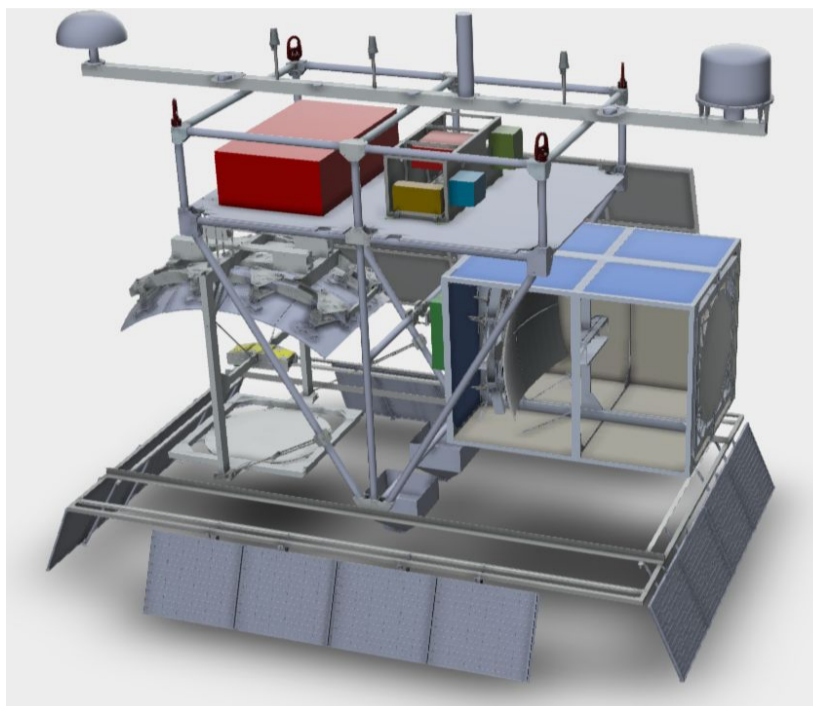


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¹University of Turin, Italy - ²INFN Torino, Italy - * Speaker

The second generation Extreme Universe Space Observatory on a Super-Pressure Balloon (EUSO-SPB2) mission has been approved by NASA for a long duration flight (up to 100 days), starting from Wanaka, New Zealand, in 2023. EUSO-SPB2 will monitor the night sky of the Southern hemisphere from 33 km altitude to study Ultra-High Energy Cosmic Rays (UHECRs) and astrophysical and cosmogenic neutrinos, and it will represent a proof of concept for POEMMA (Probe of Extreme Multi-Messenger Astrophysics). EUSO-SPB2 features two main independent telescopes, a Cherenkov (CT) and a Fluorescence (FT) Telescope. A trigger code running on the 1.05 μ s datastream of the FT looks for multiple clusters of excess signal within a certain time window. Its hardware implementation and performance both in terms of rejection of noise and ability to detect fast signals is tested taking advantage of the TurLab facility, hosted at the University of Turin.

EUSO-SPB2 Fluorescence Telescope

- Focal surface: **3 PDMs** [Photo Detection Module]
 - PDM = 48×48 pixels
 - 3 PDMs** = 3×48×48 pixels = **6912 pixels**
- Schmidt optics**
 - 6 mirror segments in 2×3 configuration
 - Pixel field of view: 0.2°
 - Total **field of view: 3×11.4°×11.4°**
- Single photon counting**
- Peak Sensitivity **~300-400 nm**
- Time resolution **1.05 μ s = 1 GTU** (Gate Time Unit)
 - double pulse resolution ~6 ns
- Pixel size on ground** (assuming flight altitude of 33 km): **115 m**
- Flight velocity: ~100 km/h



The EUSO-SPB2 payload. The two telescopes pointing nadir and towards the limb are the Fluorescence telescope and the Cherenkov Telescope, respectively.

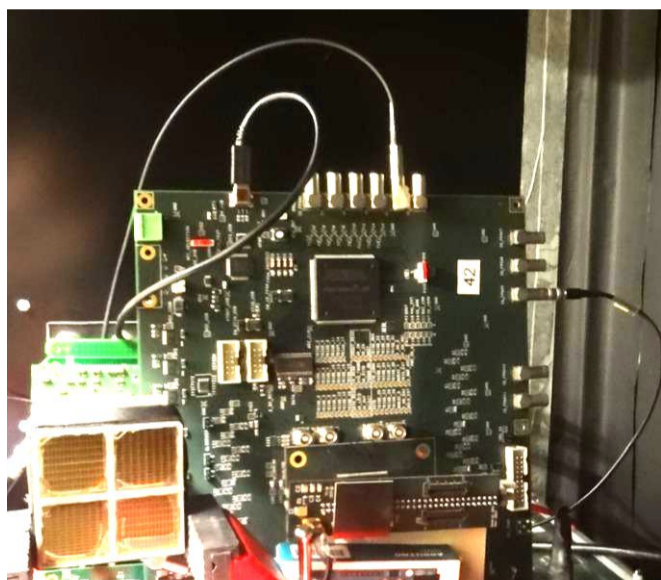


The detector used for the tests (To-EC detector) while being hung to the ceiling over the rotating tank

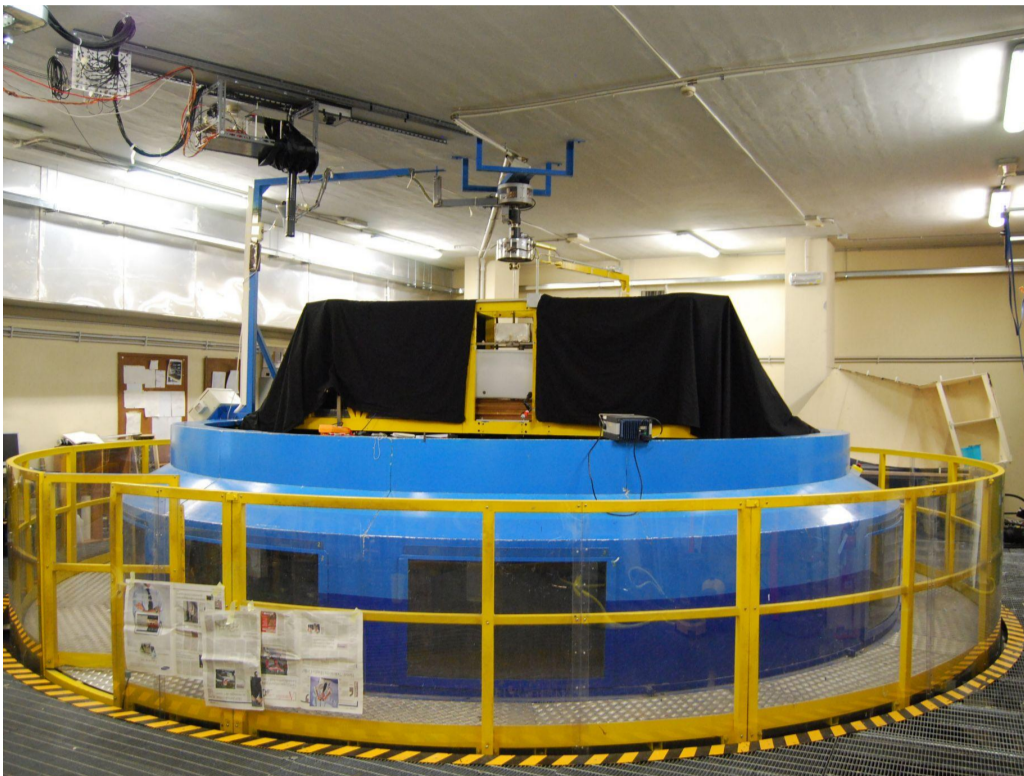
The To-EC Detector

Scaled-down version of the FT

- only one EC (16×16 pixels)
- exact same electronic of the balloon
- optical system based on a 30 cm focal length, 1" plano-convex lens.



The EUSO@TurLab



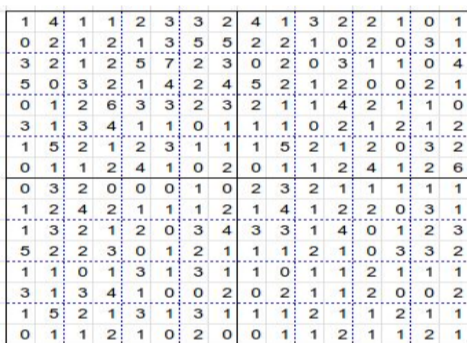
TurLab is a facility hosted at the Physics Department of the Torino University equipped with a **5 m-diameter rotating tank**

- light intensity artificially controlled
- detector can be hung from the ceiling
- light sources and different materials can be placed inside the rotating tank

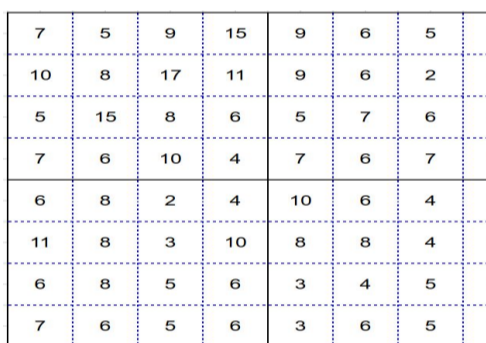
EUSO-SPB2 FT trigger logic

Works at MacroPixel level (i.e. sum of a 2×2 square grid of pixels)

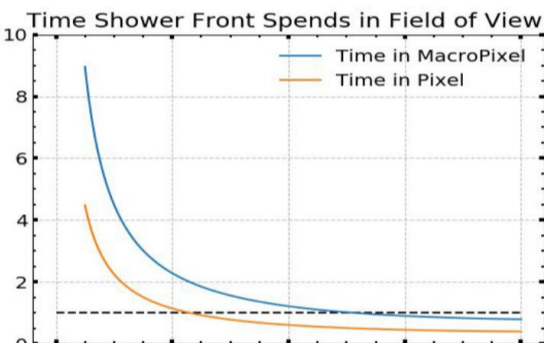
- residence time in a pixel for medium to high inclined shower is less than 1 μ s. MacroPixels fully contain the signal.



4 MAPMTs at pixel level

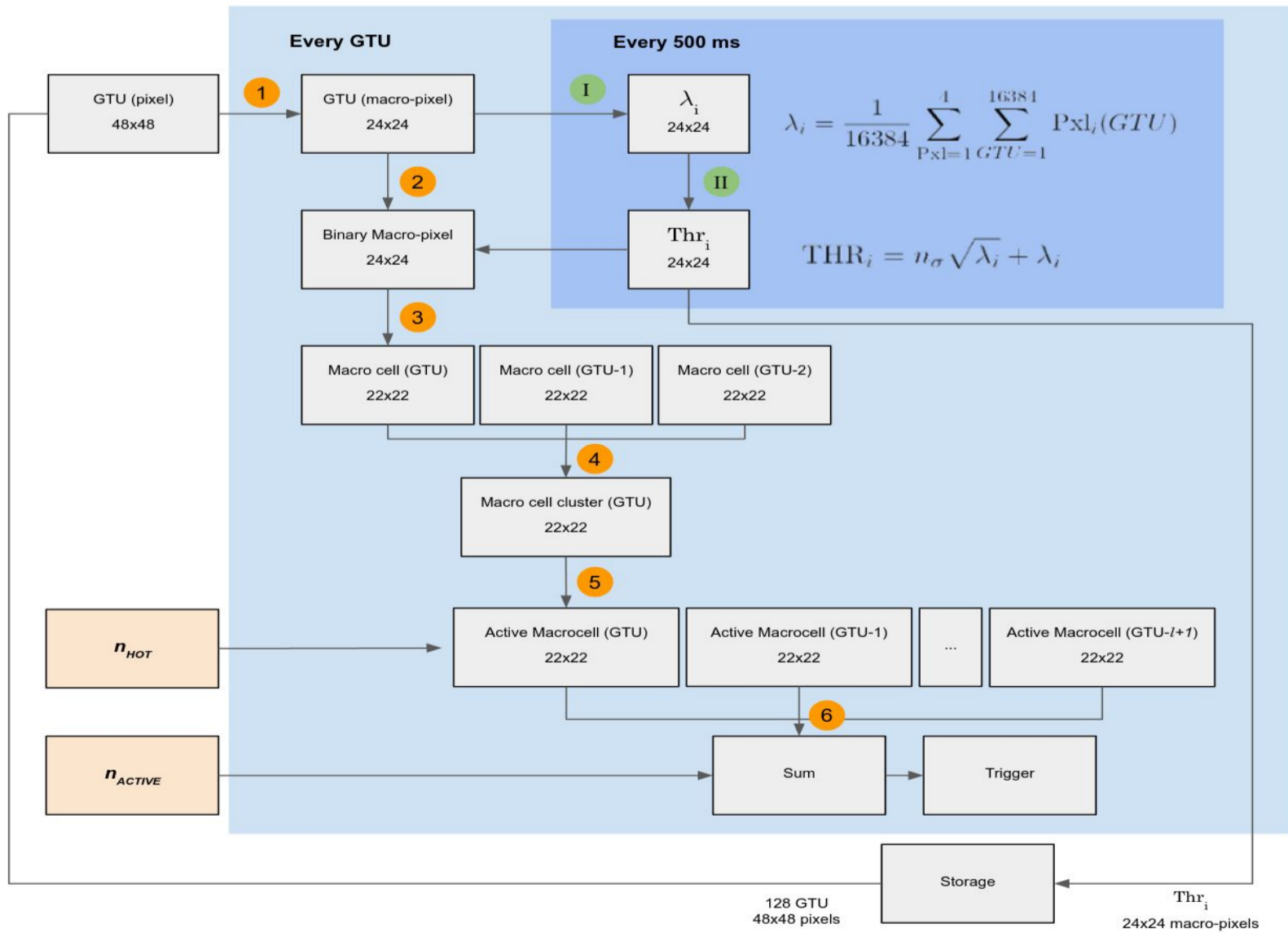


The same 4 MAPMTs at MacroPixel level



Adaptive threshold independent for each MacroPixel

- Background estimated by the integral of 16 ms of data (AVG_i)
- Background values saved for exposure estimation
- Threshold set n_{σ} above the background level of each MacroPixel
- Threshold updated every 500 ms



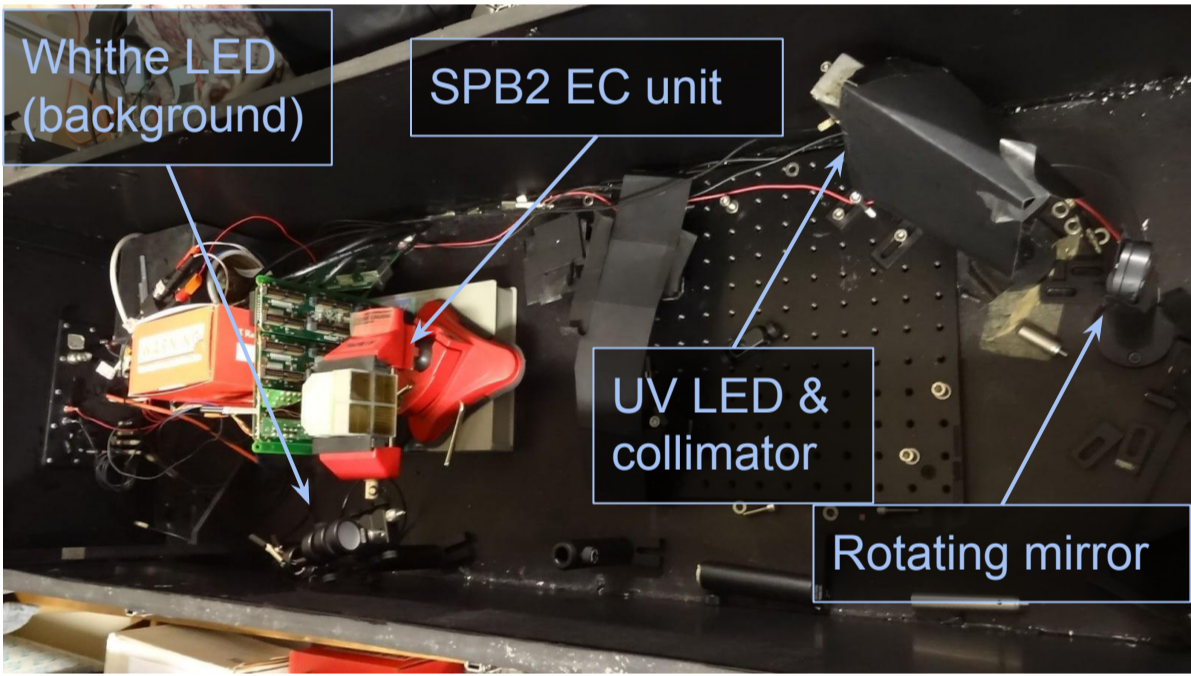
Every 500 ms

- I) the average of each macro-pixel over the previous 16384 GTUs is computed.
- II) This value is used to compute the threshold for each macro-pixel.

Every GTU

- 1) The macro-pixels values are computed, obtaining a 24×24 view of the PDM.
- 2) The Binary Matrix is created through a comparison between each macro-pixel and its threshold.
- 3) The PDM is divided into 22×22 overlapping 3×3 macro-cells, excluding macro-pixels on the border of the PDM, the value of each cell is the number of macro-pixels over threshold. This matrix is stored in a 3 slots FIFO circular buffer, containing the values for the current and the two previous GTUs.
- 4) The sum over the 3 GTUs is performed. Each element of the Cluster matrix contains the number of macro-pixels over threshold in the last 3 GTUs in each 3×3 macro-cell.
- 5) The number of clusters with more than n_{hot} macro-pixels over threshold is stored in a l length FIFO circular buffer.
- 6) The total number of active macro-cells over the last l GTUs is computed and compared to the value of n_{active} . If $SUM > n_{active}$ a trigger is issued.

Black box test

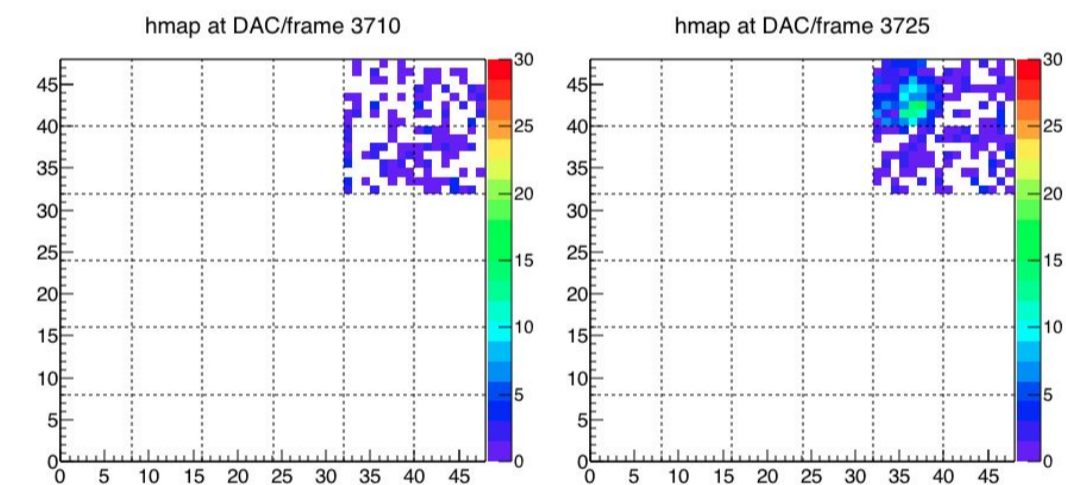


Functionality tests in the black box.

Background produced by a white LED

Track generated through a LED focused by a rotating mirror

Detect microsecond timescale track-like signals



Triggered microsecond timescale track-like signal

TurLab test

Tank rotated at minimum speed: ~15 min/rotation

Detector hung to the ceiling at ~1 m from the center of the tank

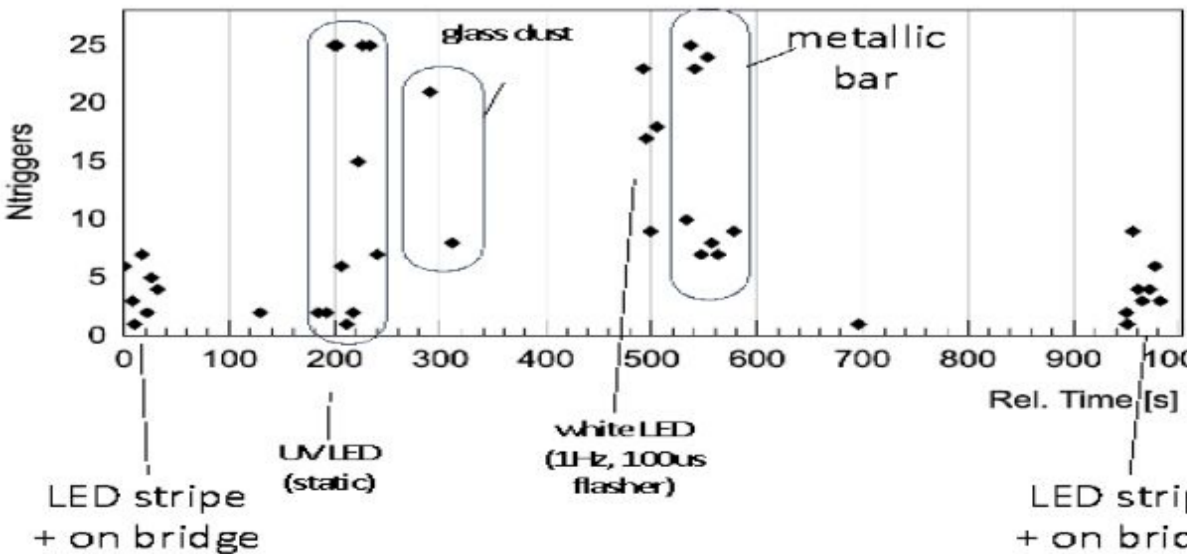
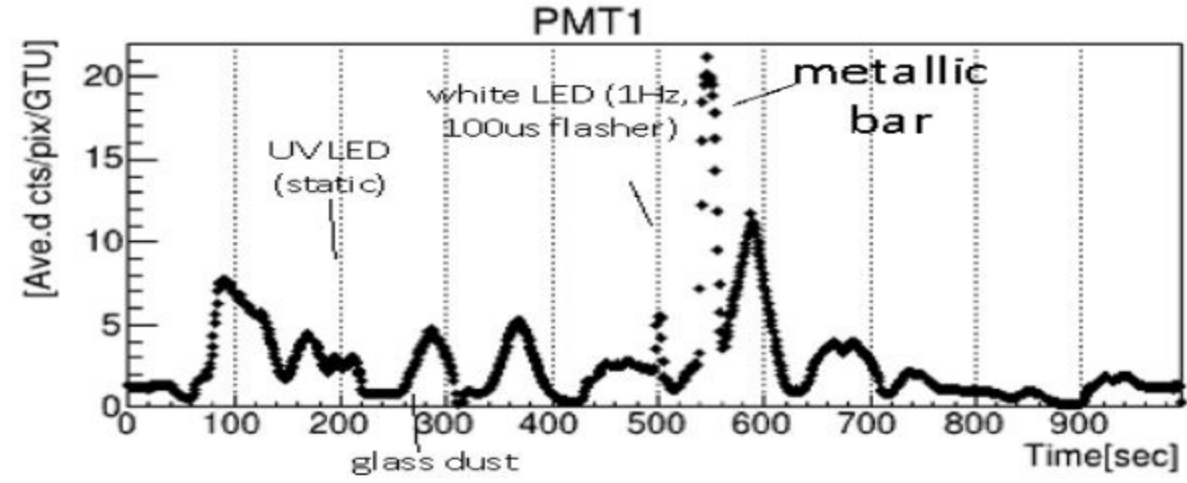
The speed V_{FoV} at which the FoV_{pix} is changed is

$$\frac{1}{V_{FoV}} \sim 4.5 \frac{s}{pix}$$

Similar to the expected V_{FoV} of the balloon.

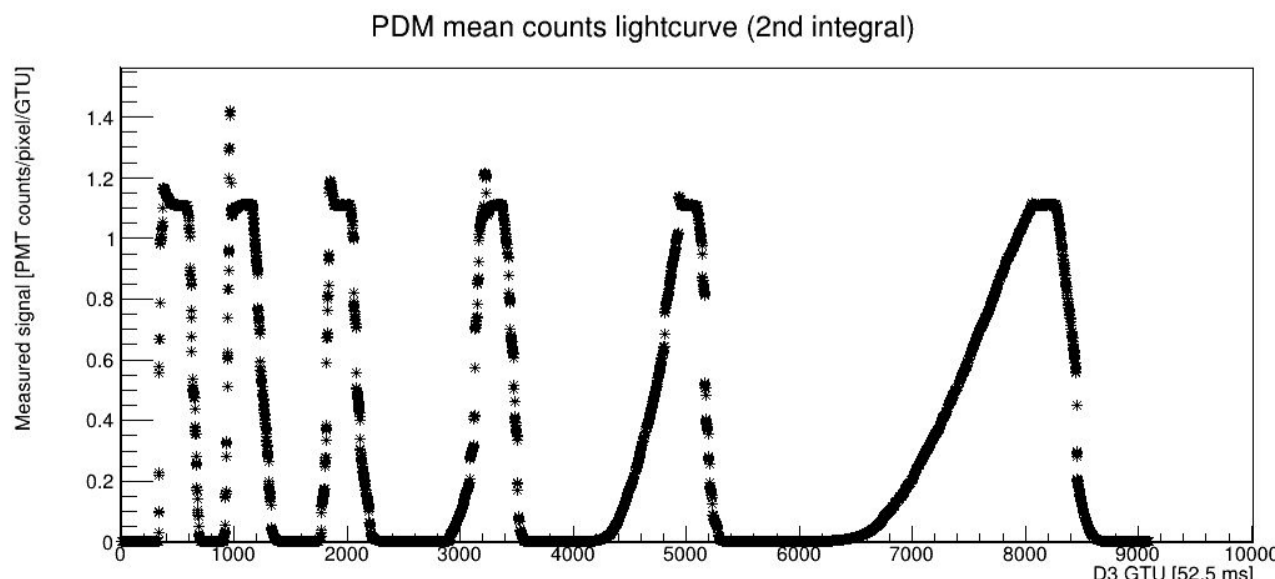


Top: Elements placed inside the tank.
Bottom right: Detector and background light.
Bottom left: White paper as it appears in the data



Top: Lightcurve of a PMT during a rotation (~15 minutes)
Bottom: Triggers detected during the rotation

- Maximum number of trigger: 25 every 5 seconds
- The triggers are concentrated only in specific portions of the rotation
 - microsecond flashers (LED stripe, white LED)
 - very bright objects (metallic bar, UV static LED)
 - Very few spurious triggers



Background conditions dynamically changing,
No trigger obtained thanks to the adaptive threshold system