



The EUSO@TurLab project

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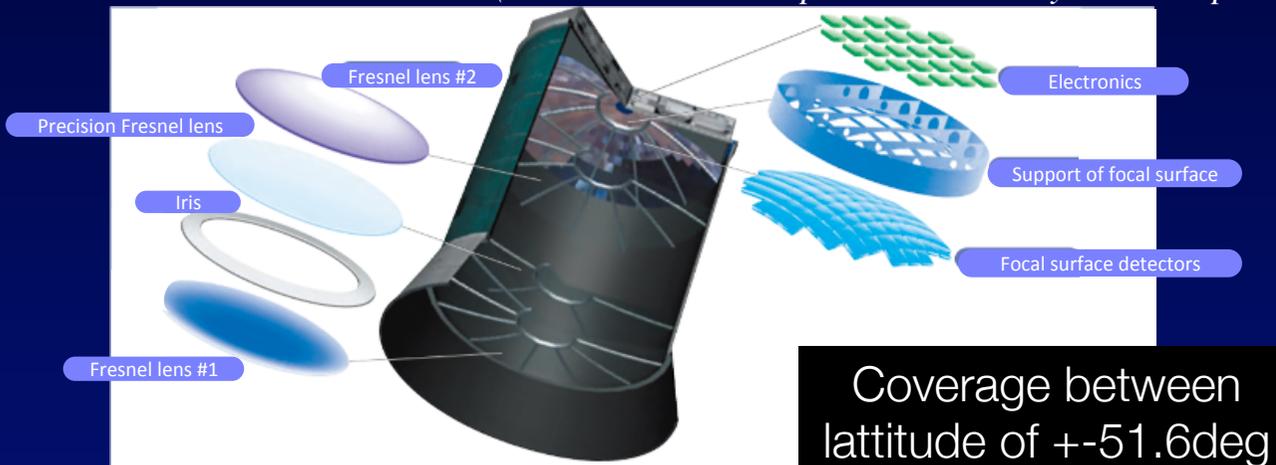
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^bAPC/CNRS, ^cLAL/CNRS/IN2P3, ^dOMEGA/CNRS/IN2P3, France

1. JEM-EUSO and its pathfinders

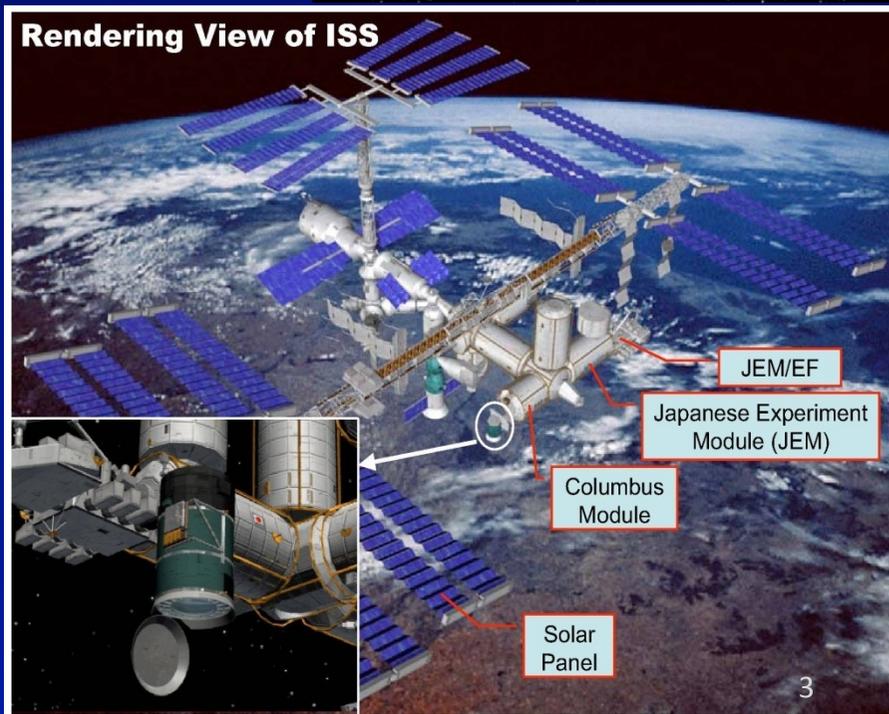
2. TurLab

3. EUSO@TurLab project

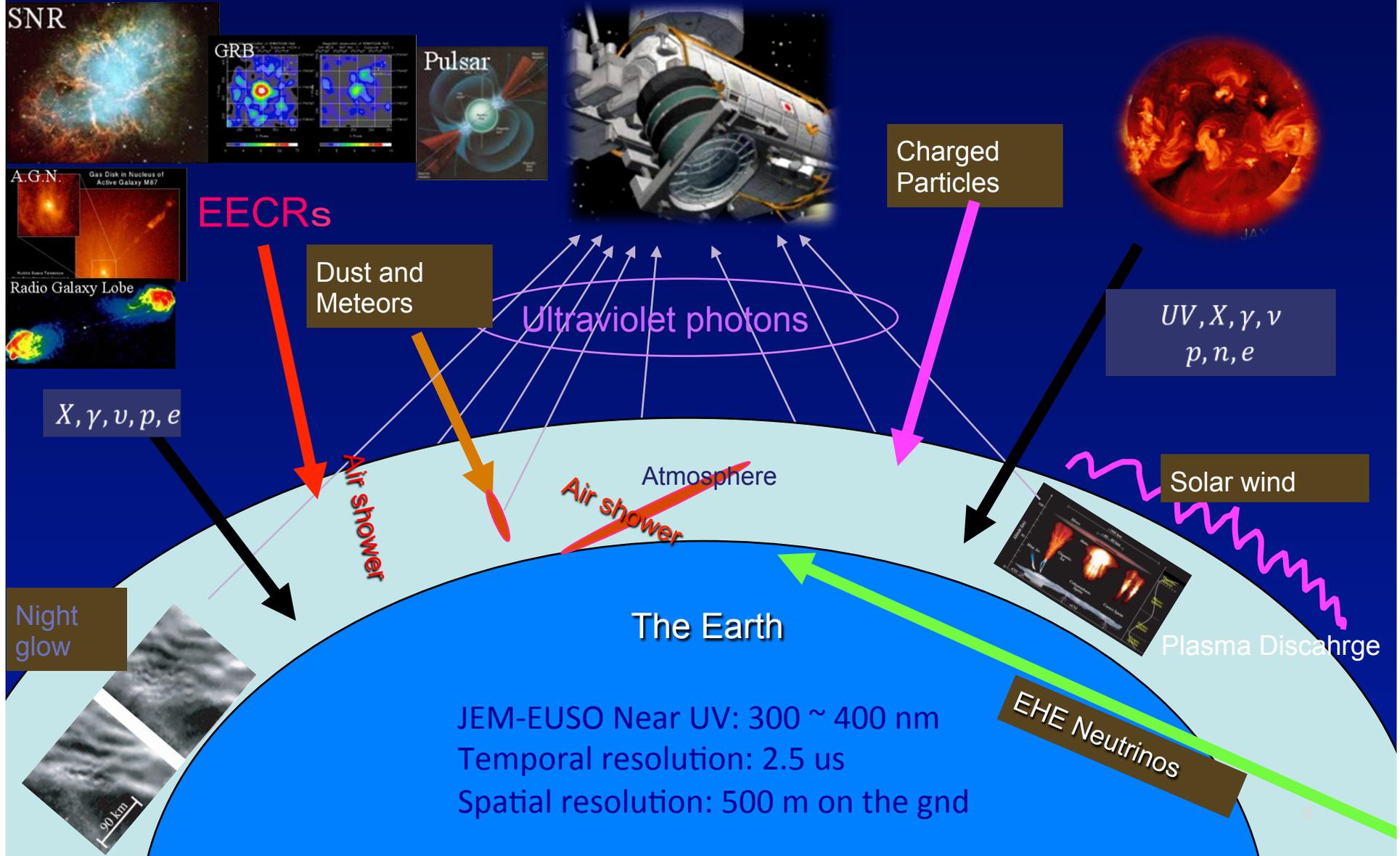
JEM-EUSO *(Extreme Universe Space Observatory on the Japanese Experimental Module on the ISS)*



Coverage between latitude of $\pm 51.6^\circ$ North to South of the earth by ISS orbit



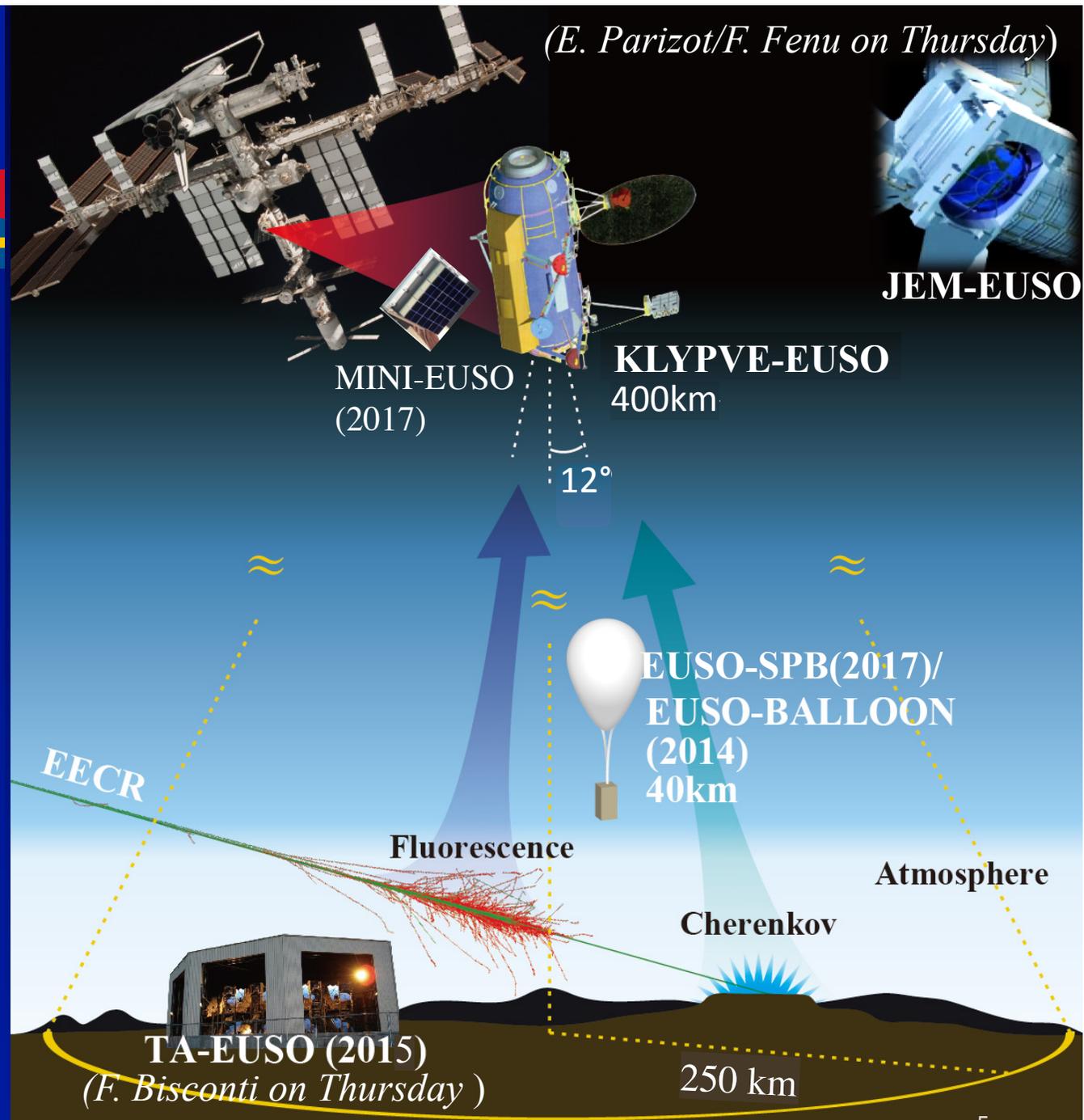
JEM-EUSO is an astronomical Earth observatory from space



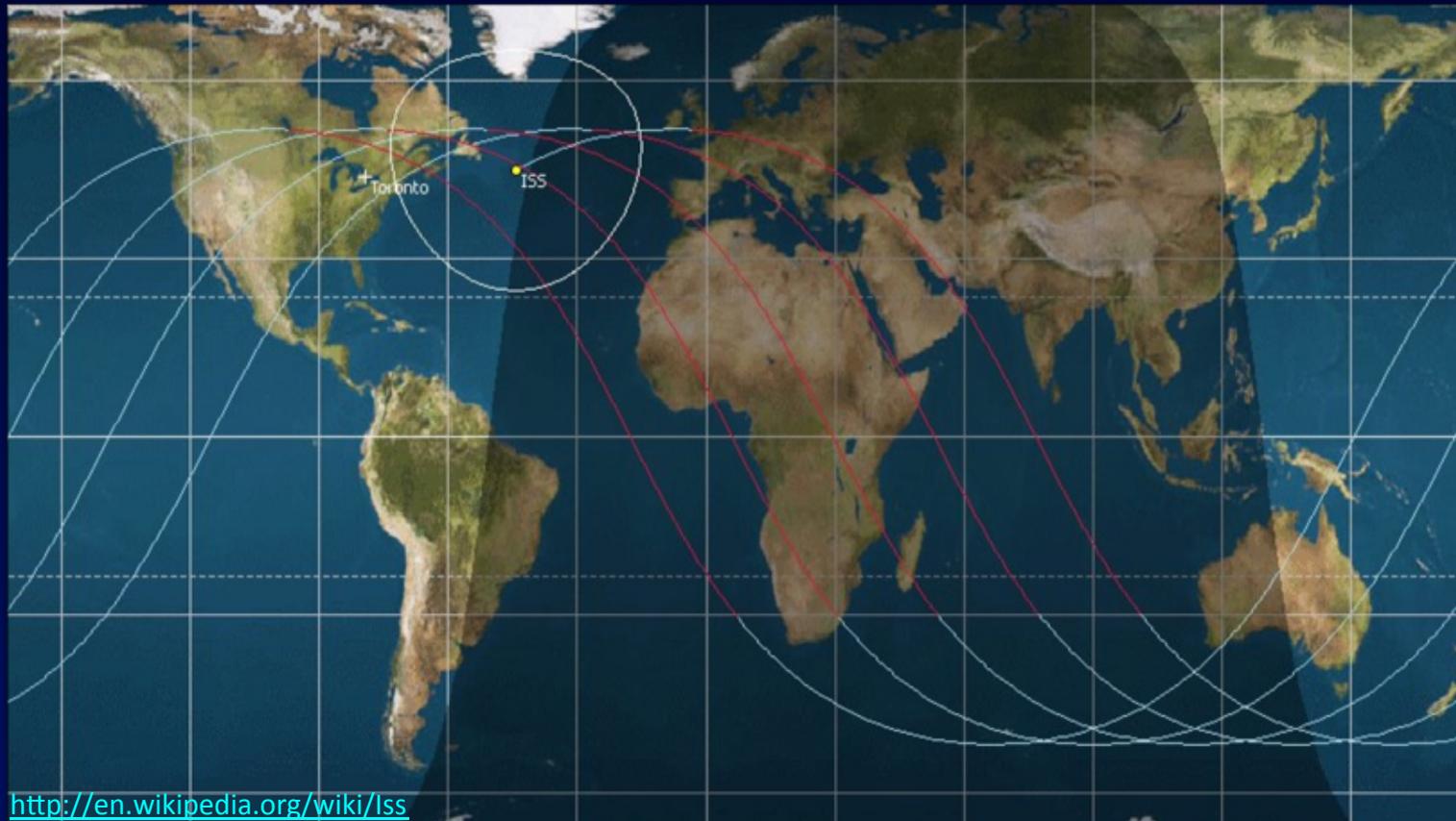
The EUSO program



1. EUSO-BALLOON:
1st balloon flight from Timmins, Canada
(French Space Agency CNES) 2014
2. TA-EUSO:
Ground detector at Telescope Array site:
2015-
3. MINI-EUSO
(ASI/INFN/Roscosmos)
2017
4. EUSO-SPB
(NASA) 2017
5. KLYPVE-EUSO
(ROSCOSMOS) >2018
6. JEM-EUSO (>2020+)



About 300 researchers from 88 institutions of 16 countries !



ISS

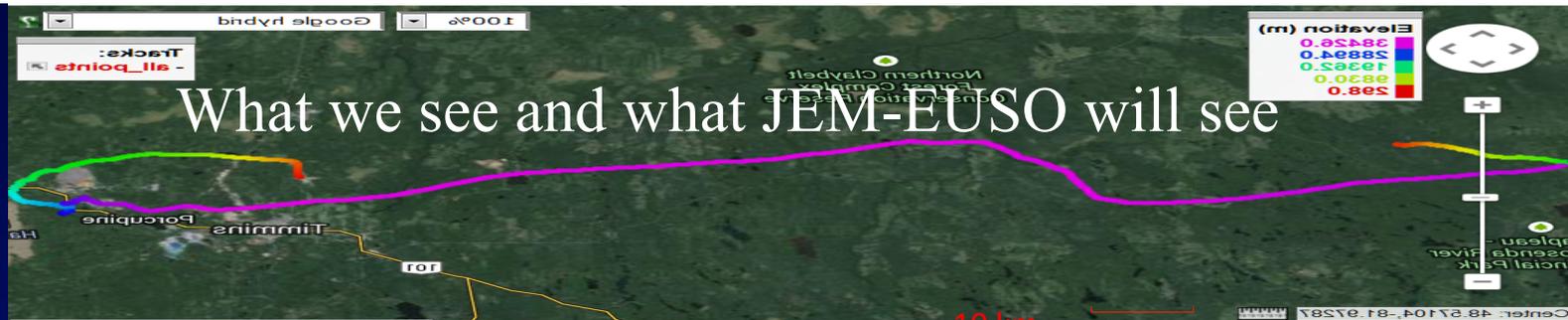
- 7.5 km/s
- 15.5 orbits per day
- 30-45 min night sight



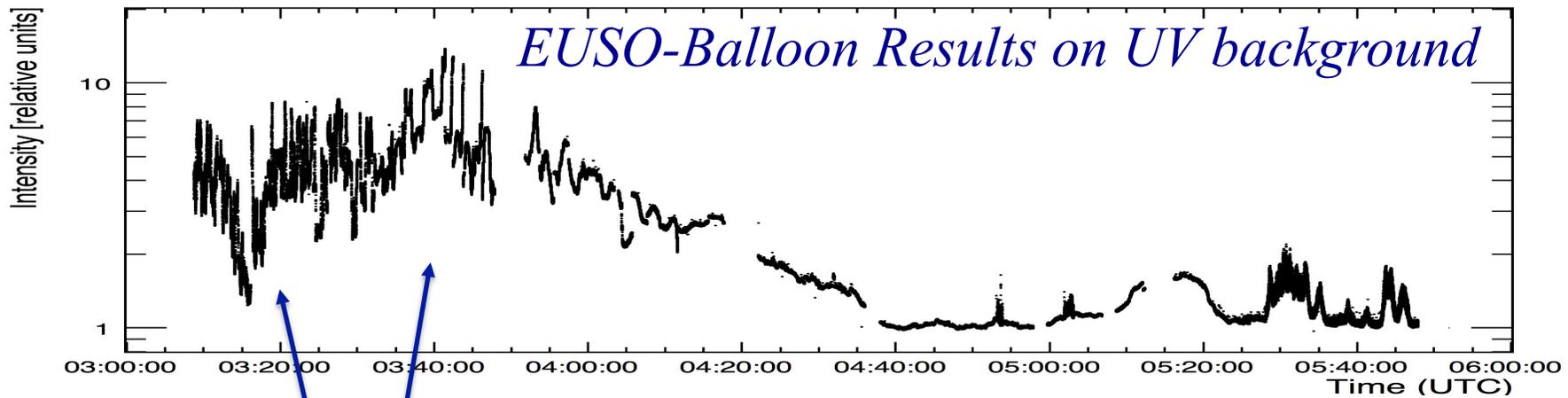
Pacific ocean view



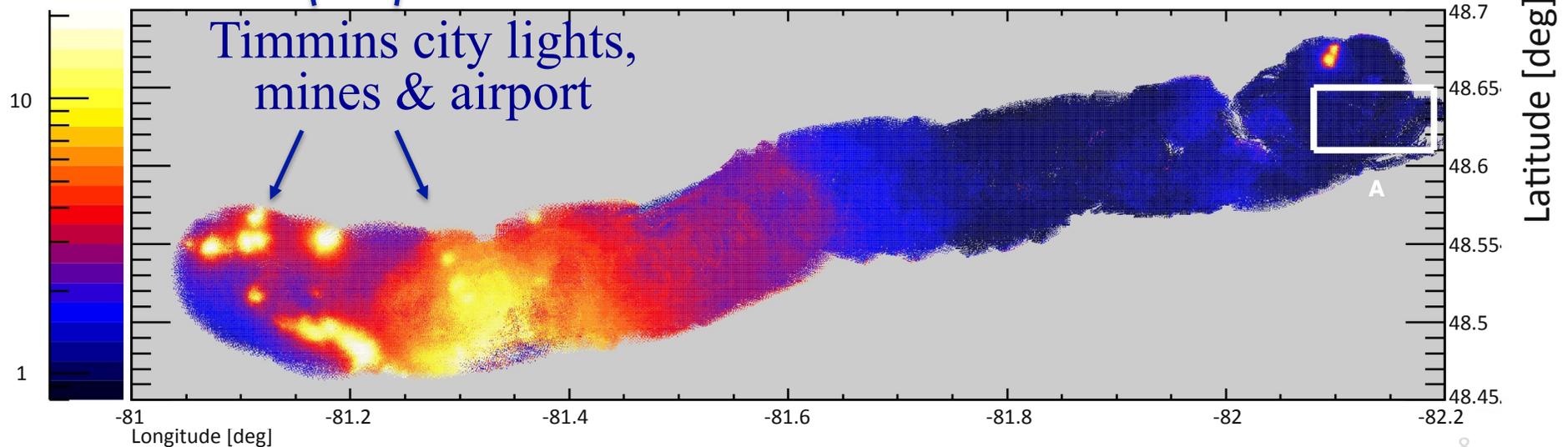
European city lights



EUSO-Balloon: Averaged UV intensities

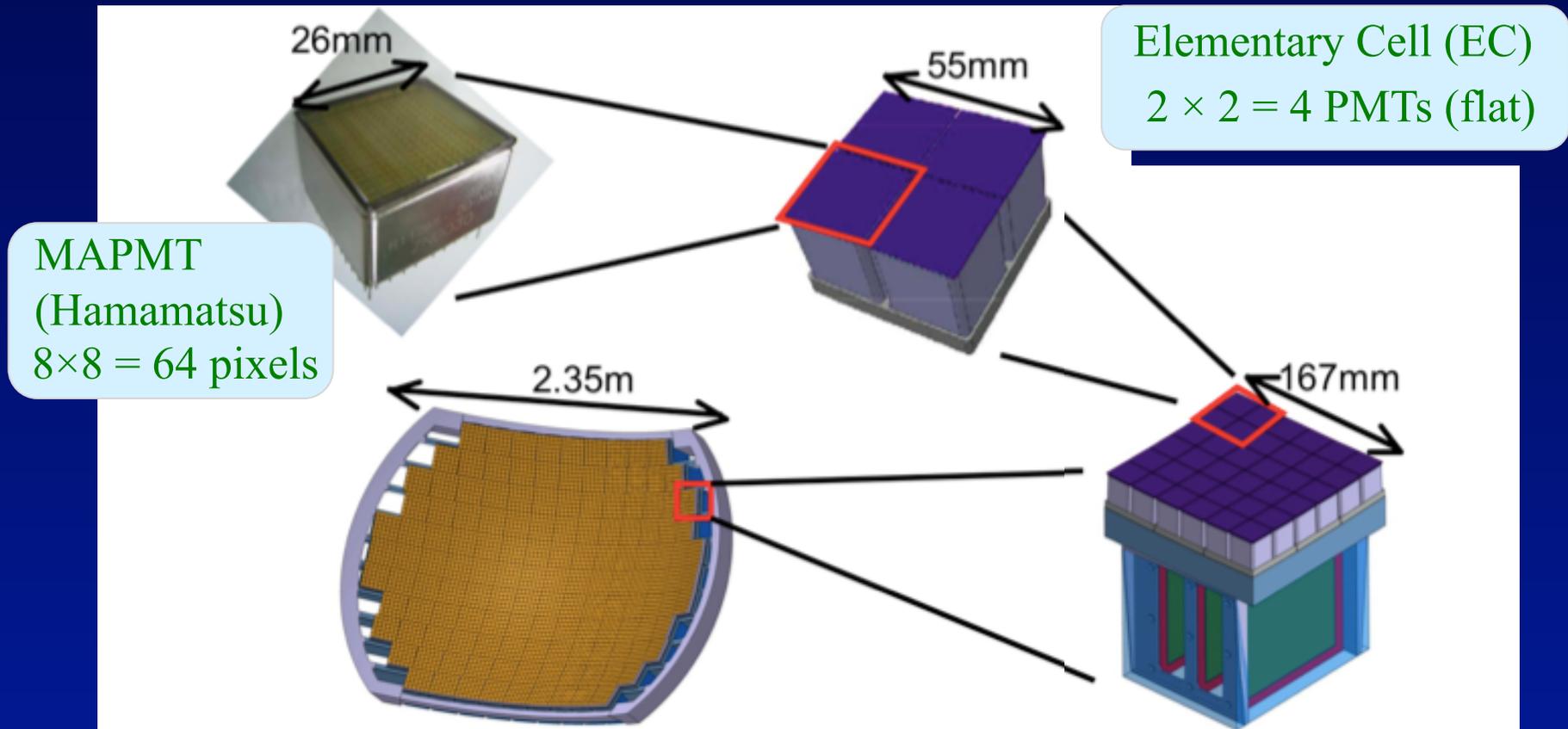


EUSO-Balloon: Intensity map of UV background [relative units], 03:08:52 – 05:48:00 (UTC)



JEM-EUSO focal surface

- Focal surface detector: Hamamatsu 64-channel Multi-anode Photomultiplier Tubes (MAPMT)



MAPMT
(Hamamatsu)
 $8 \times 8 = 64$ pixels

Elementary Cell (EC)
 $2 \times 2 = 4$ PMTs (flat)

Focal surface (FS)

$137 \text{ PDM} = 4932 \text{ PMT} = 315\,648$ pixels

Photo-Detector Module (PDM)

$3 \times 3 = 9$ EC (curved)

EUSO telescopes

Data Acquisition (DAQ) Chain



PDM

- 9 EC-Units

PMT

- Hm
- ch M
- BG3

Front-end (FE) electronics

EC-ASIC

- 6 x ASICs
- readout
- counter

PDM-Board

- Slow control
- Level 1 (L1, track) trigger

Data Processing (DP)

CPU

- Run control, config. FE electronics
- Console & GUI, remote access, etc.
- Data processing
- managing Mass Memory for data storage

CCB
(Cluster Control Board)

- Receive data from 9 PDMs

HK, LVPS

FLT – First Level Trigger

0.3M pixels counting every $2.5\mu\text{s}$ ($=10^{11}$ data/s)

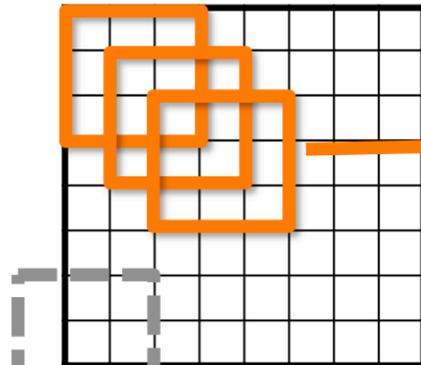
vs

ISS data transferring 300 kbit/s

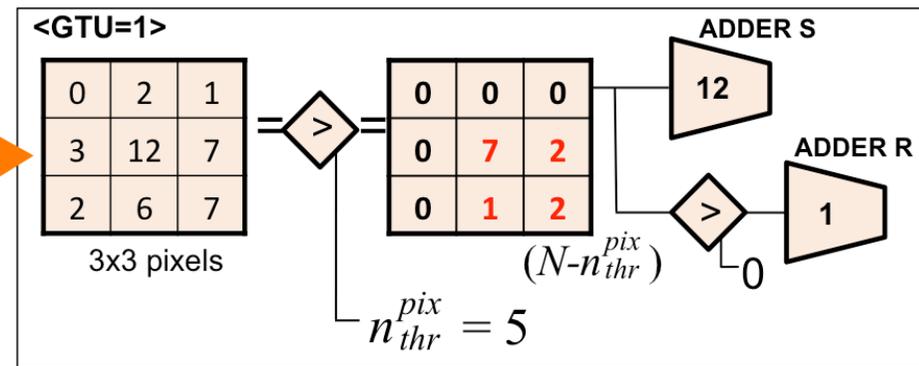
-> allowed acquisition rate: a few Hz/PDM

Concept of JEM-EUSO FLT

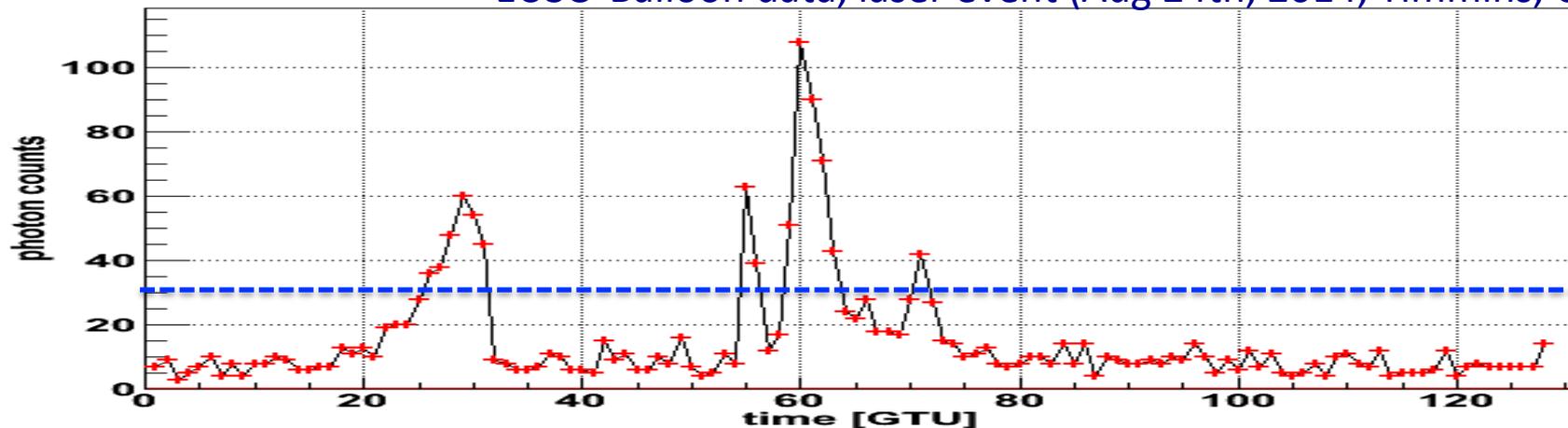
cells of 3x3 pixels on MAPMT



3x3 Pixel Cell



EUSO-Balloon data, laser event (Aug 24th, 2014, Timmins, Canada)



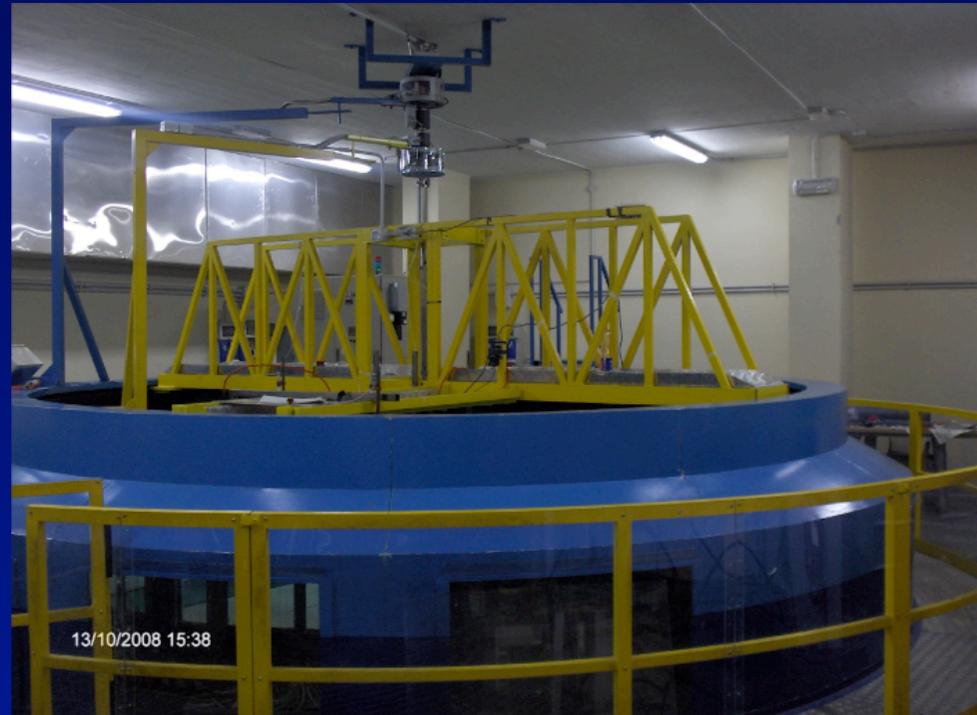
S

The TurLab@Physics Department - Torino University

<http://www.turlab.ph.unito.it/turlab.php>

A laboratory for geo-fluido-dynamics studies, where rotation is a key parameter:

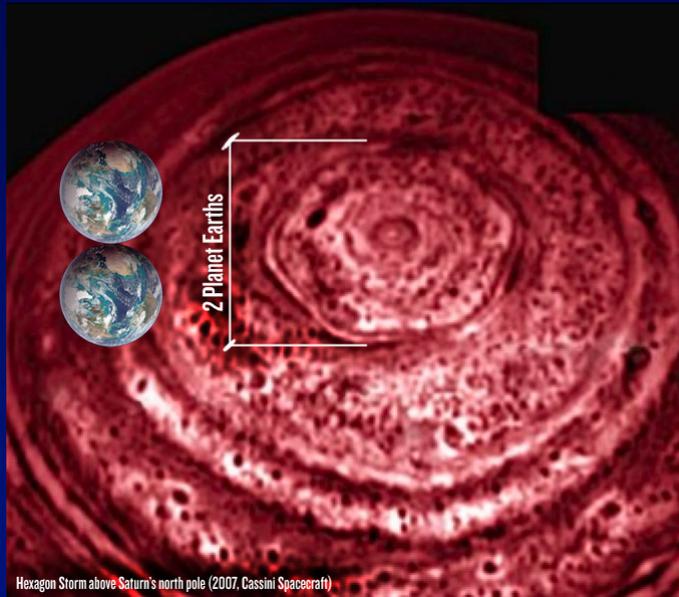
- Coriolis force
- Rossby Number



Advantage of such a laboratory:
Possibility of controlling the boundary conditions

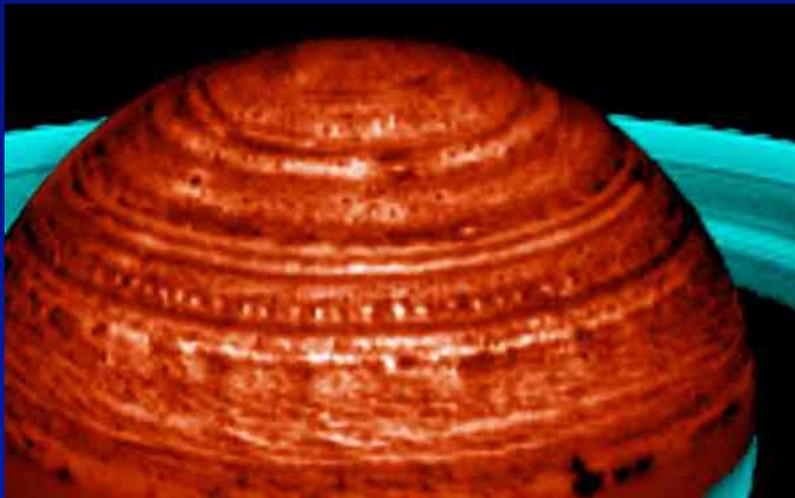
Planetary Atmospheric & Fluid instabilities

instability of Kelvin-Helmholtz
in not confined streams

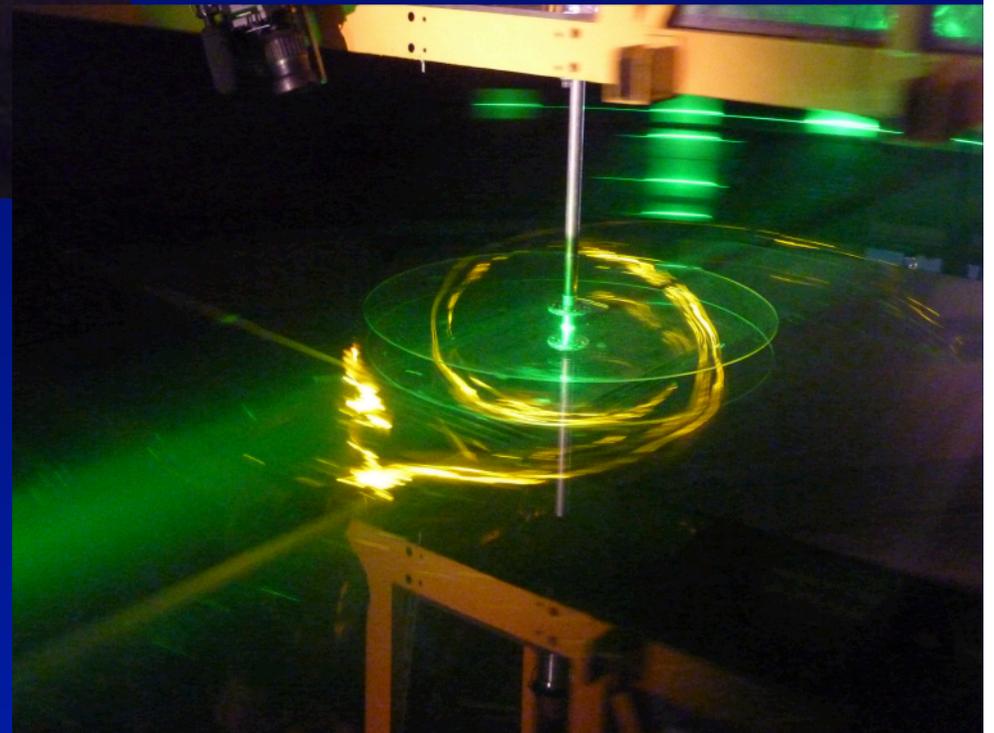
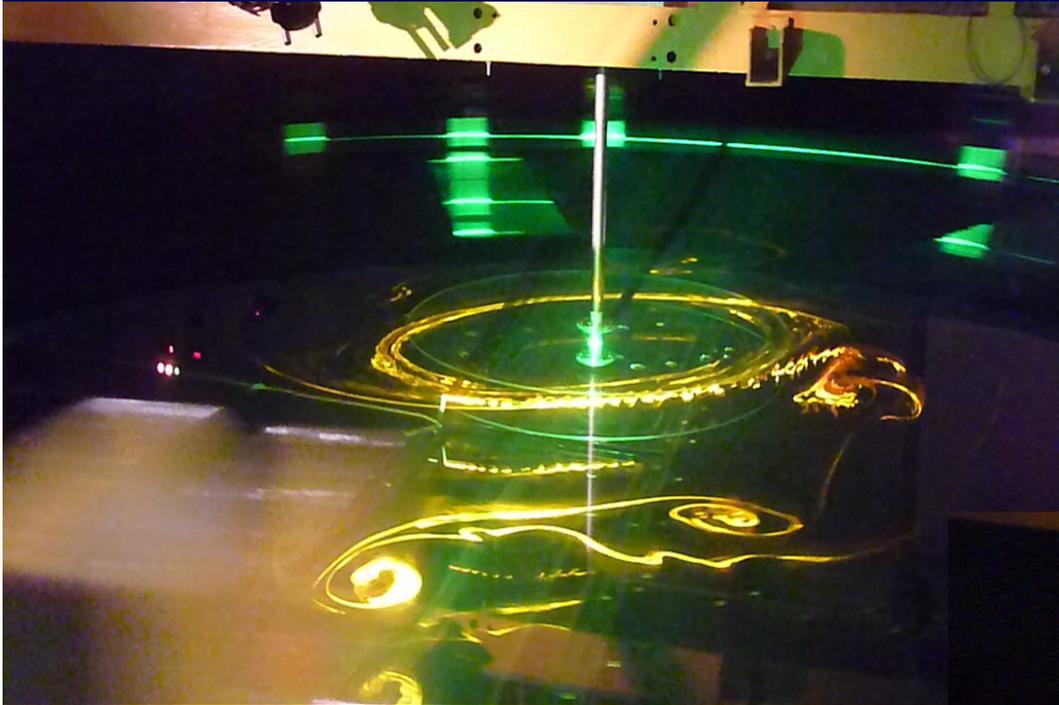


Hexagon at Saturn's North Pole

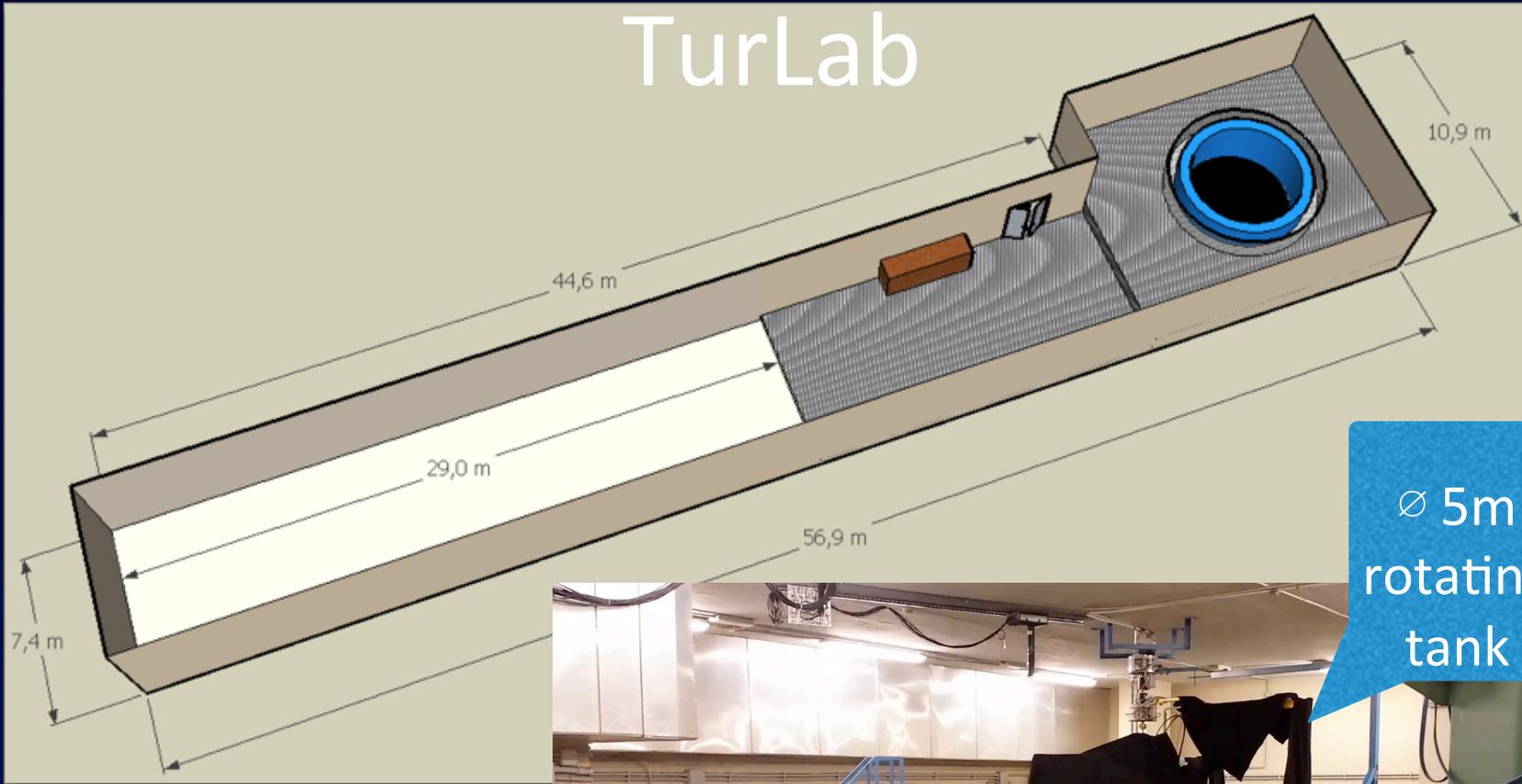
instability in confined streams



Results at a large rotating tank (TurLab)



TurLab



∅ 5m
rotating
tank

- ❖ Rotational speed
- ❖ max: 1 rot. in 12 s
- ❖ min: 1 rot. in 20 min
- ❖ -4F@Phys. Dept.

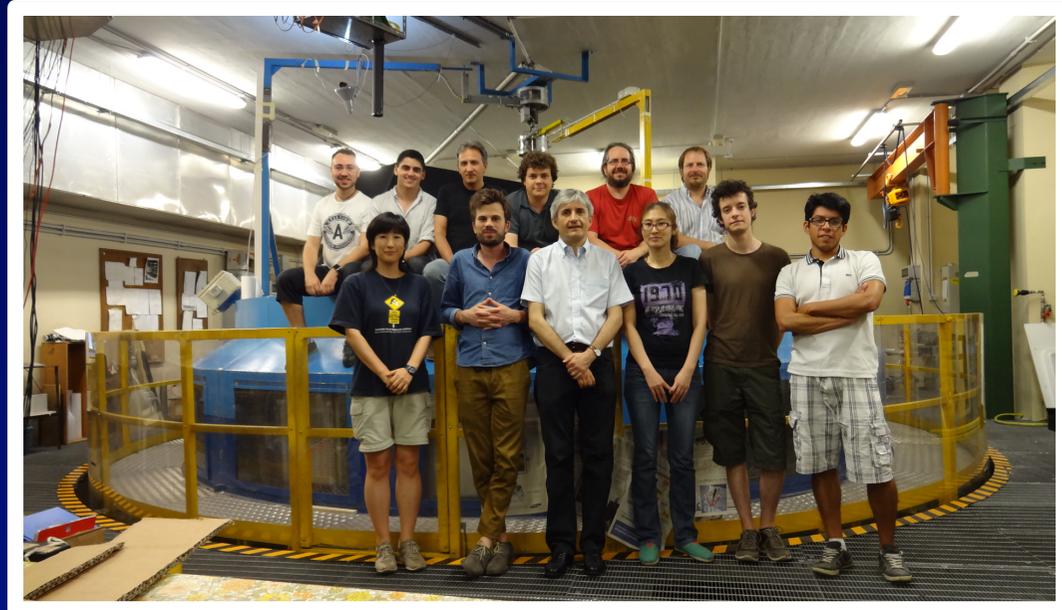
dynamic range:
1-100



EUSO@TurLab for electronics & trigger study

Controlled environment to simulate EUSO observations

- ✓ Completely dark environment (deep underground, -F4 in the building of department of physics, UNITO)
- ✓ Tank rotation: simulate ISS orbit
- ✓ Reproduction of atmospheric phenomena, ocean waves already available
- ✓ Cosmic rays, meteors, city lights can be easily implemented artificially



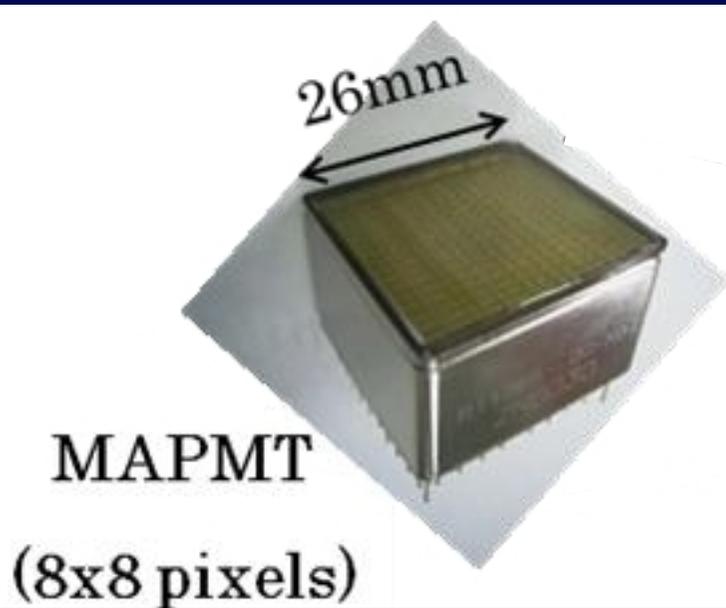
TurLab (<http://www.turlab.ph.unito.it>)

- inner radius of 2.5 m, can be filled up to 75 cm with fluid
- 20 min to 12 s / anti-clockwise rotation
- location: -4F in department of physics building of UNITO

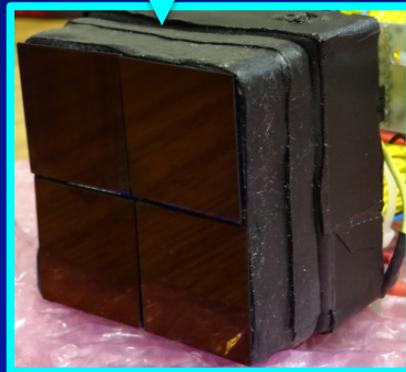


Installing EUSO-Balloon electronics on TurLab, July 2015

Resolution

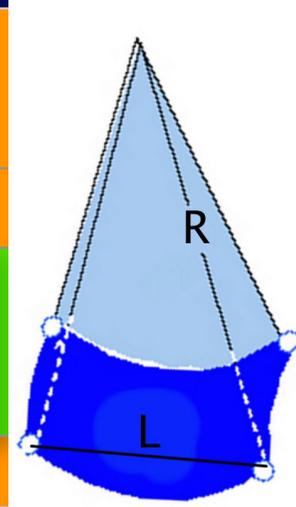


EUSO ECunit:
2x2 MAPMTs
= 256 pixels



TurLab (ECEUSO) vs ISS (JEM-EUSO)

TurLab	JEM-EUSO
2 m	400 km
$\Omega = 6.25 \times 10^{-6}$ sr	$\Omega = 1.56 \times 10^{-6}$ sr
5 mm	500 m



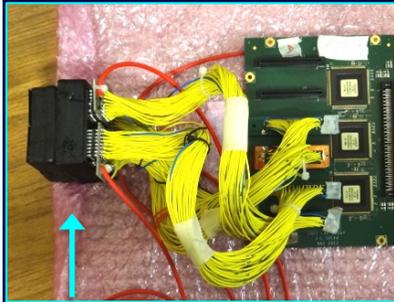
1 rot/2 min
R = 2 m

ISS: 8 km/s — TurLab: 10^{-1} m/s
speed ratio TurLab/ISS: 10^{-5}

$5 \text{ mm}/500 \text{ m} = 10^{-5}$

JEM-EUSO phenomena can be reproduced in TurLab!

ECunit configuration: light sources, materials, DAQ & monitoring



detector
(ECunit
=4x64chMAPMTs+BG3 filters)

bkg by
high power LED



lens



Meteor & CR (ARDUINO)



moss

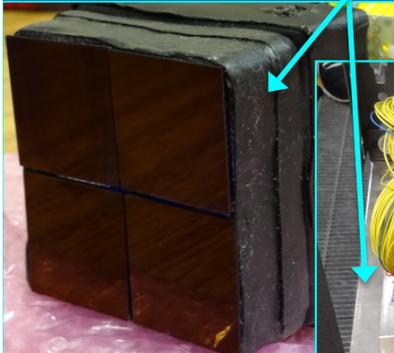
bricks

glass with LED

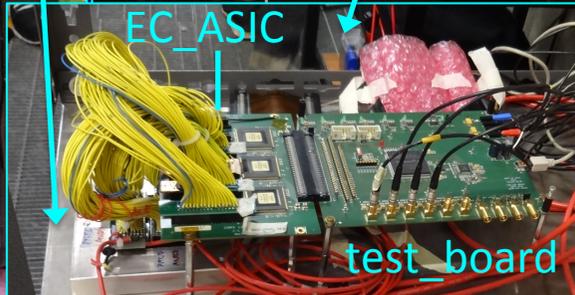
sand

glass

cloud



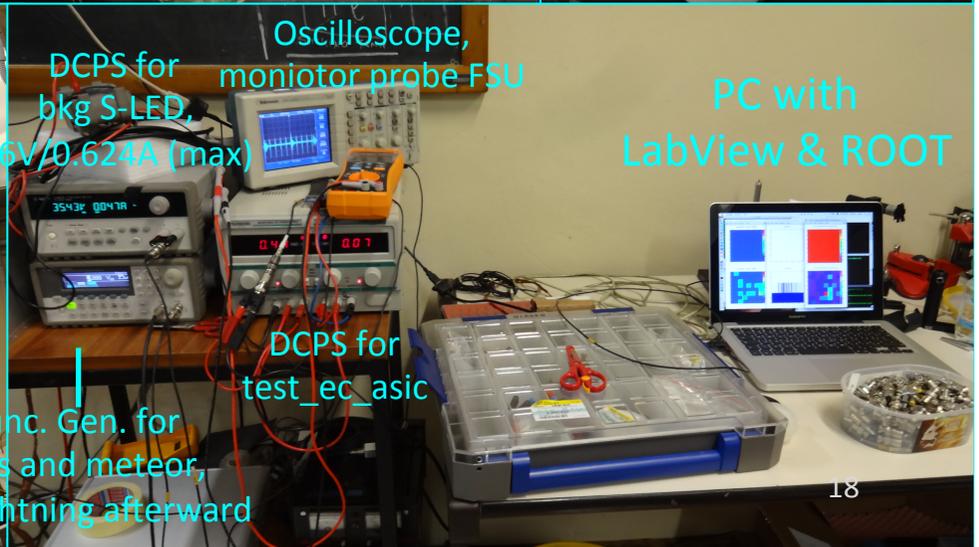
EC ASIC



test_board



Torino City



DCPS for
bkg S-LED,
36V/0.624A (max)

Oscilloscope,
monitor probe FSU

PC with
LabView & ROOT

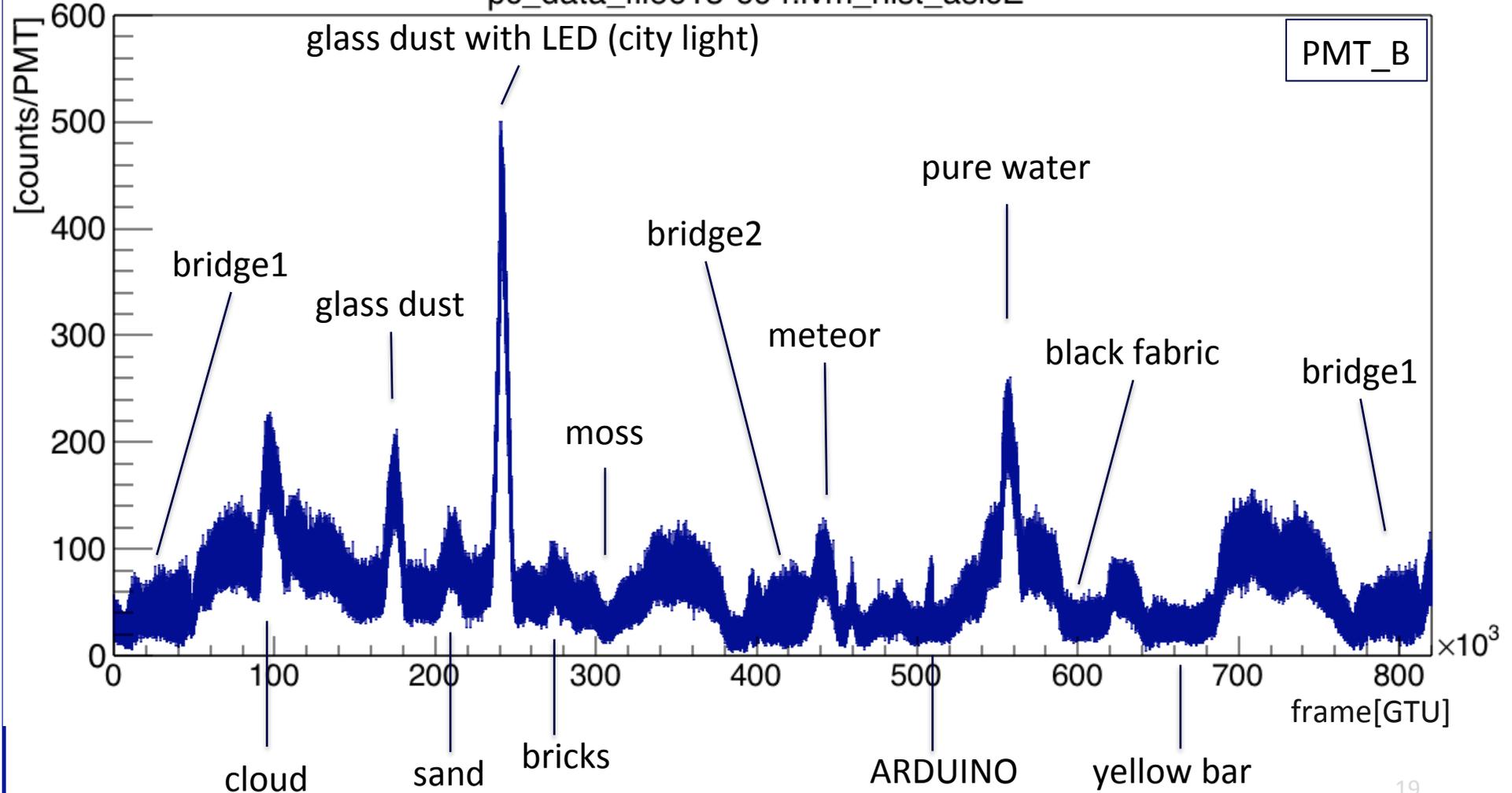
DCPS for
test_ec_asic

Func. Gen. for
LEDs and meteor,
and lightning afterward

Counts/PMT, entire rotation (~9min)



pc_data_file613-694.lvm_hist_asicE

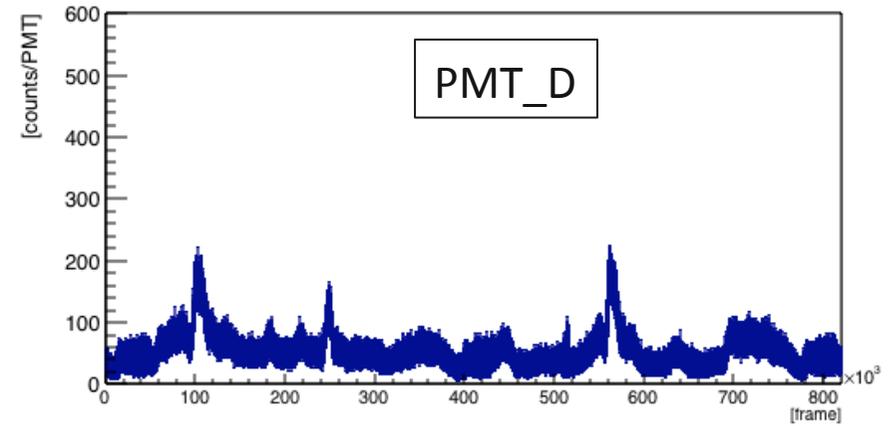
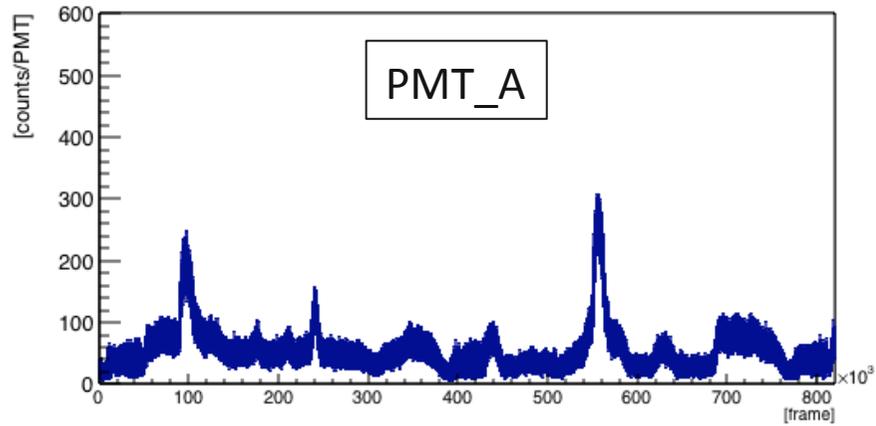


Counts/PMT, entire rotation (~9min)



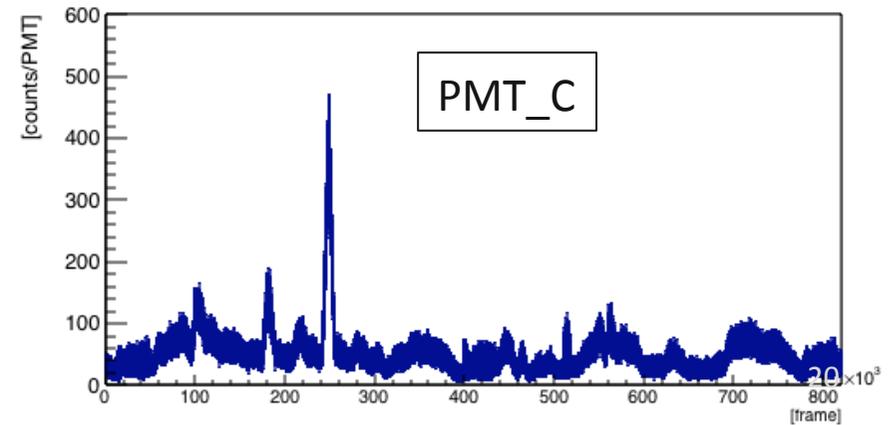
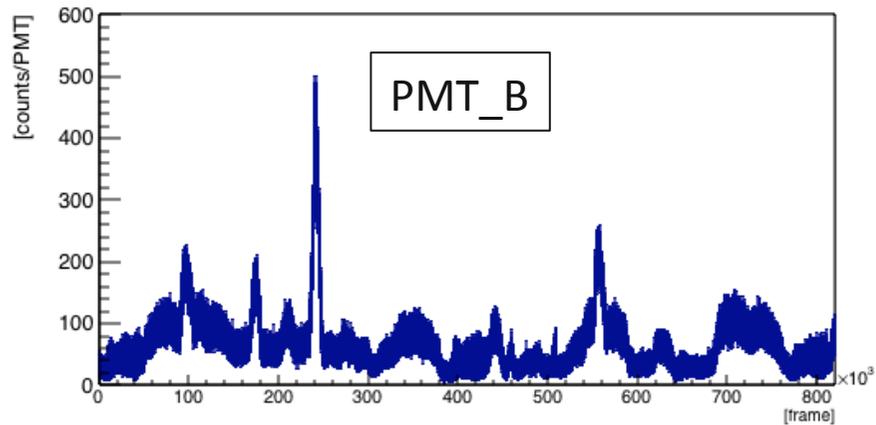
pc_data_file613-694.lvm_hist_asicF

pc_data_file613-694.lvm_hist_asicC



pc_data_file613-694.lvm_hist_asicE

pc_data_file613-694.lvm_hist_asicD

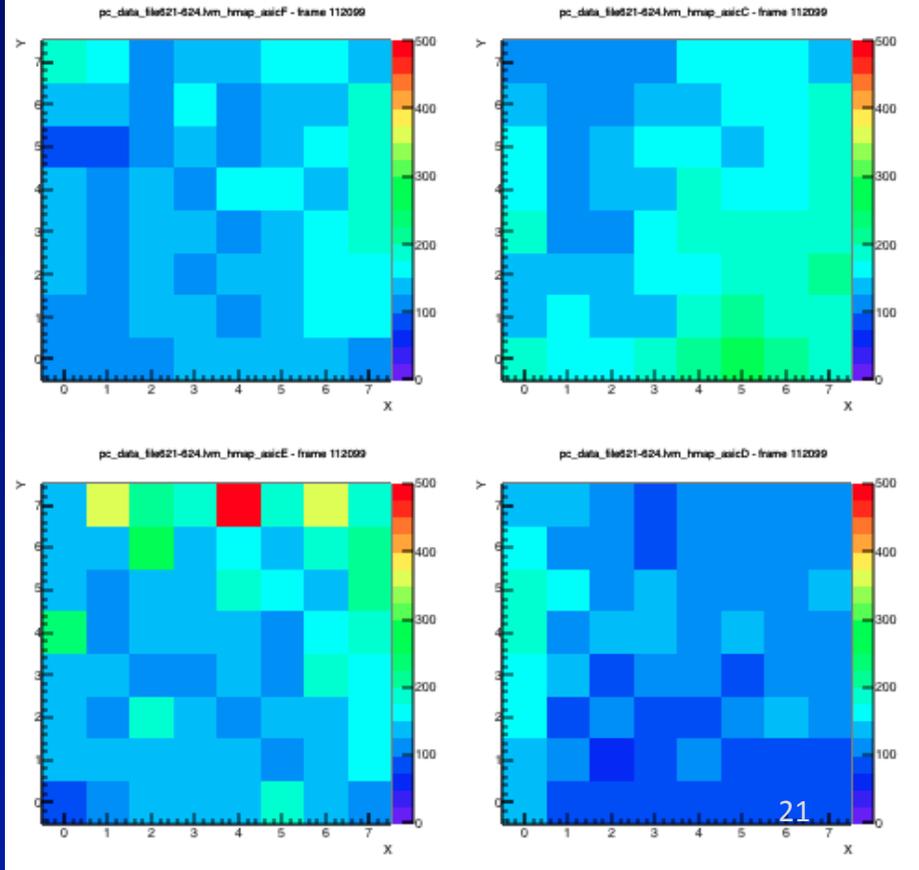
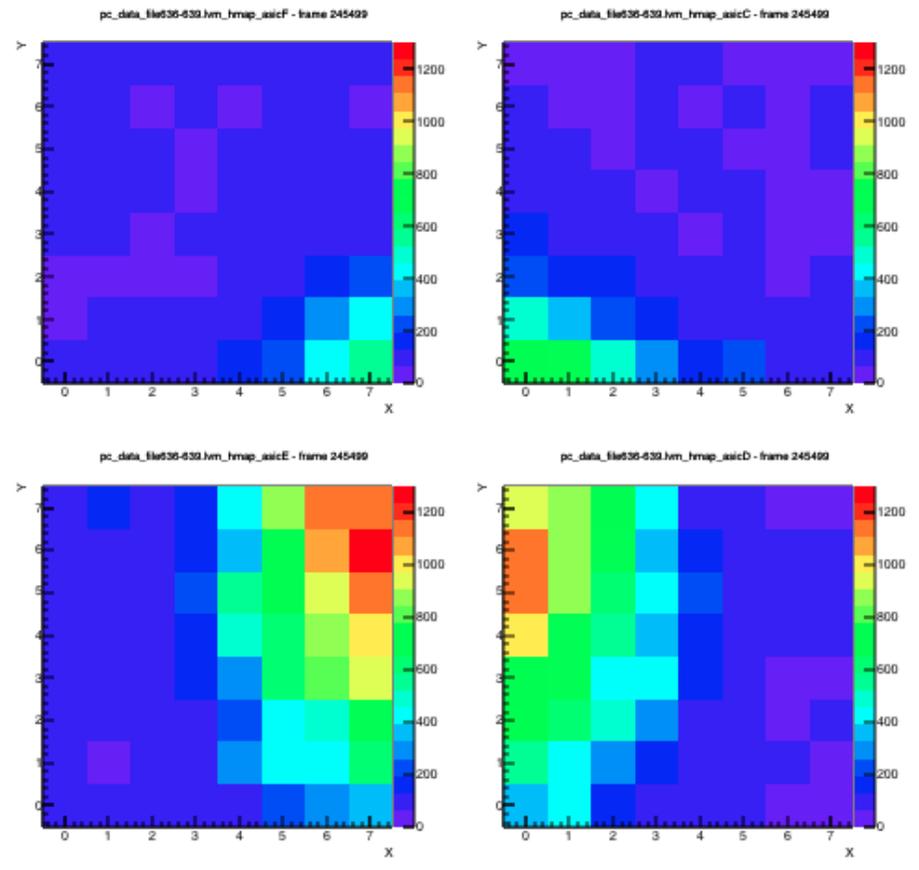


Glass dust with LED (City Light)

Cloud Water



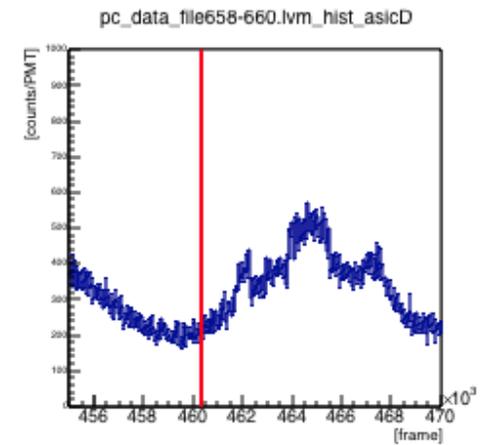
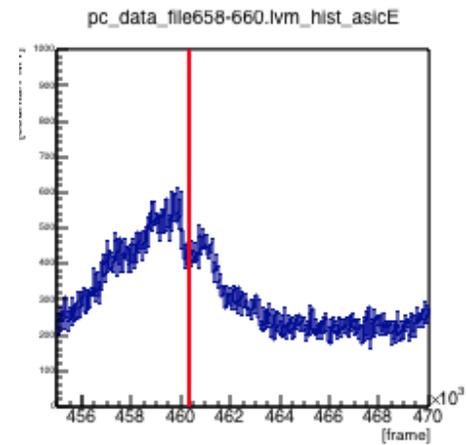
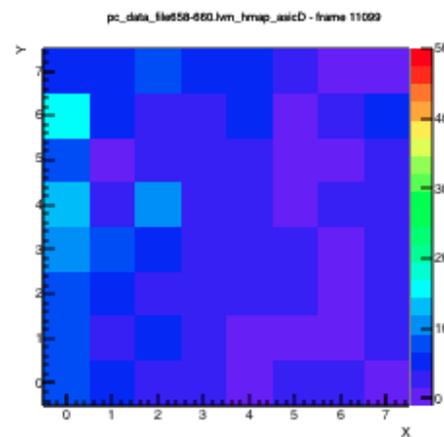
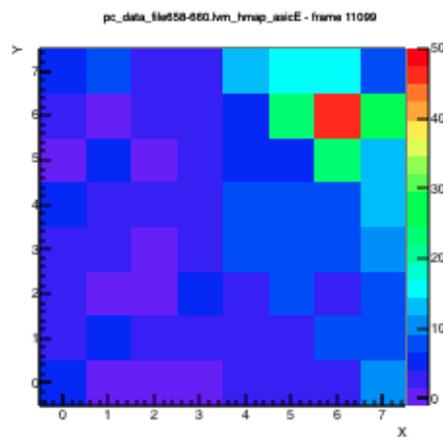
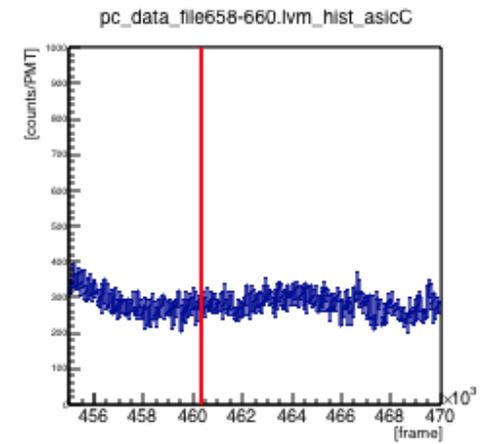
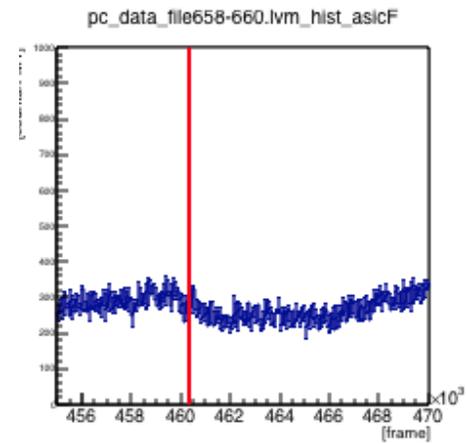
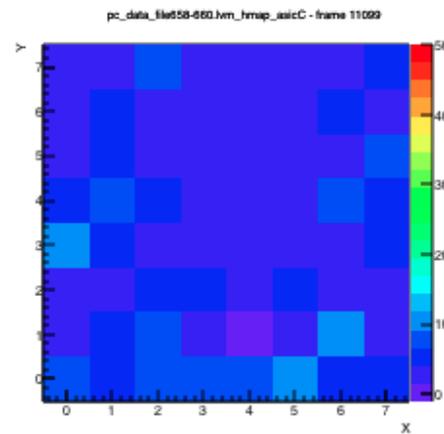
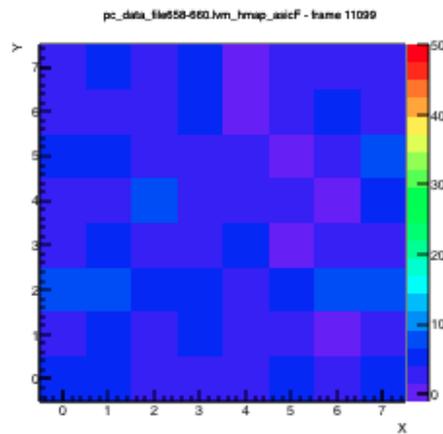
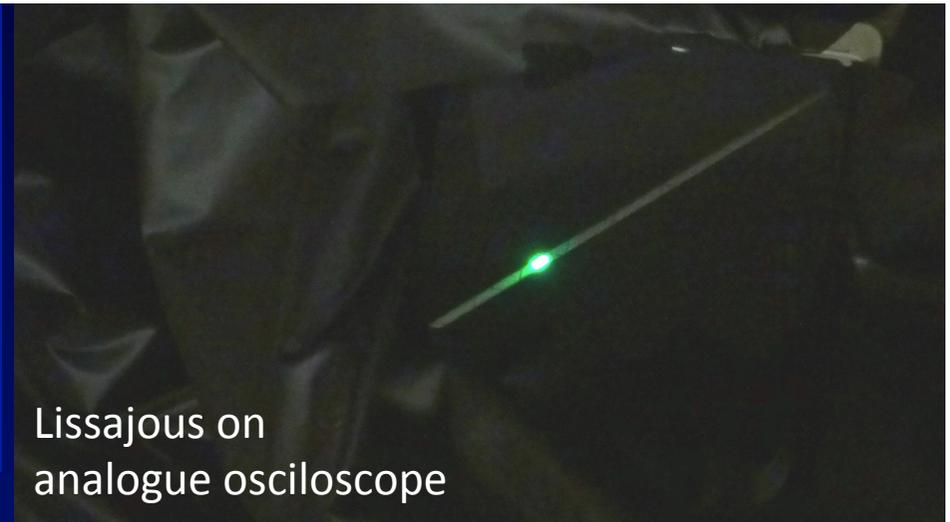
integration every 100GTUs



Meteor

integration every 10GTUs

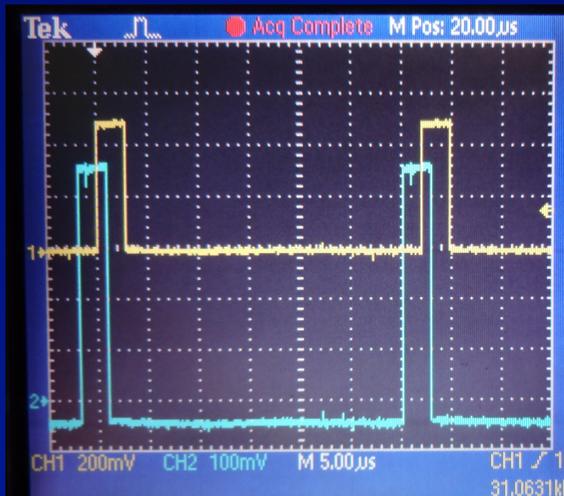
Lissajous on
analogue oscilloscope



Cosmic Ray (LEDs + ARDUINO)

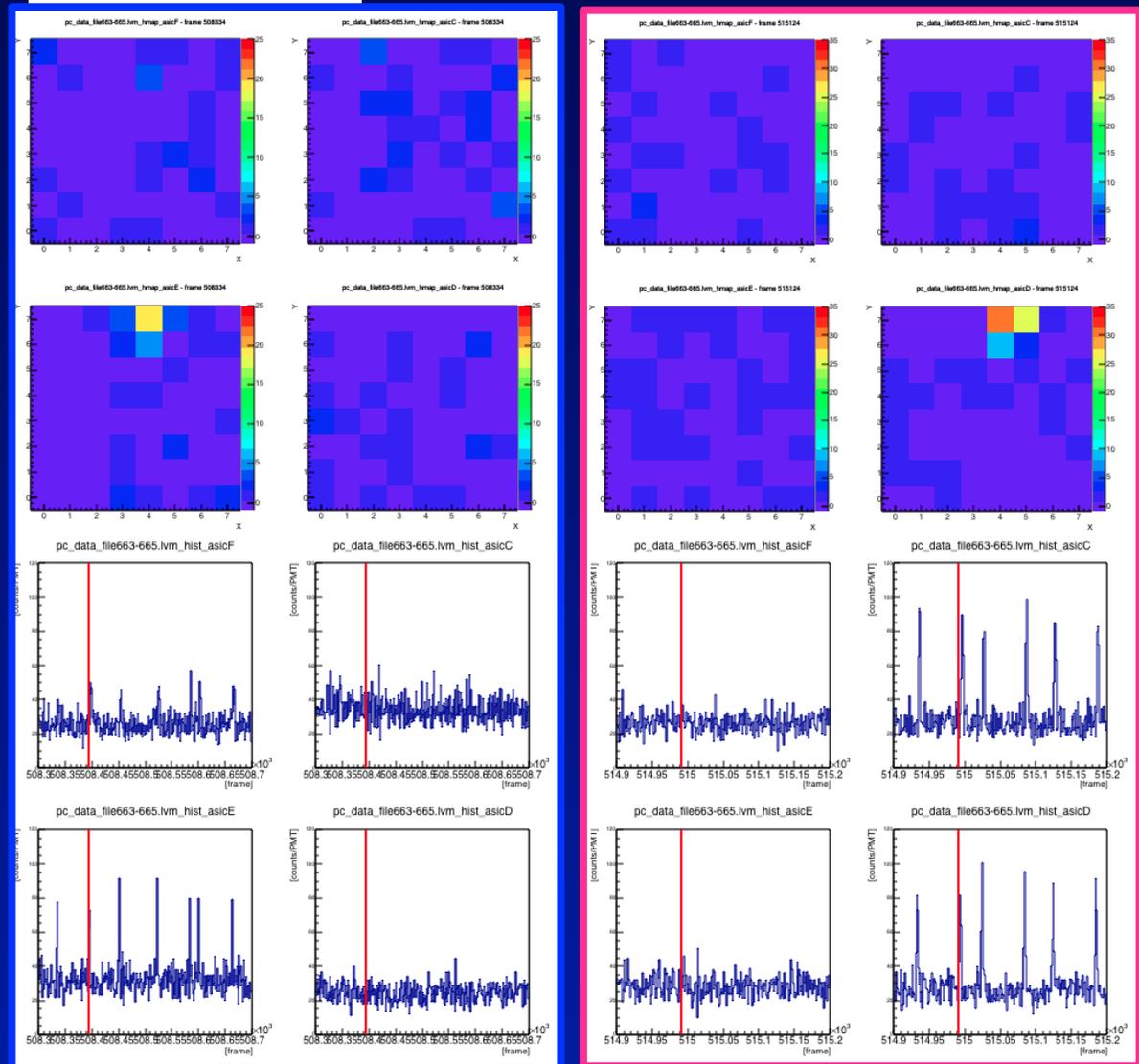


10 white LEDs controlled by ARDUINO circuit with cosmic ray profile

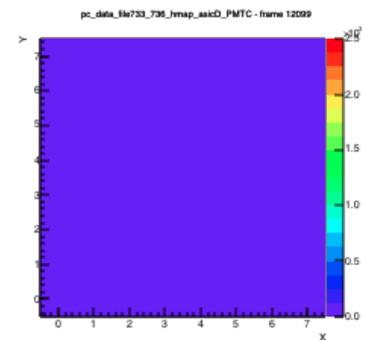
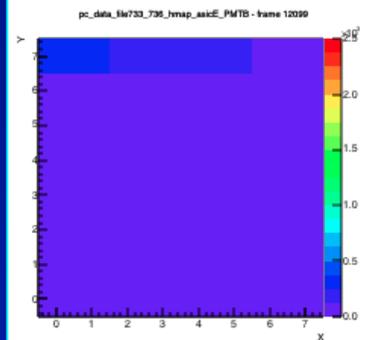
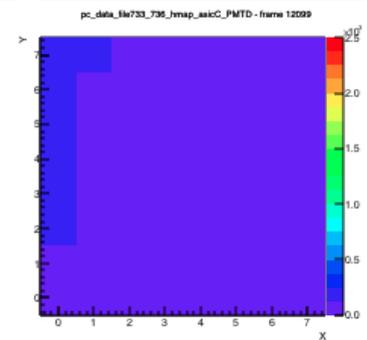
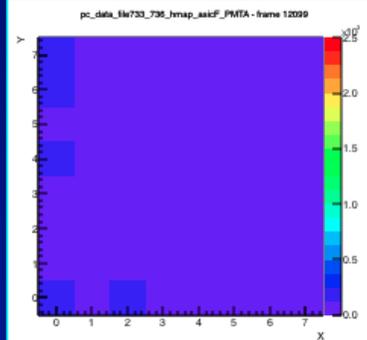
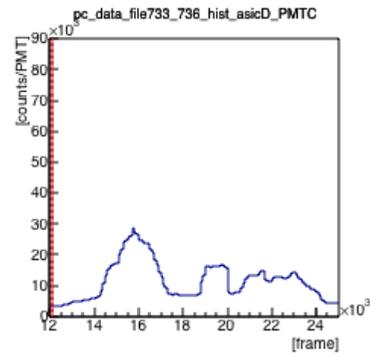
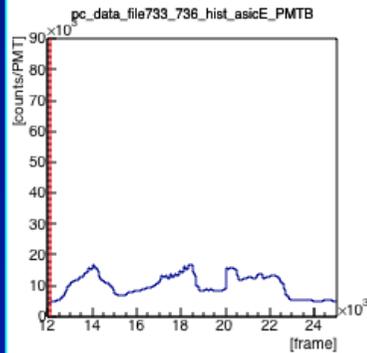
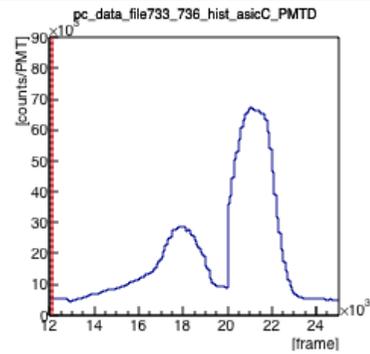
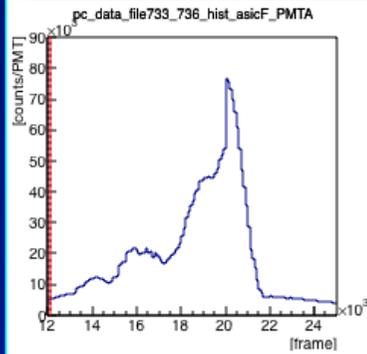


- Input pulse width: $3\mu\text{s}$
- Overlap: $1\mu\text{s}$
- Continuous loop

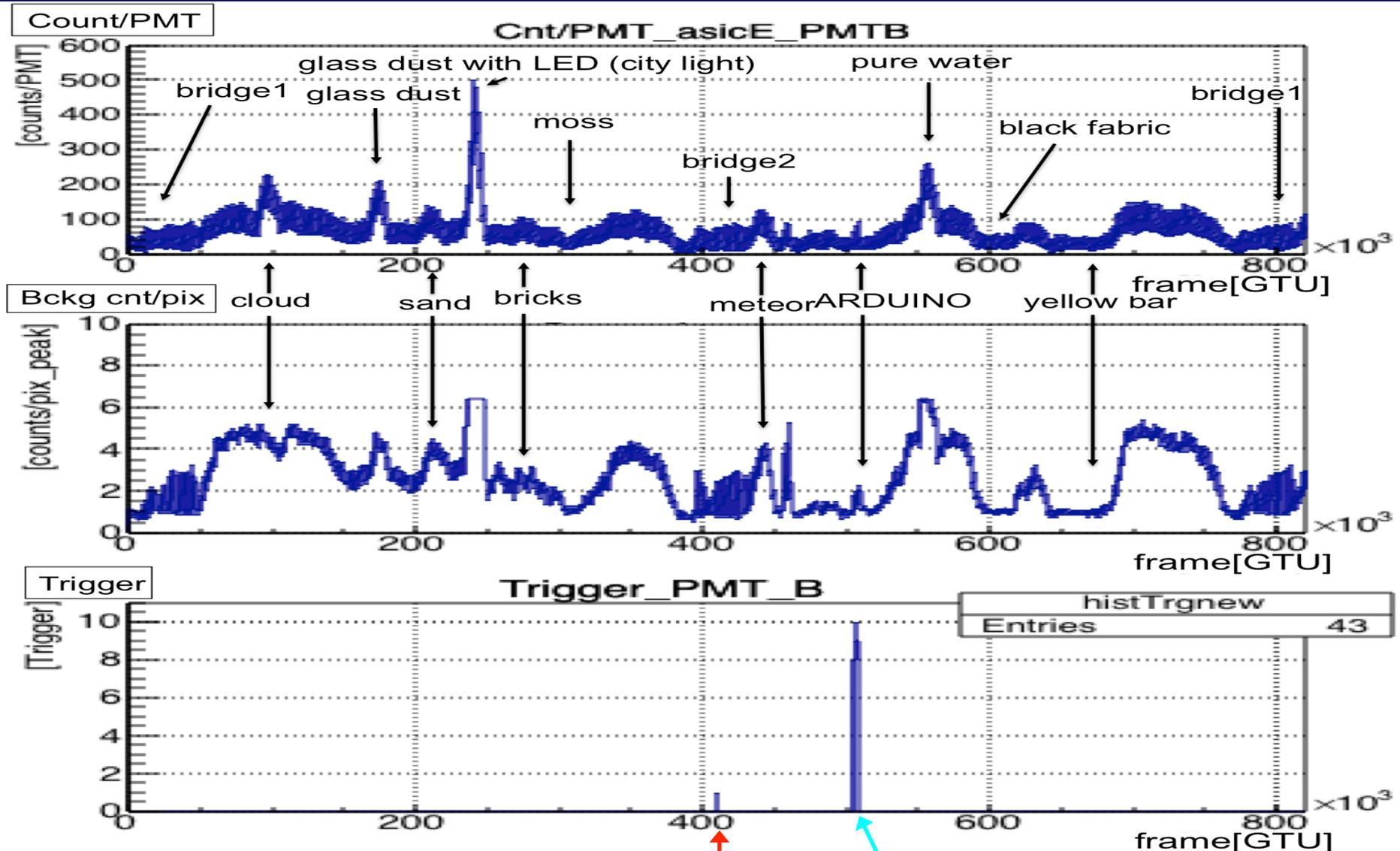
(no integration)



Torino City Night View



First Level Trigger (Offline)



Artificial trigger due to the deadtime of test board (which would not be the case)

Triggers on Cosmic Ray (ARDUINO) events

Summary

- **JEM-EUSO** and its pathfinders will observe various cosmic/atmospheric phenomena in UV region from the space/stratosphere
- **TurLab** is a **unique facility** in Turin with interdisciplinary experts (waves, geophysics, atmospheric science, meteors, astroparticle/cosmic ray physics...), capable of providing an ideal condition to test EUSO electronics in an **controlled environment** against various scenarios which the telescopes will encounter
- The TurLab system has been used to verify/implement **FLT** in use of **EUSO-SPB**. Analysis and development of FLT for Mini-EUSO are currently ongoing.