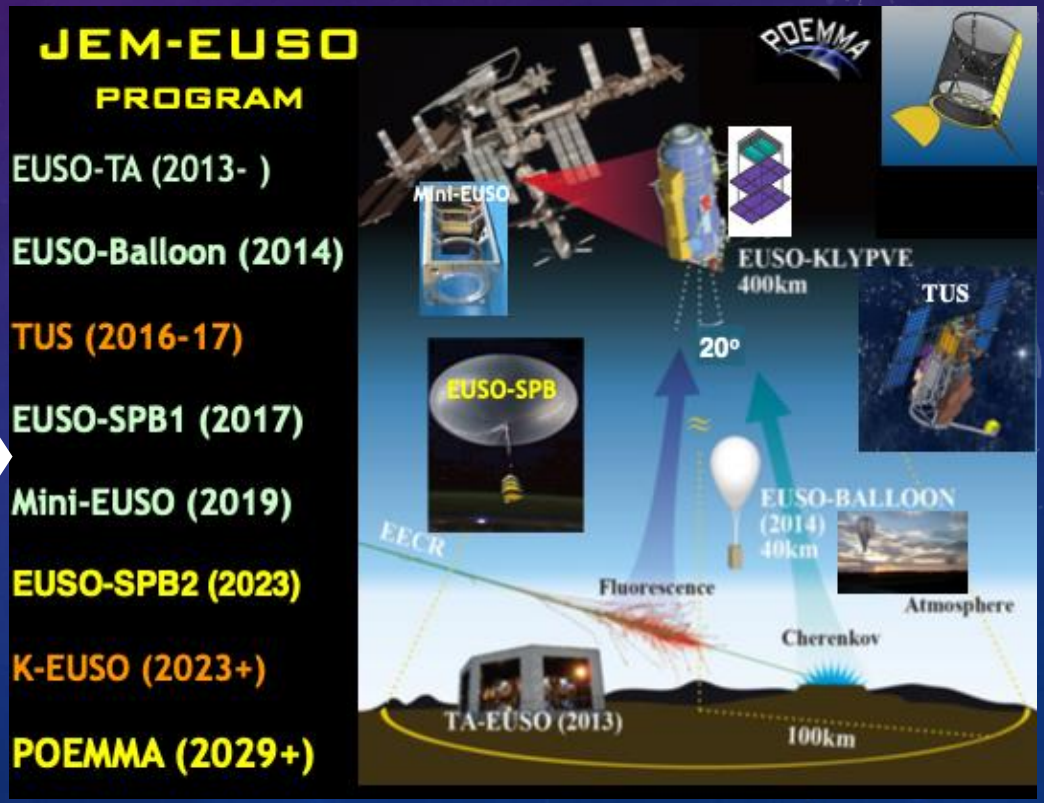
Joint Experiment Mission for the Extreme Universe Space Observatory

MAIN GOAL: Observation of the fluorescence tracks produced at (330-400)nm by Extensive Air Showers (EAS) originated by UHECR (Ultra High Energy Cosmic Ray) primaries, using the Earth's atmosphere as detector.

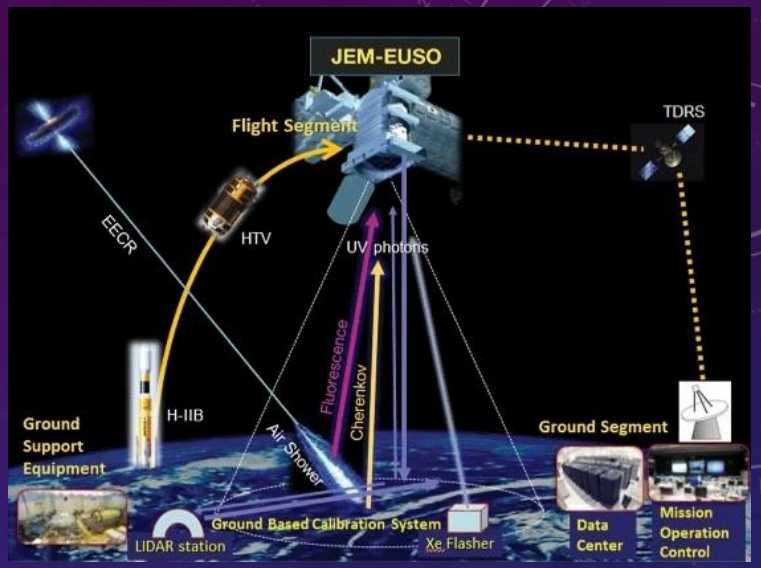
FROM A MISSION TO A PROGRAM:

From the concept of a single large UV telescope, the JEM-EUSO program comprehend now many different instruments. They will study the UHECRs from ISS, satellites and from ground.





THE JEM-EUSO MISSION:
The Original Concept

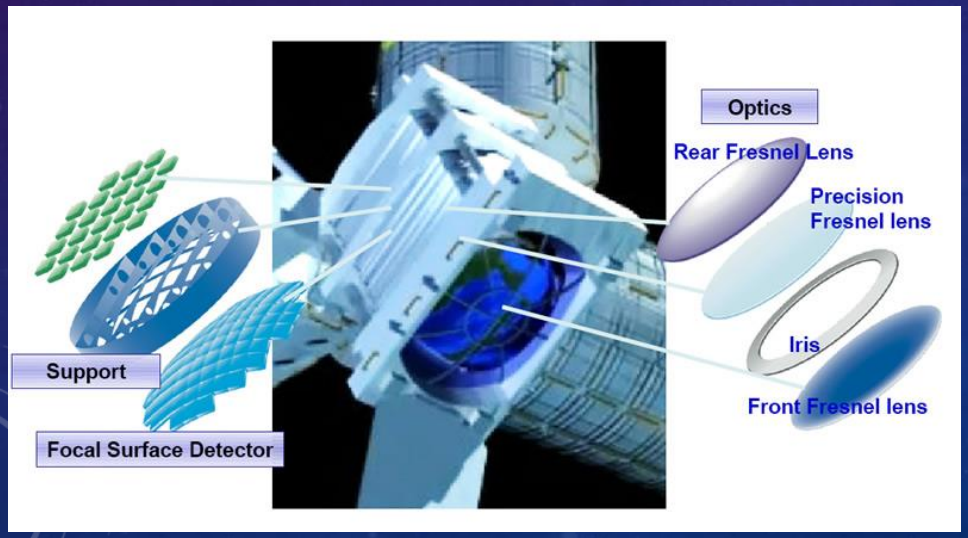


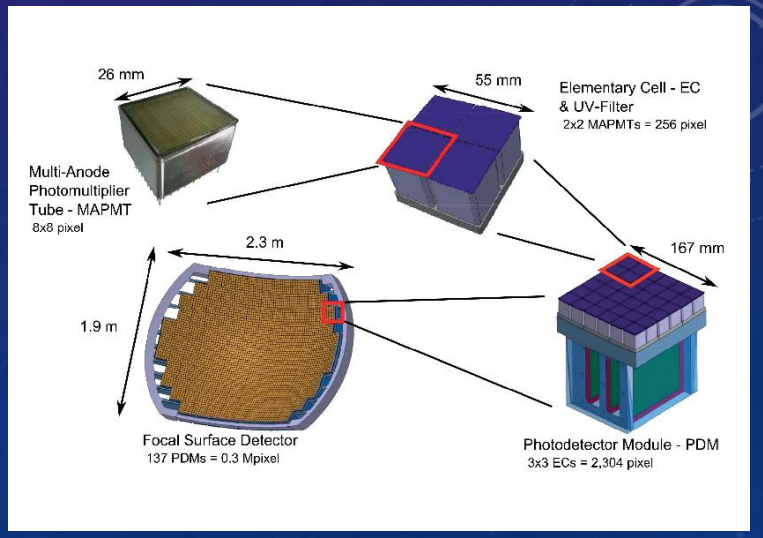
MAIN SUB-SYSTEMS: will characterize most of the future missions

- Optical System: Fresnel lenses-based optical system
- Focal Surface: 137 Photo-Detector Module (PDM)
- Data Acquisition: SPACIROC ASICs array

The Data Acquisition System has a time resolution of 2,5μs (D1 GTUs – Gate Time Units).
D1 GTUs are integrated at higher levels (D2 and D3):

D1 GTU 2,5μs ⟶ 128 x D1 = D2 GTU 320μs ⟶ 128 x D2 = D3 GTU 40,96ms



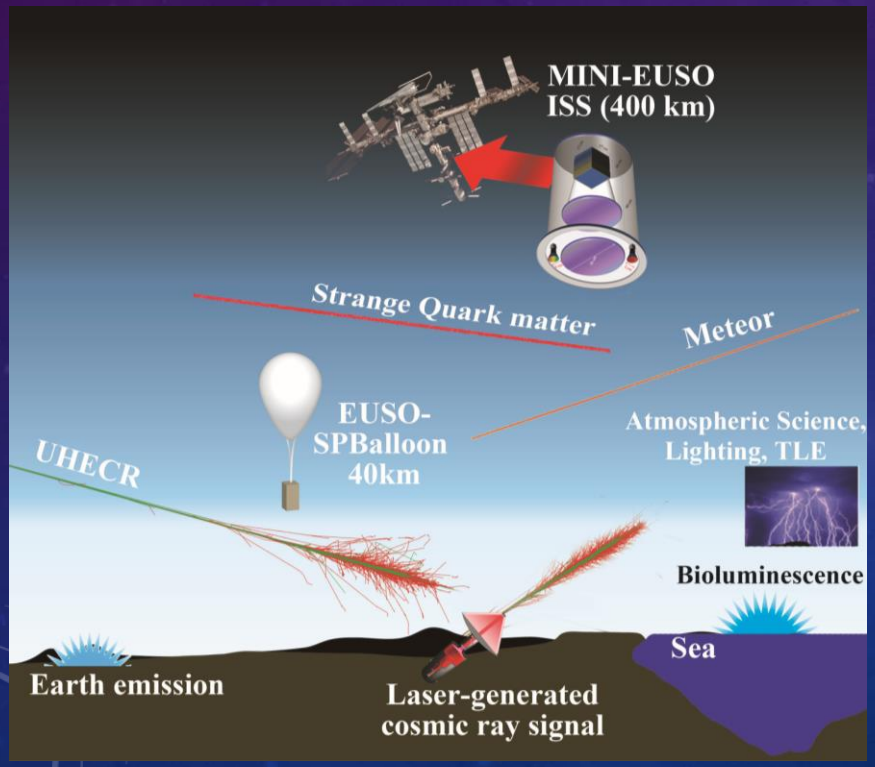


THE MINI-EUSO MISSION

Multiwavelength Imaging New Instrument for the EUSO program

MAIN PURPOSE: Pathfinder mission for EUSO program, study of UHECRs related phenomena.

Currently hosted in the nadir facing, UV-transparent window of the Zvezda Russian module on the ISS



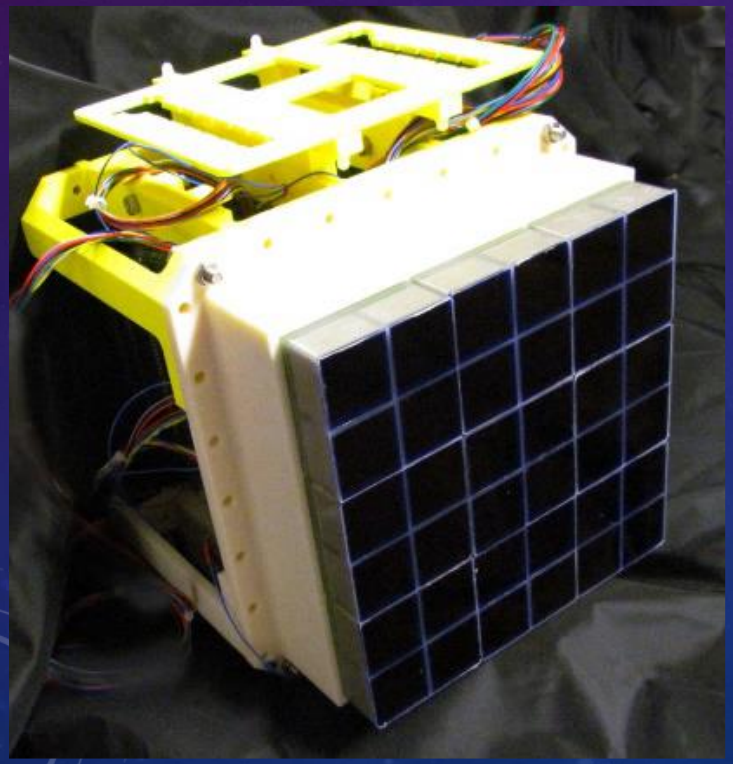
OTHER OBJECTIVES:

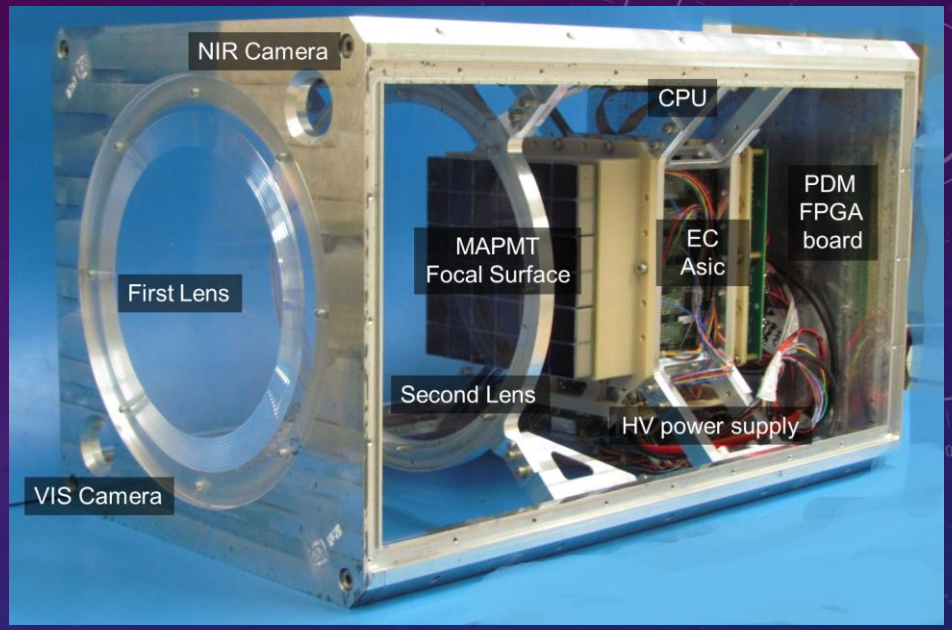
- high-resolution mapping of night-Earth UV emission (300 – 400 nm)
- Meteoroids burning in atmosphere
- TLEs (Transient Luminous Events)
- Bioluminescence sources (algae)
- SQM (Space debris mapping
- Strange Quark Matter) signals

MINI-EUSO: The Instrument

MAIN SUB-SYSTEMS:

- Optics: double Fresnel lenses-based UV optical system for the main detector + RGB camera (400—780)nm + NIR camera (1500—1600)nm
- Focal Surface: 48x48 px PDM (1/137 of JEM-EUSO concept)
- Data Acquisition: SPACIROC3 ASICs

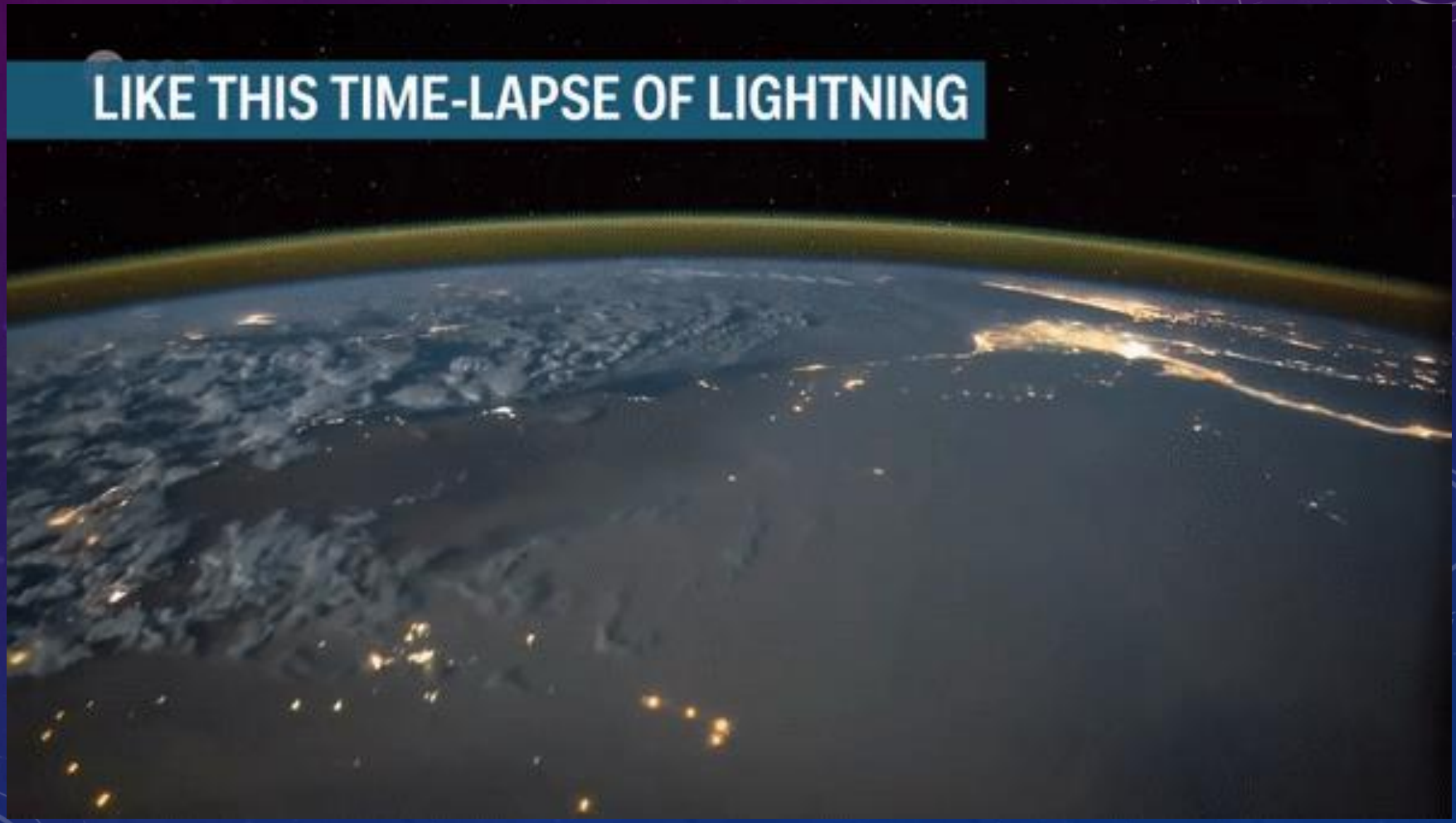




Instrument	**Mini-EUSO**	**JEM-EUSO**
Field of View	$\pm 22°$	$\pm 30°$
Aperture Area	$490\ cm^2$	$\geq 2{,}5\ \mathrm{m}^2$
Operational Wavelength	$300 - 400\ nm$	$300 - 400\ nm$
Pixel Size	$< 3\ mm$	$< 3\ mm$
Number of Pixel	**2304**	$\approx \mathbf{3 \times 10^5}$
Resolution Angle	$\mathbf{0,8°}$	$\mathbf{0,075°}$
Pixel Size on Ground	$\mathbf{\sim 6\ km}$	$\mathbf{\sim 550\ m}$
Monitored Area	$2{,}6 \times 10^2\ \mathrm{km}^2$	$> 1{,}3 \times 10^5\ \mathrm{km}^2$
Temporal Resolution	$2{,}5\ \mu s$	$2{,}5\ \mu s$

EUSO@TURLAB

Physics Department - University of Turin



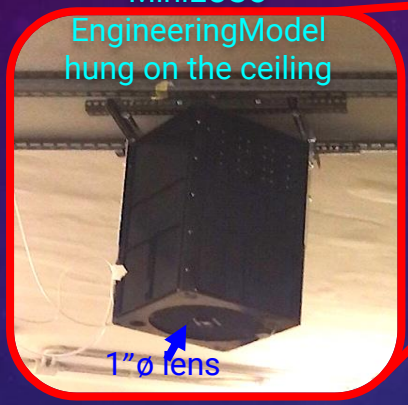
EUSO@TURLAB: The Facility

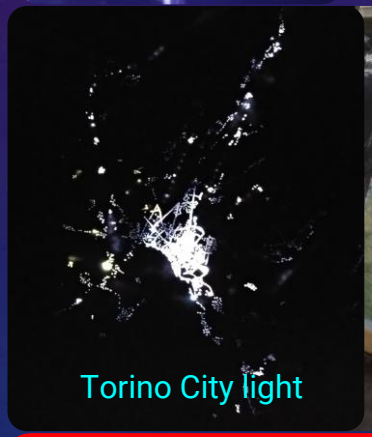
MAIN PURPOSES:

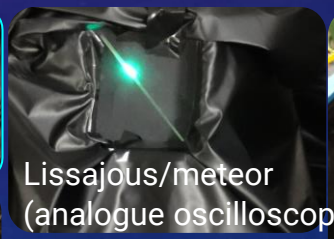
- Reproducing different luminosity variations to test the trigger logic
- simulating different terrain and atmospheric conditions as seen from orbit
- evaluating the performances of the EUSO instruments
- comparing the data collected in the TurLab and from the ISS

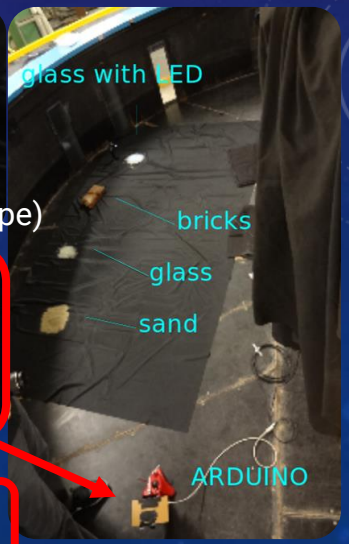
Background Light (2 strips of white LEDs)

MiniEUSO EngineeringModel hung on the ceiling









Pieces of SD materials for the reflectivity measurement

EUSO@TURLAB: Turin City Model - Calculations

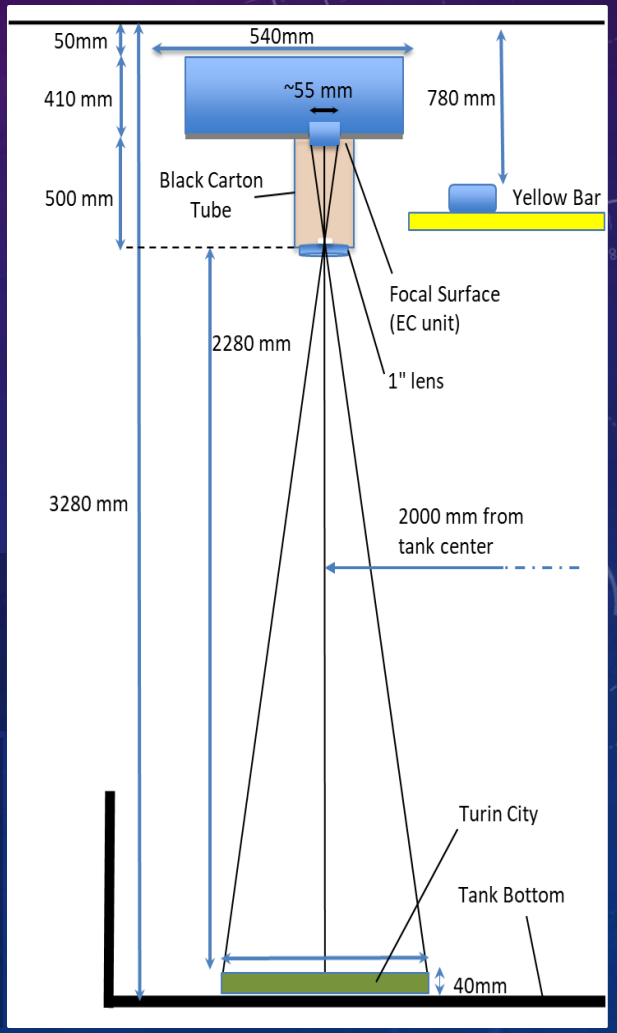
To reproduce the Turin Metropolitan area in a scale compatible with the dimension of our tank, and in a range compatible with the FoV of the instruments in orbit, we choose to start form a standard A0 paper format $(1189 \times 841)\ mm$:

- Printed Area: $(83 \times 58 \times 3)\ km$
- Final Dimensions : $(1180 \times 830 \times 40)\ mm$
- Conversion Scale: 1: 70000
- C.so Francia 11,75 $km \rightarrow 168mm$

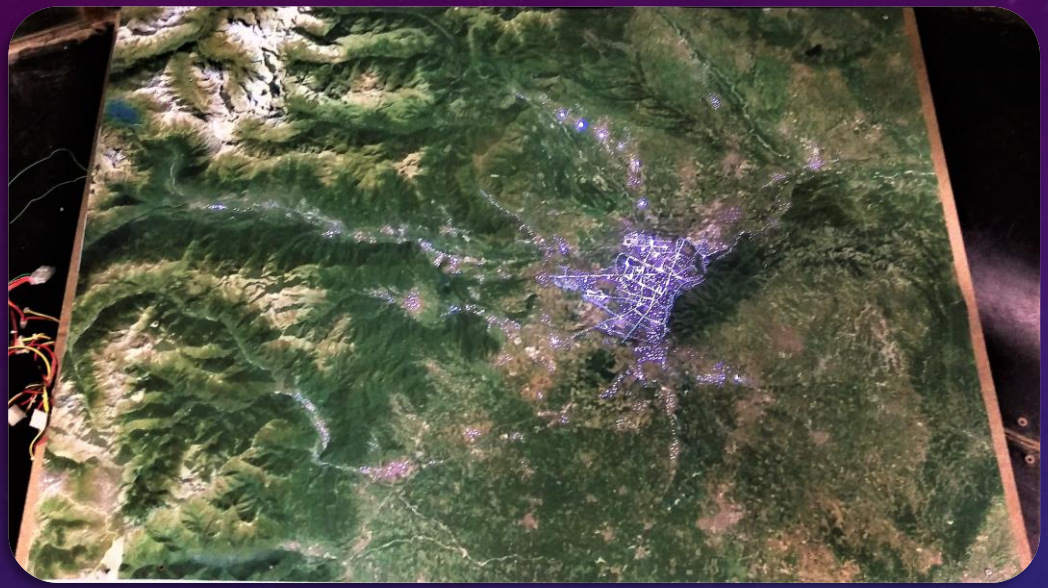
Ceiling-bottom distance	$\sim 3280\ mm$	Real Pixel Linear FoV	$Dist \frac{PixelFS}{Focal\ Length}$
MAPMT (pixel) focal surface	$27\ mm$ $(3{,}38\ mm)$	Scaled Pixel FoV	$\frac{Real\ C.Francia}{Scaled\ C.Francia} PxFoV$

	JEM-EUSO	Mini-EUSO
Pixel FoV from 400km altitude	$\sim 560\ m/px$ (on Earth)	$\sim 6110\ m/px$ (on Earth)

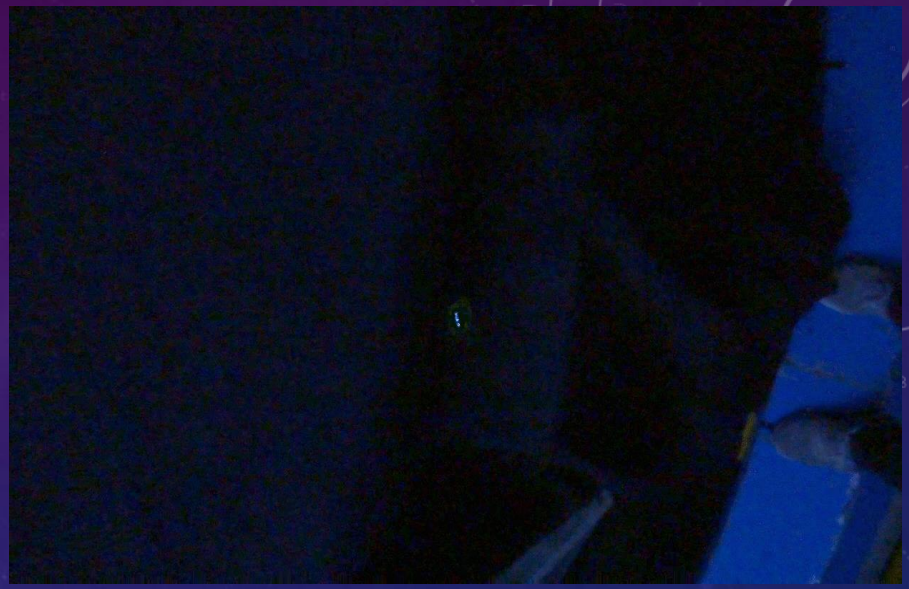
	Focal Length	Lens-Bottom Distance	Real Pixel FoV	Converted Pixel FoV	TurLab/JEM-EUSO Scale Factor	TurLab/Mini-EUSO Scale Factor
JEM@ TurLab	$500\ mm$	$2280\ mm$	$15{,}4\ mm$ (on model)	$1077\ m/px$ (on model)	$\times\ 1,92$	$\div\ 5{,}67$
Mini@ TurLab	$300\ mm$	$2480\ mm$	$27{,}9\ mm$ (on model)	$1951 m/px$ (on model)	$\times\ 3{,}48$	$\div\ 3,13$



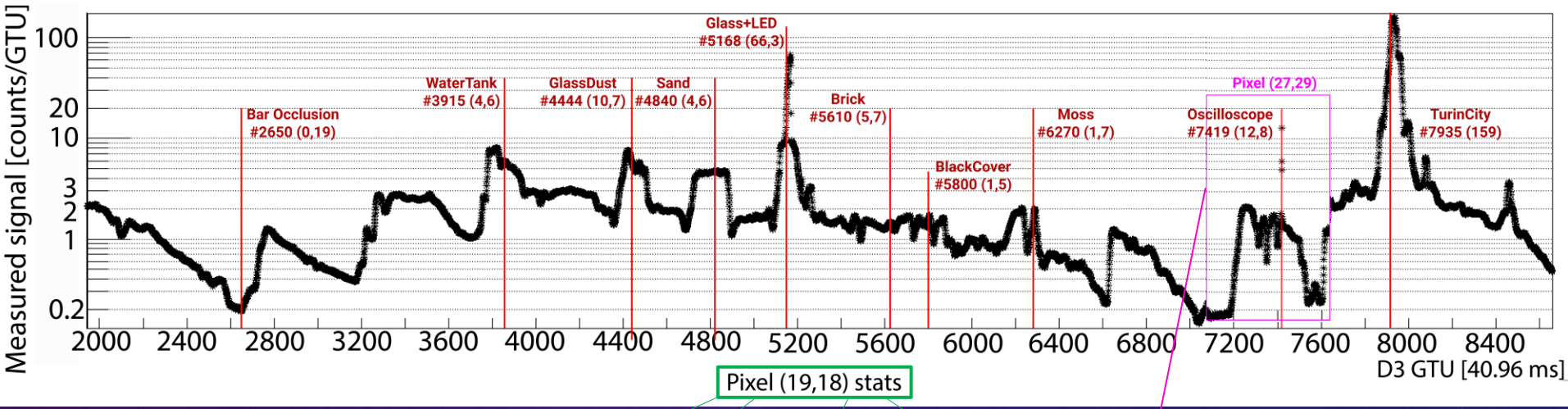
EUSO@TURLAB: Turin City Model – The Making



EUSO@TURLAB: Visual Results

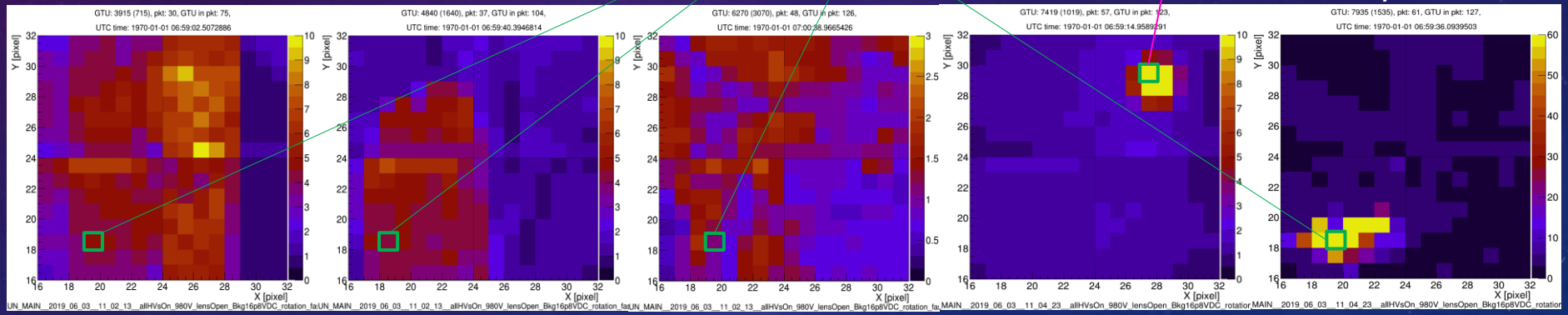


EUSO@TURLAB: Lightcurves



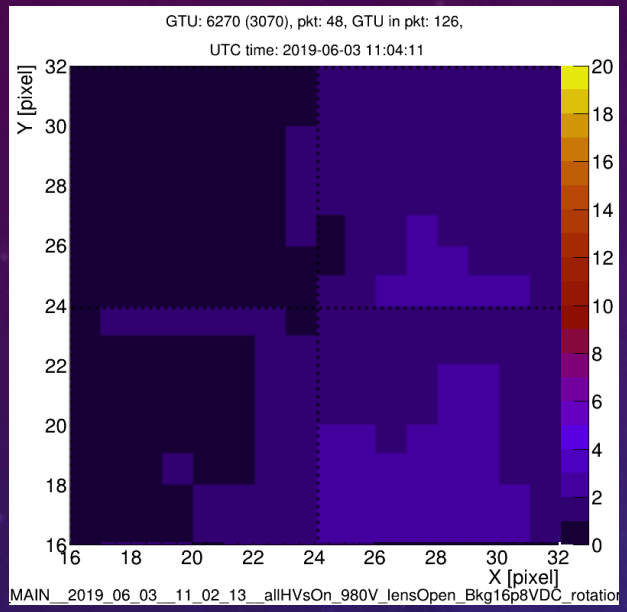
Pixel (19,18) stats

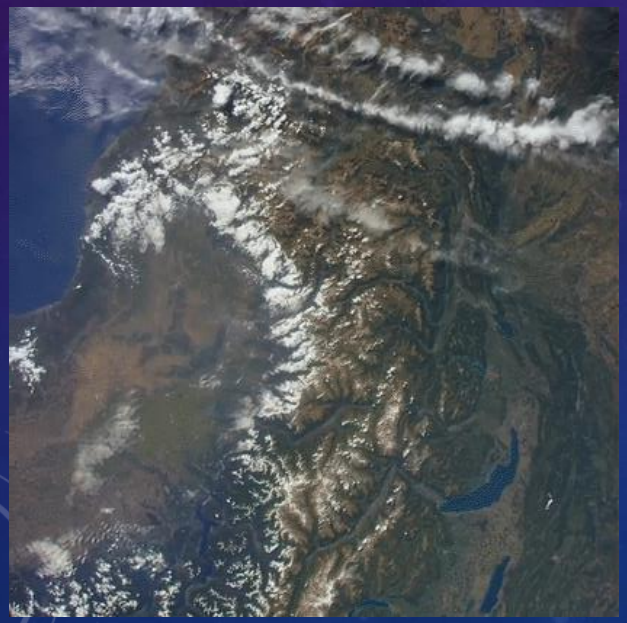
Clouds Sand Moss Meteor Turin city .

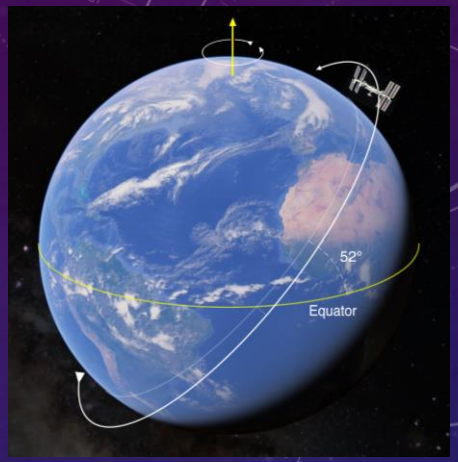


	Covered Bar Occlusion	Water tank (clouds)	Glass Dust	Sand (desert)	Glass + LED (On)	Brick	Black Cover Background	Moss (forest)	Oscilloscope (Meteor)	Turin City
GTU #	2650	3915	4430	4840	5167	5610	**5800**	6280	7419	7935
Central Px Count	0,20	4,6	7,2	4,6	67,4	5,7	**1,5**	1,6	12,8	159
Diagonal 8x8 Avg	0,20	4,0	6,5	4,4	28,7	2,5	**1,2**	1,3	5,7	14,8

EUSO@TURLAB: Rotation Period







Dynamical Scale Factor between the configurations at TurLab and onboard the ISS, using the length of C.so Francia as a reference (from 11,75 km to 16,8 cm).

ISS Orbits Inclination = 51,65°

Relative Ground Velocity = 7,3 km/s

Tank rotational period to match the ISS ground speed:

$$T = \frac{2\pi\ 2000\ mm\ 11,75\ km}{7,3\ km\ s^{-1}\ 168\ mm} = 120,3s$$

Comparing how fast the pixel FoV changes in Mini-EUSO and at TurLab, we have two different speeds:

In the TurLab: $V_{px\_TLab} = \frac{7,3\ km\ s^{-1}}{1,98\ km\ px^{-1}} = 3,69\ px\ s^{-1}$

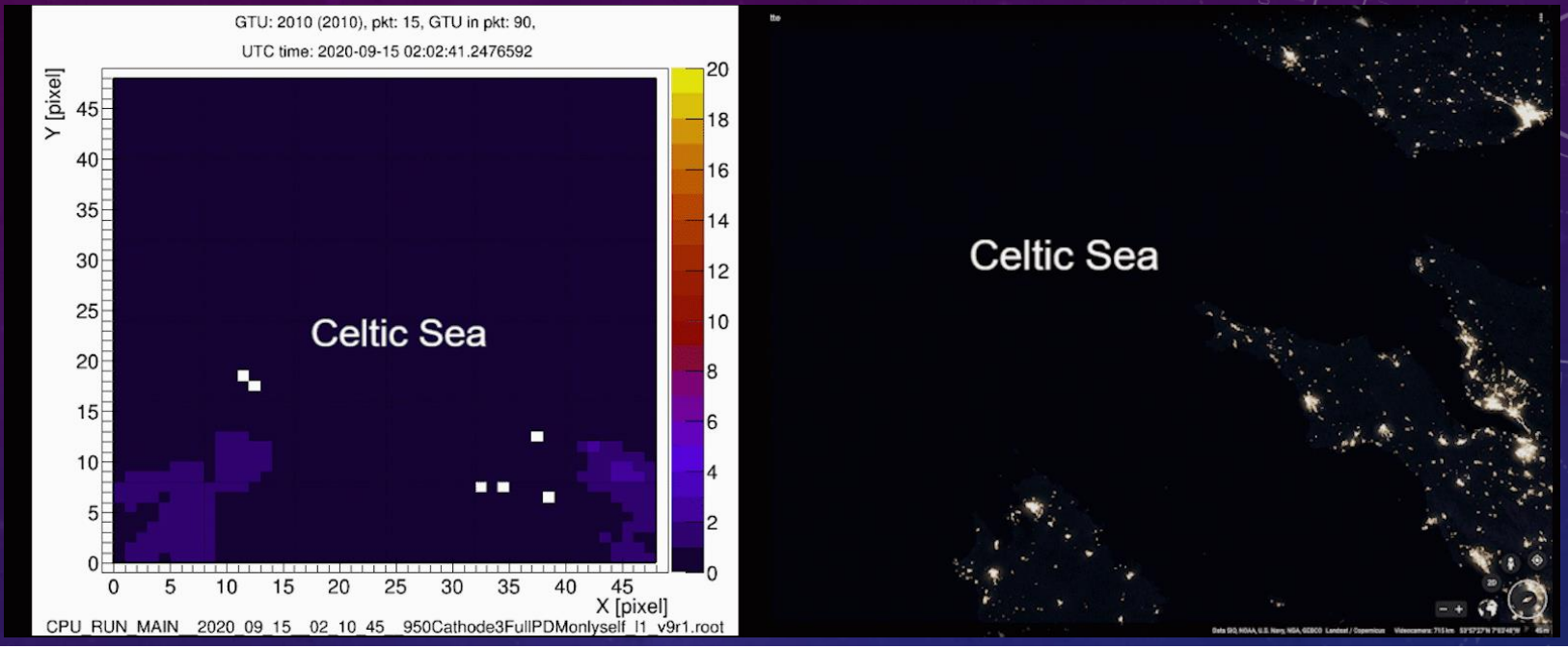
On the ISS: $V_{px\_ISS} = \frac{7,3\ km\ s^{-1}}{6,11\ km\ px^{-1}} = 1,20\ px\ s^{-1}$

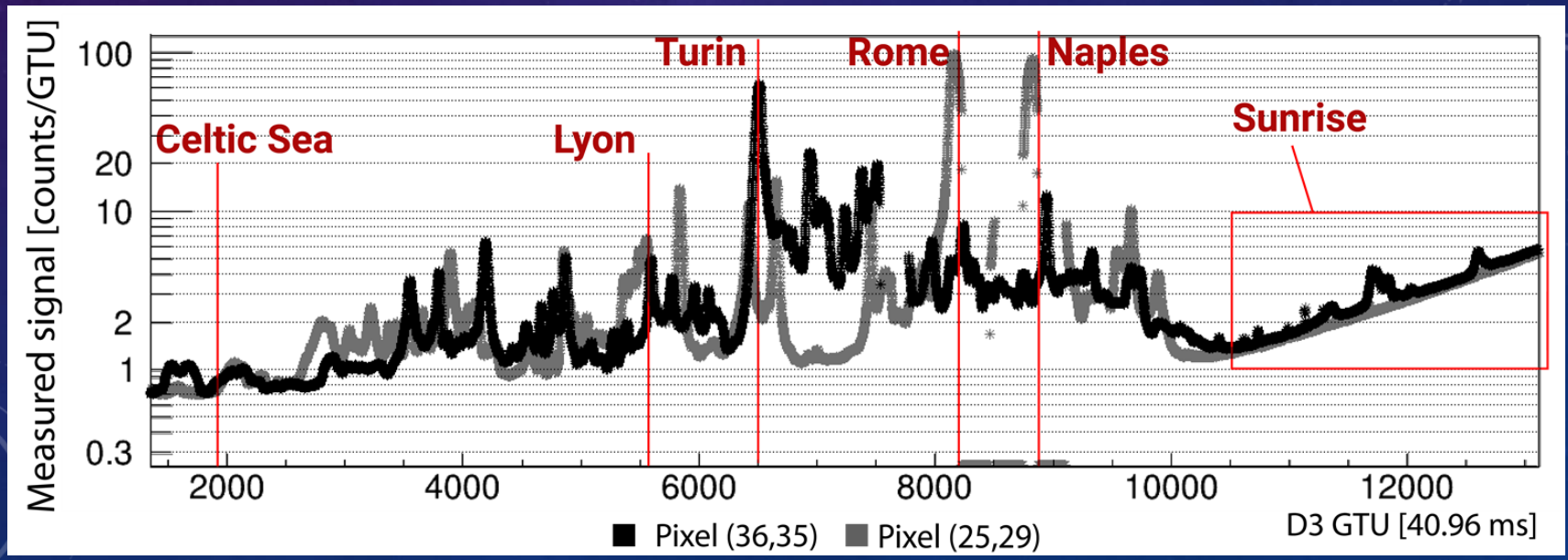
DYNAMICAL SCALE FACTOR: $V_{pxTLab}/V_{pxISS} \sim 3$

(TurLab is 3 time faster)

Ideal tank rotation period: $\sim 6\ min$

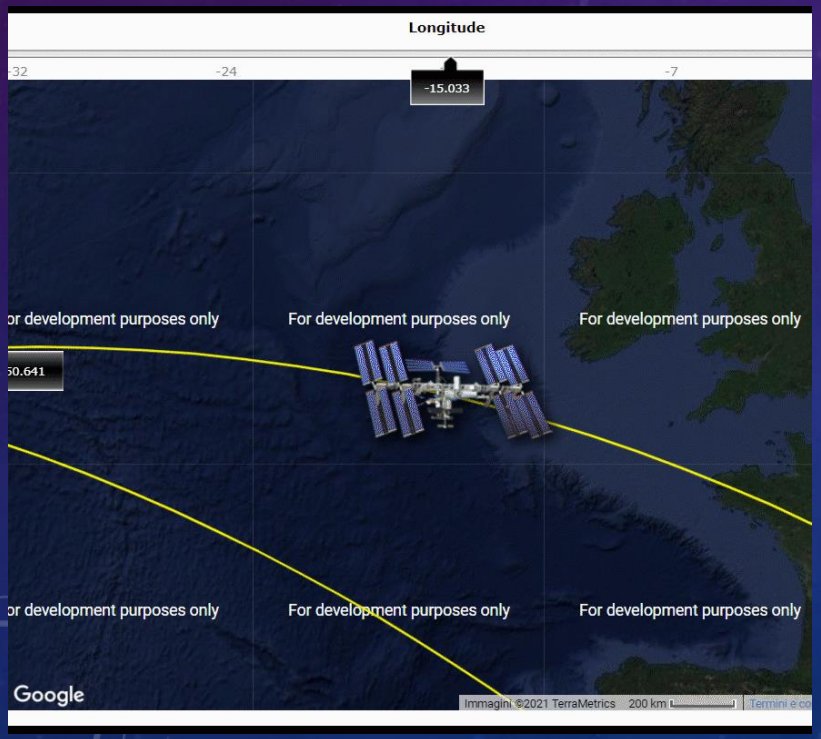
MINI-EUSO ON ISS: A Flight Over Europe



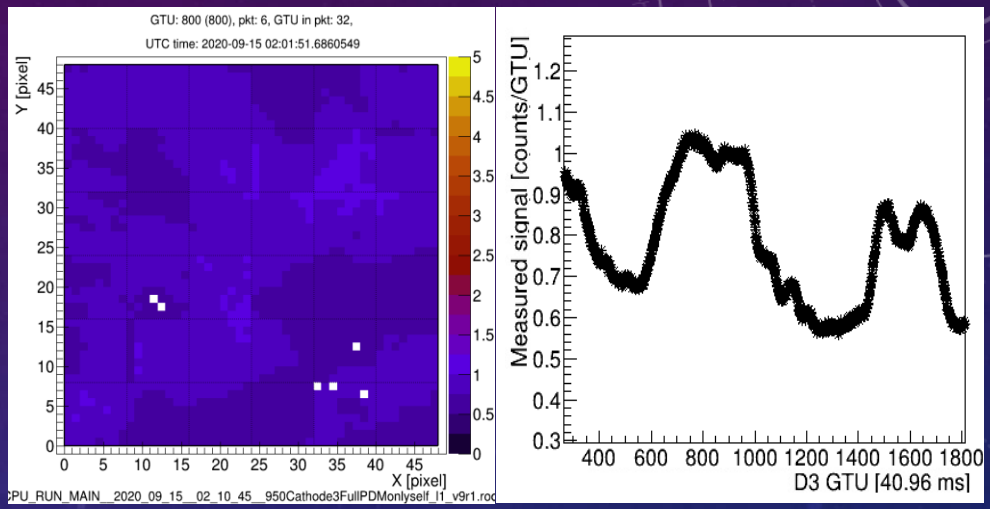


MINI-EUSO ON ISS: Session 25 - Ocean

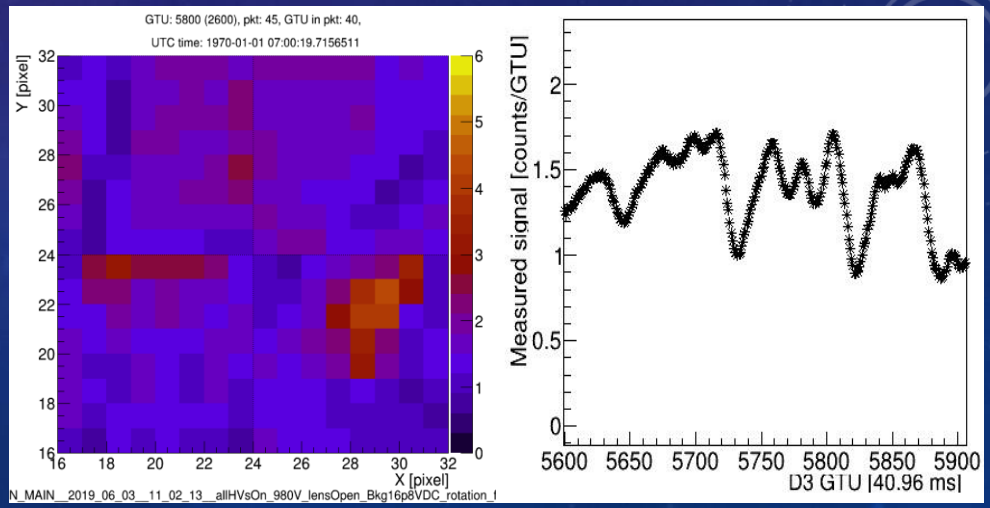
Position	Celtic Sea	TurLab
Environment	Ocean	Black Cover
Px Count	1,0	1,5
Moon Phase	8%	



Mini-EUSO on ISS (48x48 px)



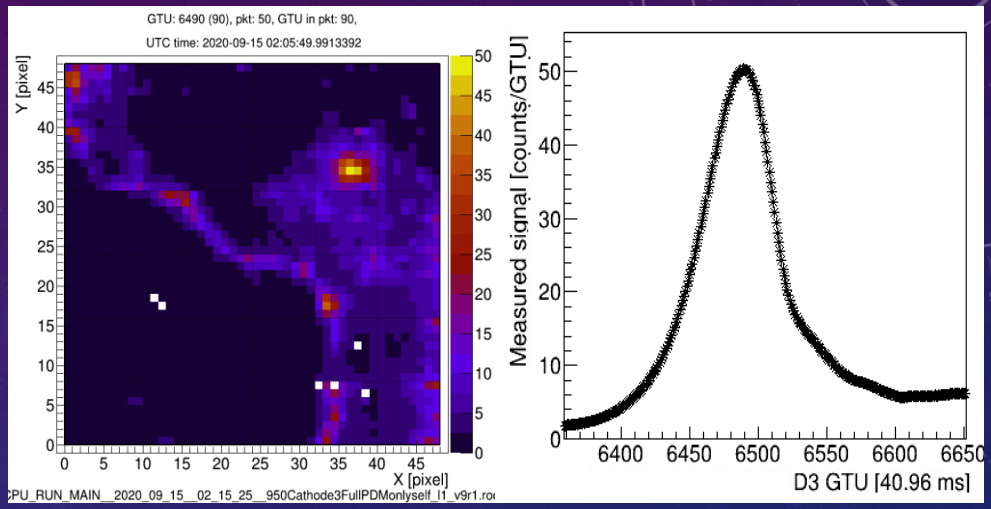
Background @ TurLab (16x16 px)



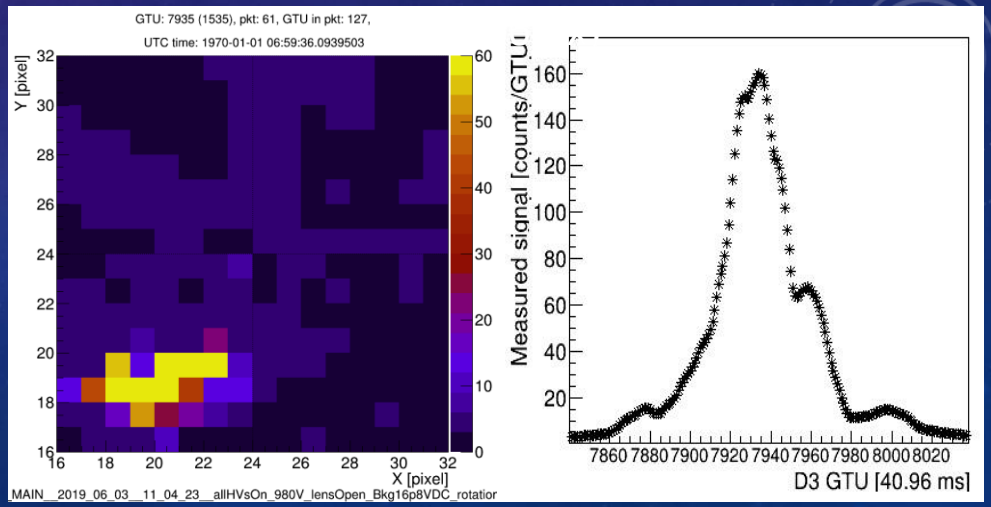
MINI-EUSO ON ISS: Session 25 - Turin

Position	Italy - Turin	TurLab
Environment	Urban Area	Turin Model
Px Count	66	159
Moon Phase	8%	

Mini-EUSO on ISS (48x48 px)

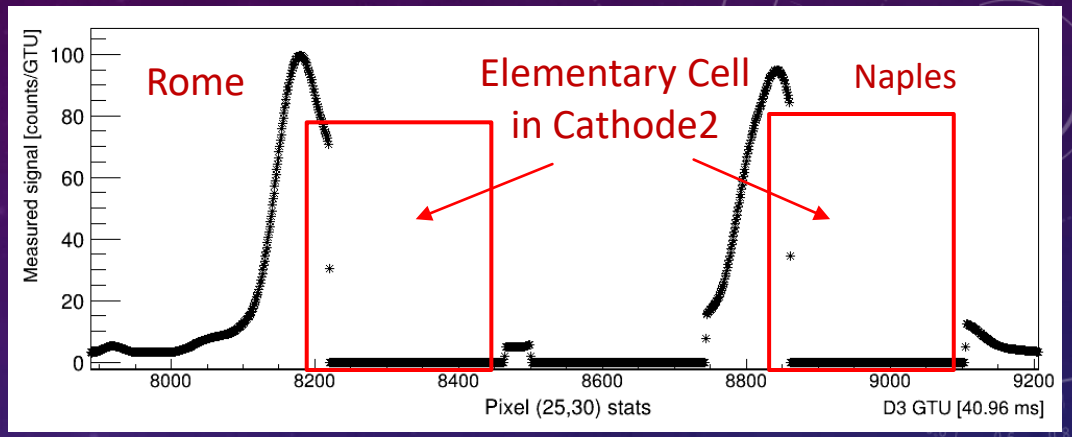


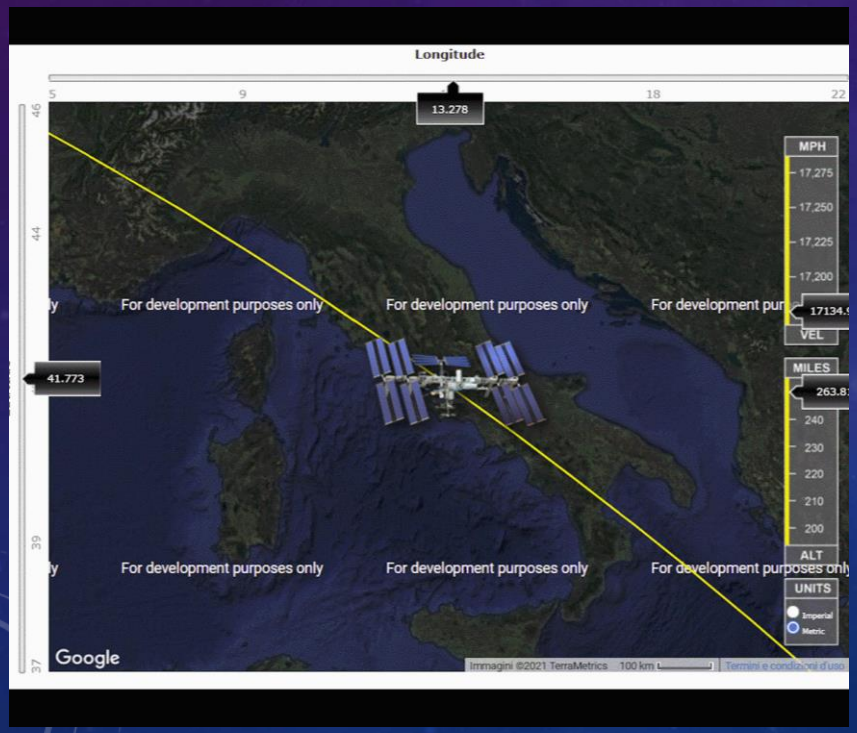
Turin Model @ TurLab



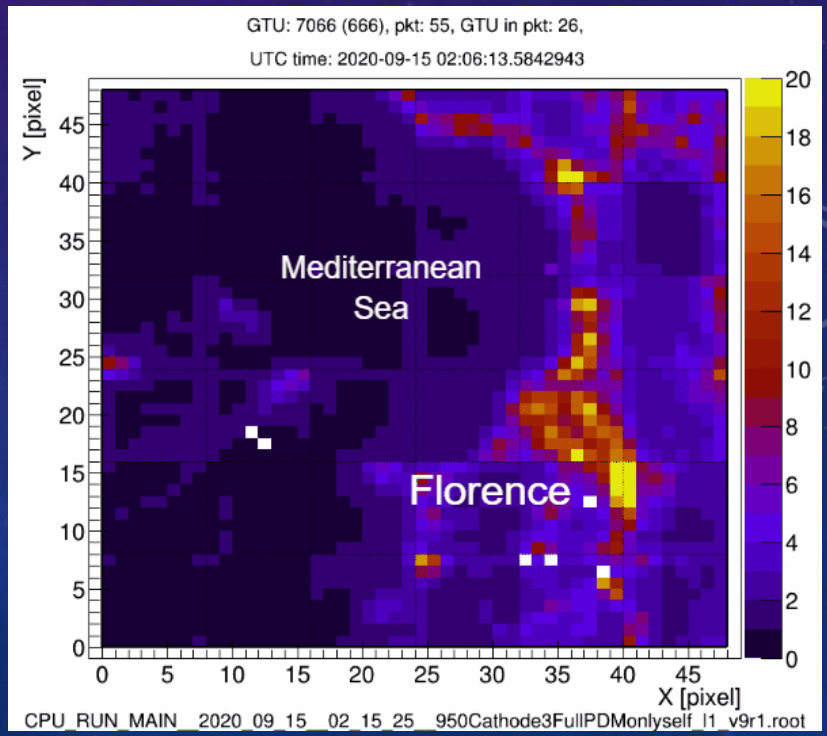
MINI-EUSO ON ISS: Session 25 - Rome

Position	Italy - Rome	TurLab
Environment	Urban Area	Turin Model
Px Count	100	159
Moon Phase	8%	-



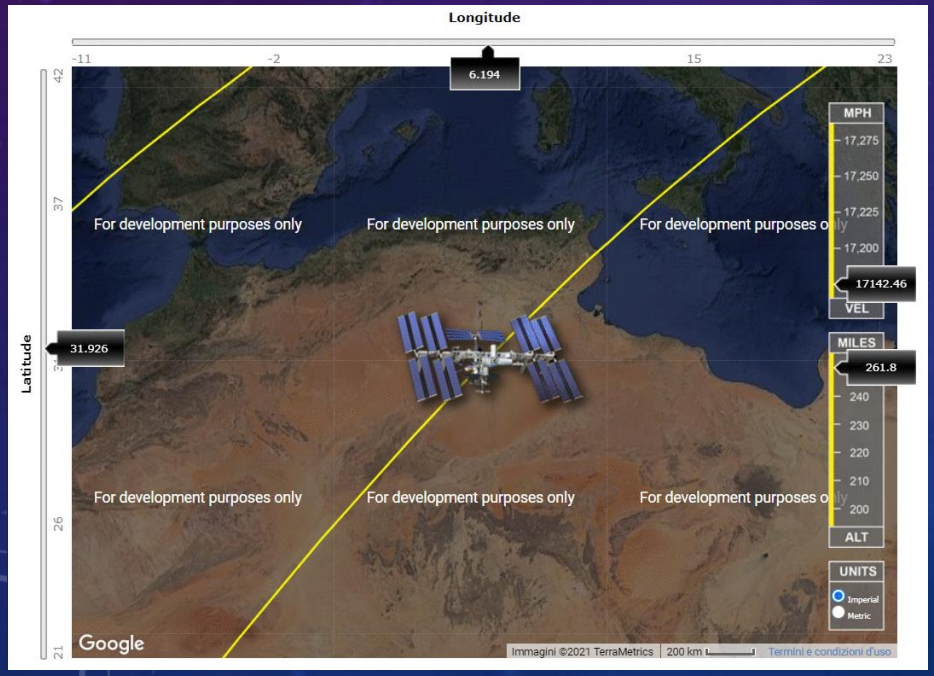


Mini-EUSO on ISS (48x48 px)

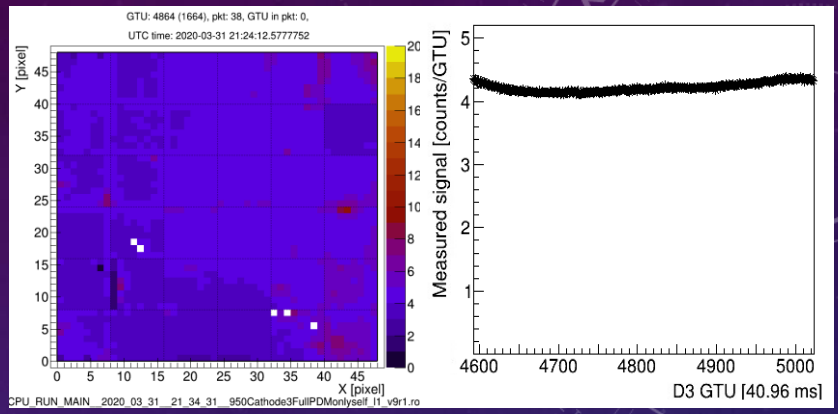


MINI-EUSO ON ISS:
Sessions 14 And 25 - Desert

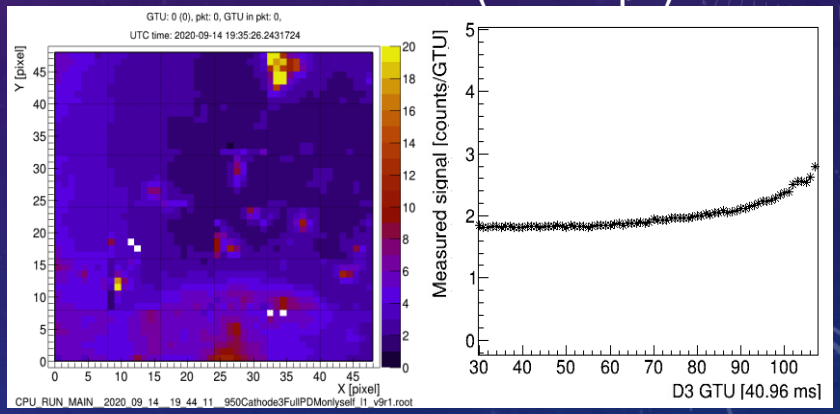
Position	Algeria S25	Algeria S14	TurLab
Environment	Desert	Desert	Sand
Px Count	1,5	4,2	4,5
Moon Phase	9%	44%	-



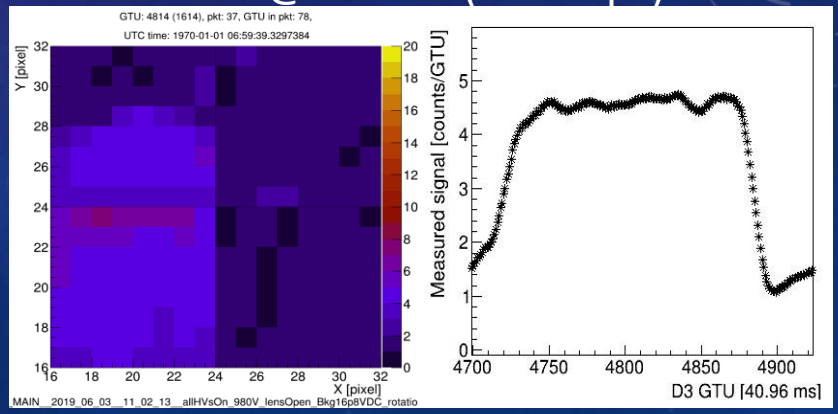
Mini-EUSO S14 (48x48 px)



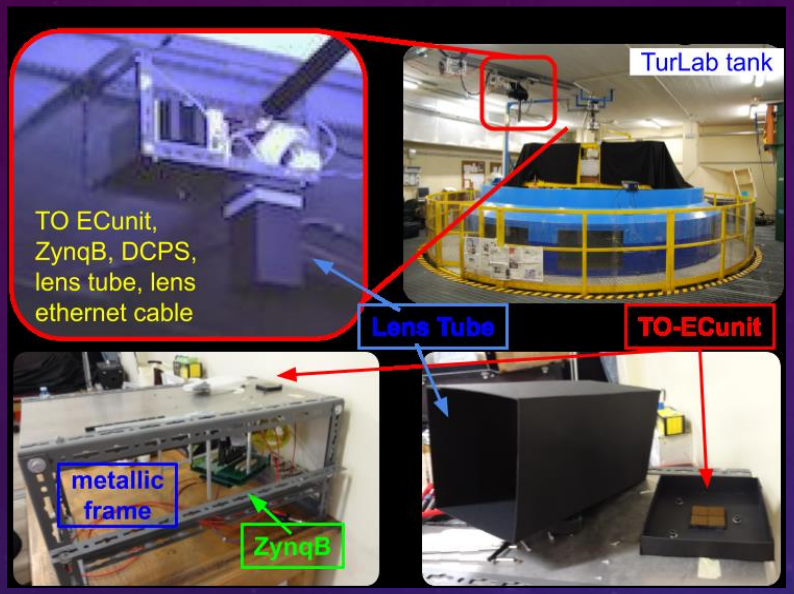
Mini-EUSO S25 (48x48 px)



Sand @ TurLab (16x16 px)



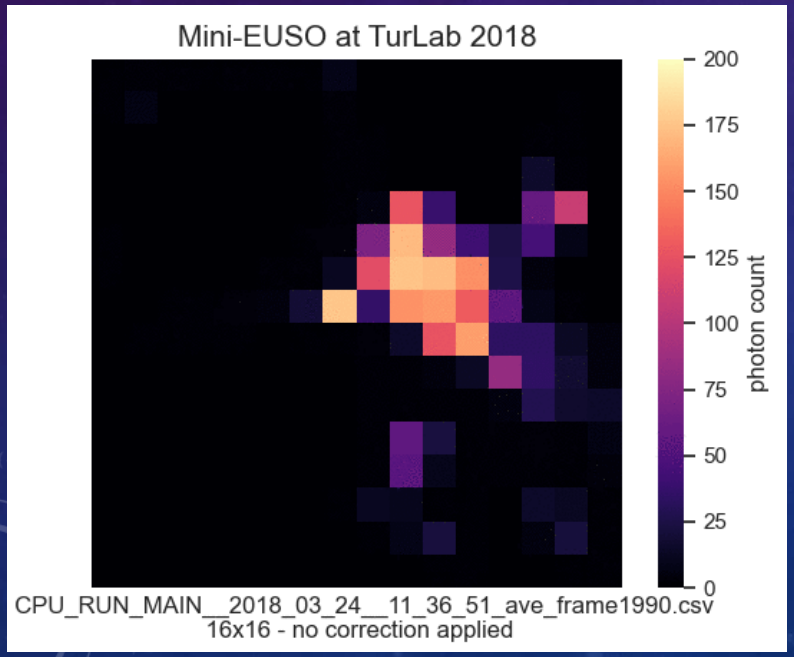
MINI-EUSO@TURLAB 2018: Turin City Model

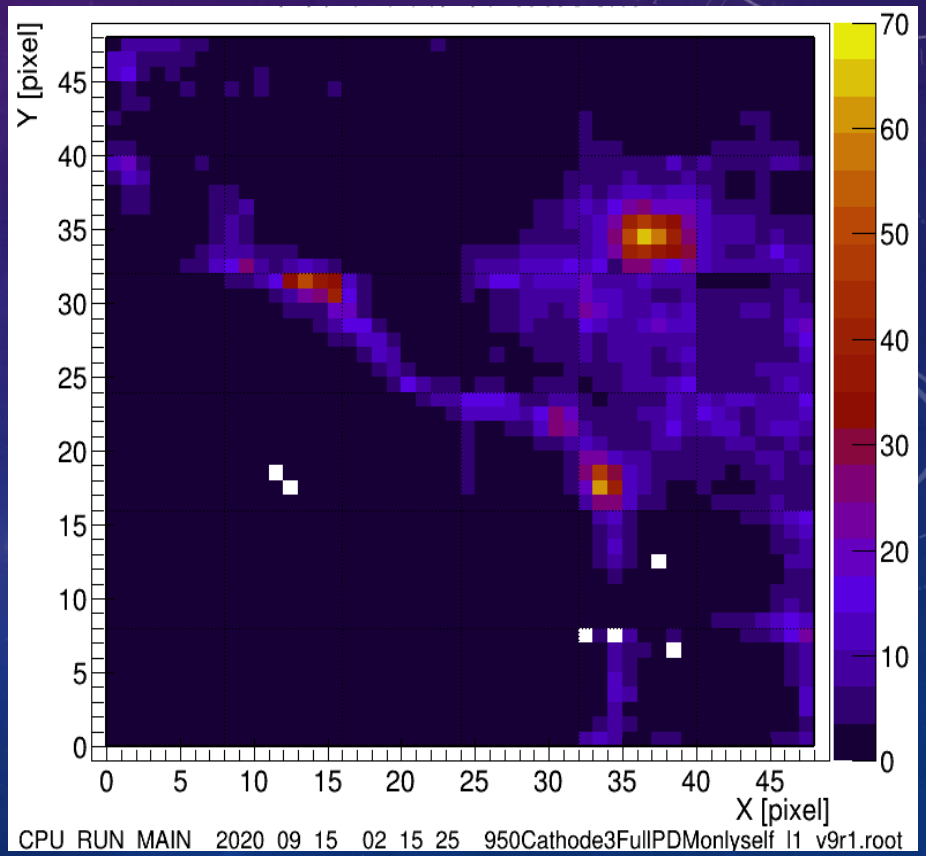


Corrections to consider:

- Point Spread Function
- FoV scale factor of 3

Mini-EUSO on ISS – Session 25 - North Italy



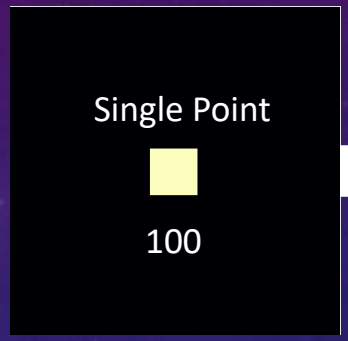


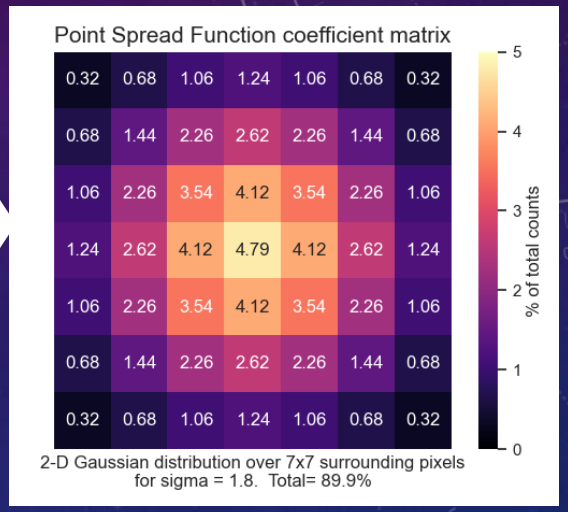
DATA CORRECTION: The Point Spread Function

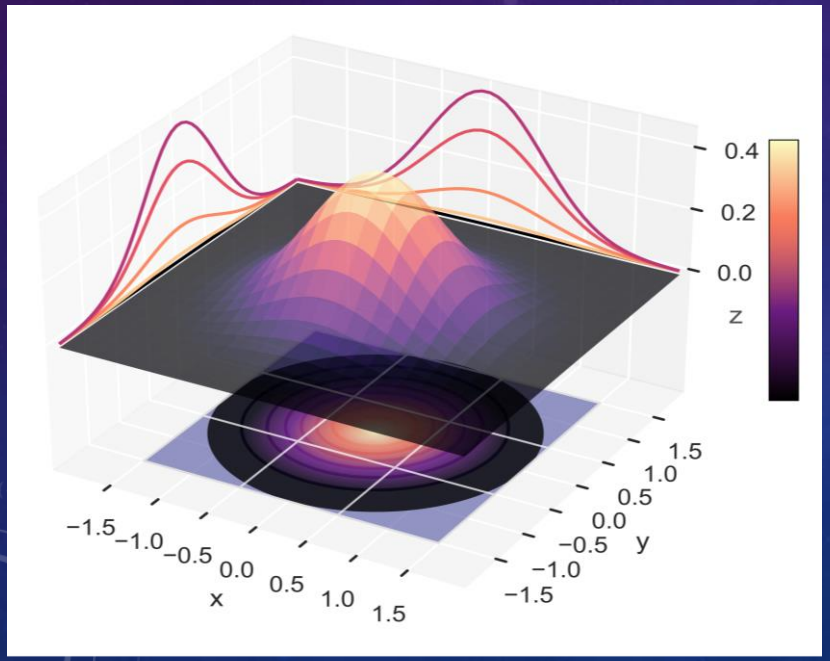
The data collected from each pixels need to be corrected for the Point Spread Function (PSF), which indicates how much of the particles are effectively collected by the pixel itself, and how much is instead collected by the surrounding pixels.

Assuming for the PSF a bidimensional Gaussian function with $\sigma_x = \sigma_y = 1.8$ and the pixel as a unitary square, we define the PSF function and integrate it over the boundaries of every pixel:

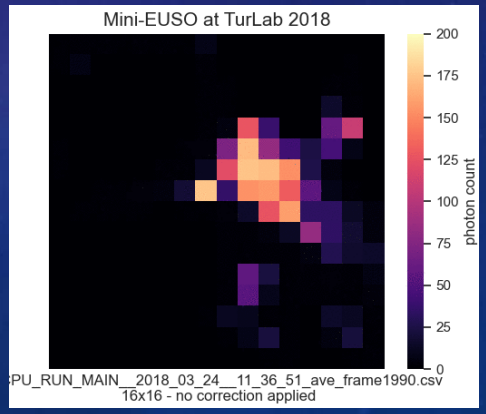
$$PSF(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\left(\frac{x^2 \cdot y^2}{2\sigma^2}\right)}$$



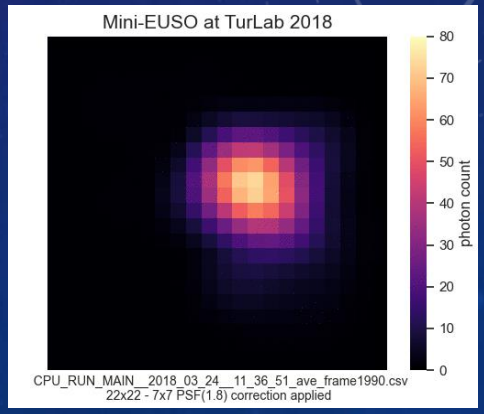




Original (16x16 px)

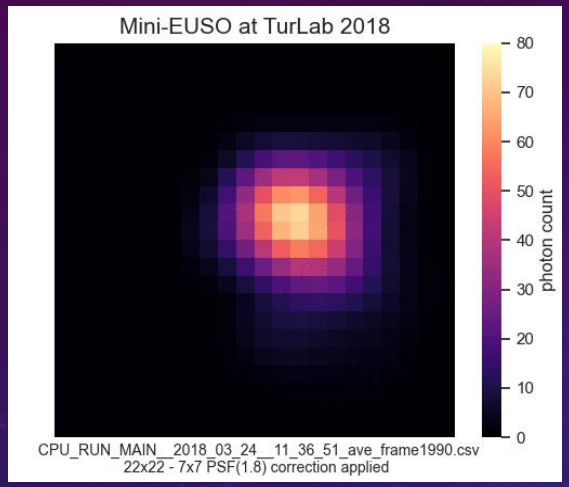


Corrected (22x22 px)

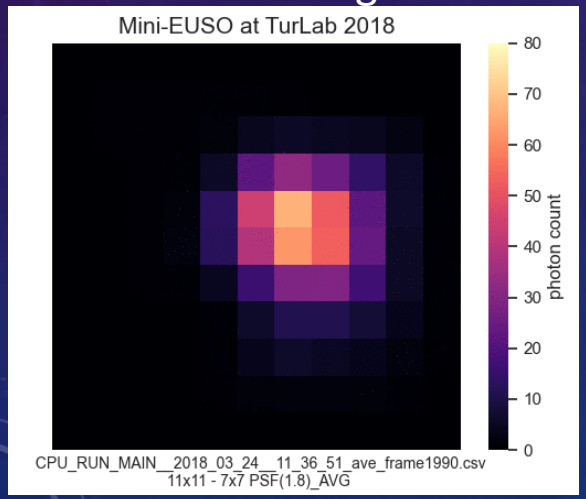


MINI-EUSO@TURLAB 2018: Corrected Image Comparison

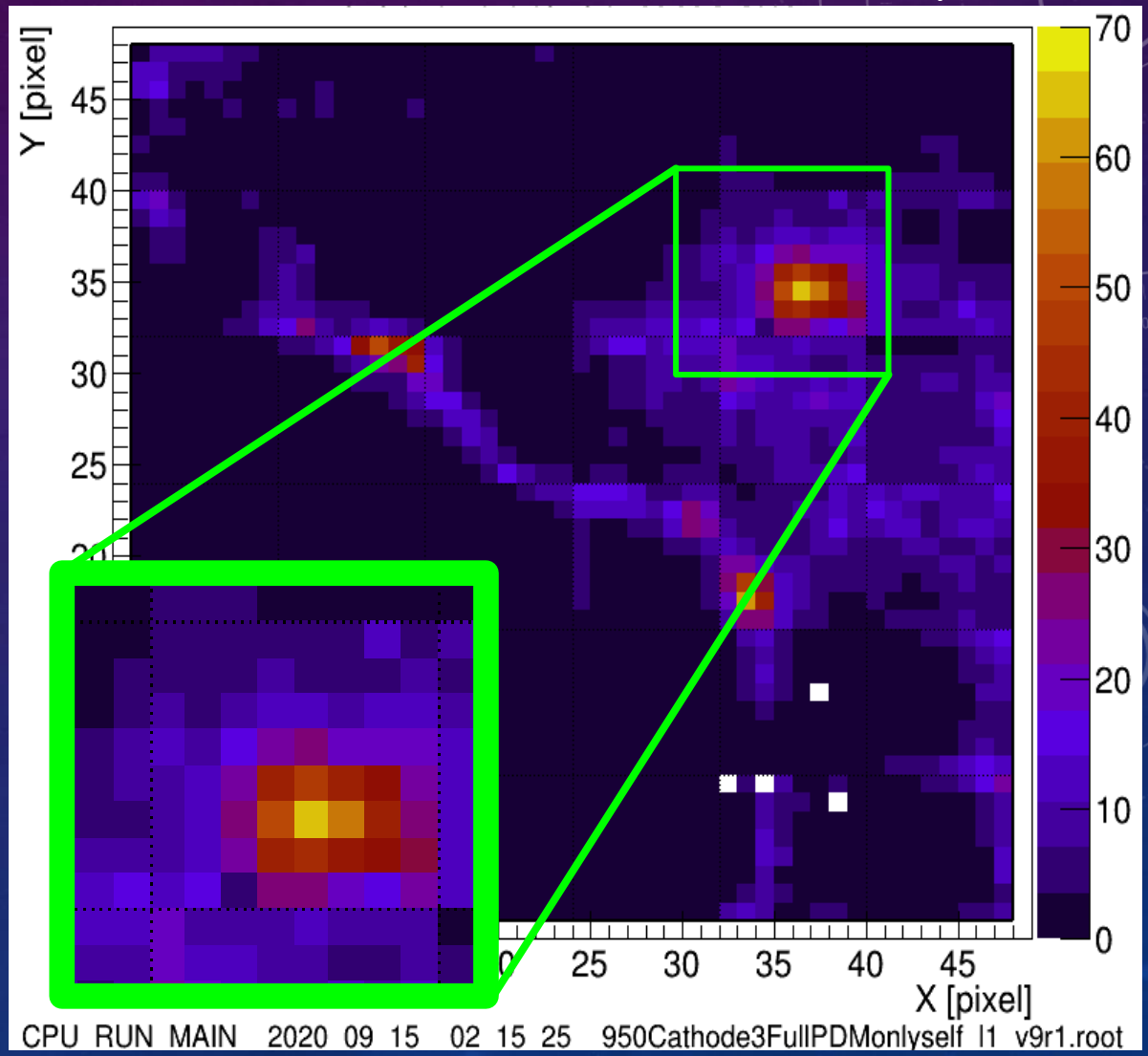
PSF Corrected



2x2 Average



Mini-EUSO on ISS – Session 25 - North Italy



SUMMARY AND CONCLUSIONS

WHAT HAS BEEN DONE:

- We have reproduced in laboratory a wide range of luminosity and terrain conditions
- We have built an illuminated scaled reproduction of the province of Turin and its lights
- We compared the data recently taken by Mini-EUSO on the ISS with those obtained several years before at TurLab, founding a correspondence between them, and thus proving the predictive value of the experiments
- We successfully corrected and compared the images obtained using the Turin model with those taken from orbit, finding correspondence in extension, shape and counts.

WHAT CAN BE DONE:

- Repairing and updating the Turin city model to better represent its real shape and luminosity
- Repeating the TurLab simulations with a configuration specifically scaled for the reproduction of Mini-EUSO characteristics
- Analyzing and comparing the most recent data sent from the mission, which are more consistent and with less portion of the PDM in Cathode2


GRAZIE!