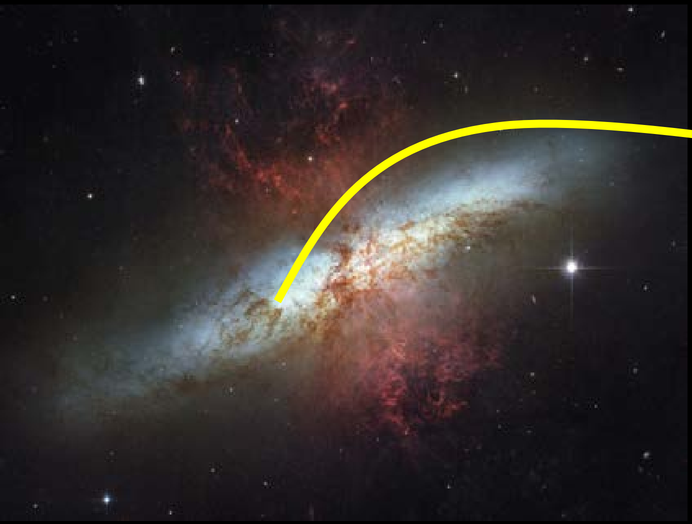
The Fluorescence Telescope on board EUSO-SPB2 for the detection of Ultra High Energy Cosmic Rays

37th International Cosmic Ray Conference
Berlin | Germany 12-23 July 2021



Giuseppe Osteria
On behalf of the JEM EUSO Collaboration
Istituto Nazionale di Fisica Nucleare Sezione di Napoli

Fluorescence: UHECRs EeV

First observation of UHECRs from near-orbit altitude with the fluorescence technique

Search for Upward Event Candidates

Cherenkov: PeV

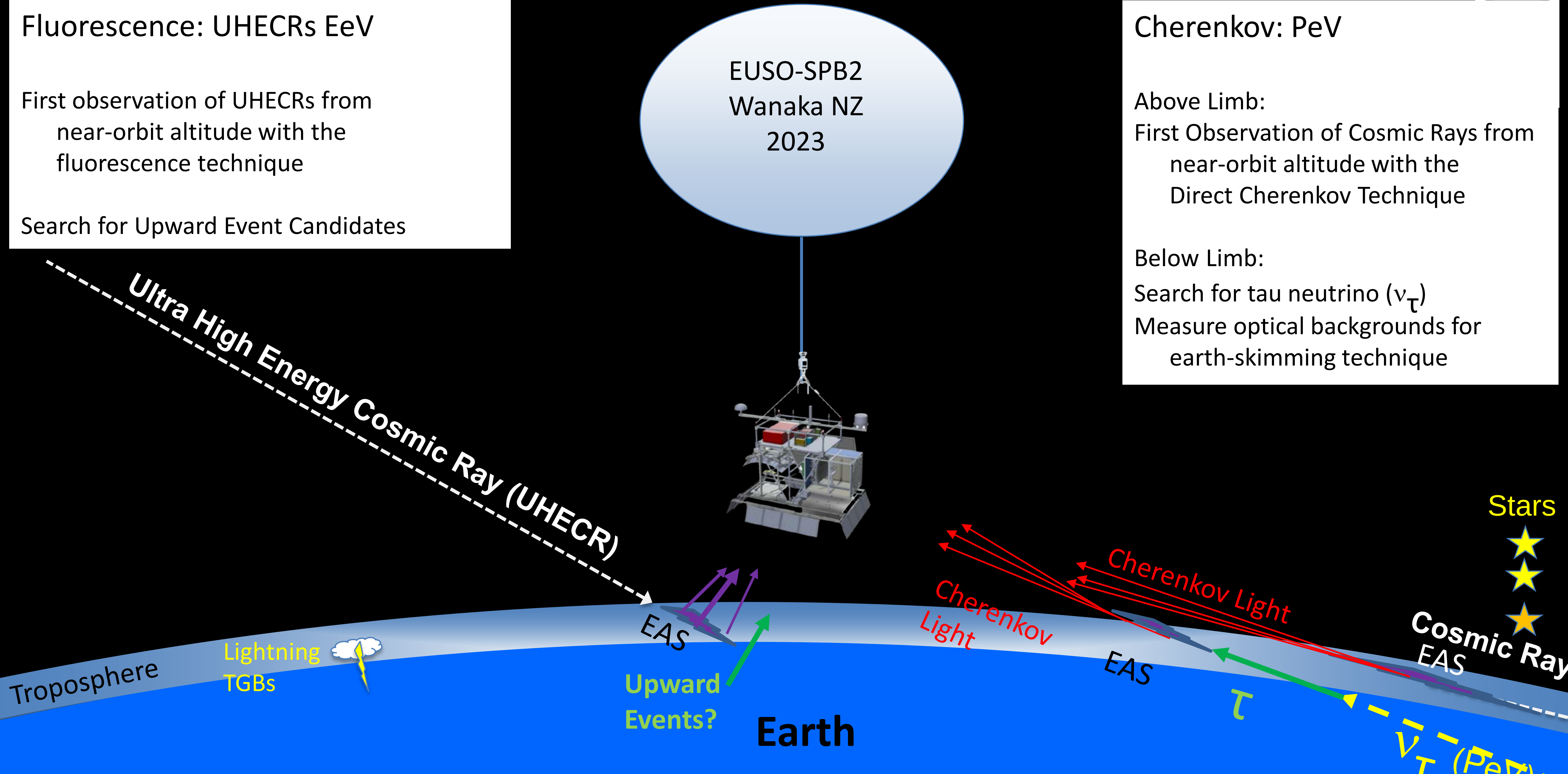
Above Limb:

First Observation of Cosmic Rays from near-orbit altitude with the Direct Cherenkov Technique

Below Limb:

Search for tau neutrino (ν_τ)

Measure optical backgrounds for earth-skimming technique



J. Eser et al., [JEM-EUSO Coll.], *Science and mission status of EUSO-SPB2*, this Conference

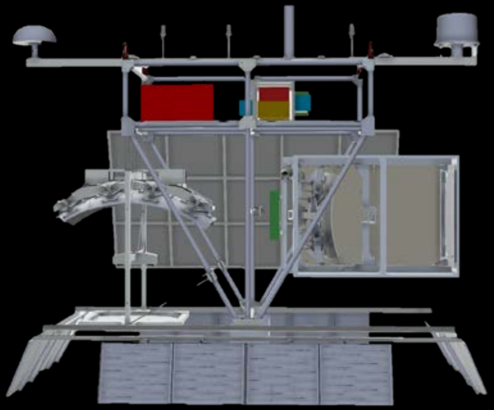
EUSO-
Balloon

2014 Timmins

EUSO-SPB1

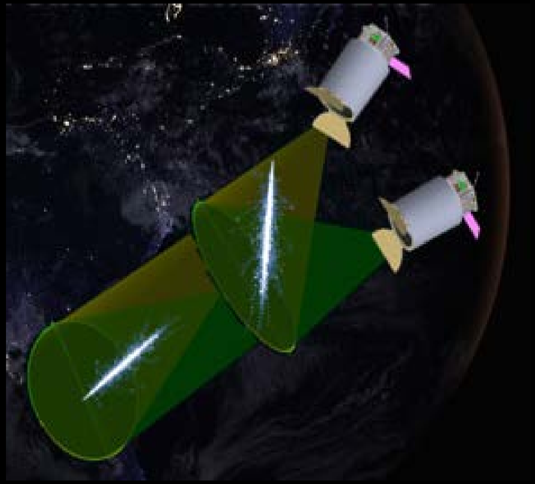
2017 Wanaka

EUSO-SPB2



(2023) Wanaka

POEMMA



(2029) Earth Orbit

K-EUSO

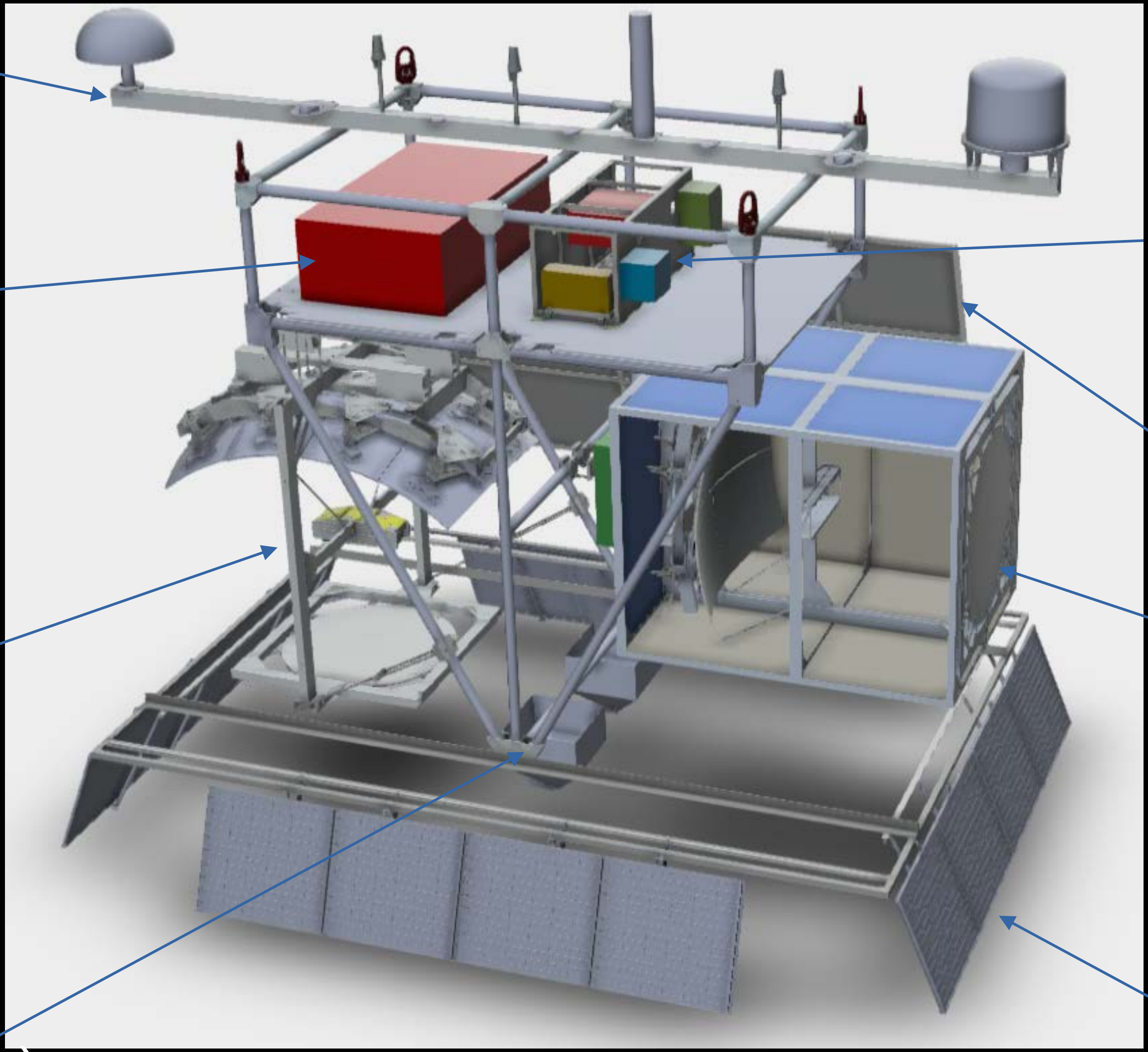
EUSO SPB2

Two Telescopes

Antenna Boom
(CSBF antennas)

Battery-Box
(GCC+batteries)

Fluorescence Telescope (FT)



SIP

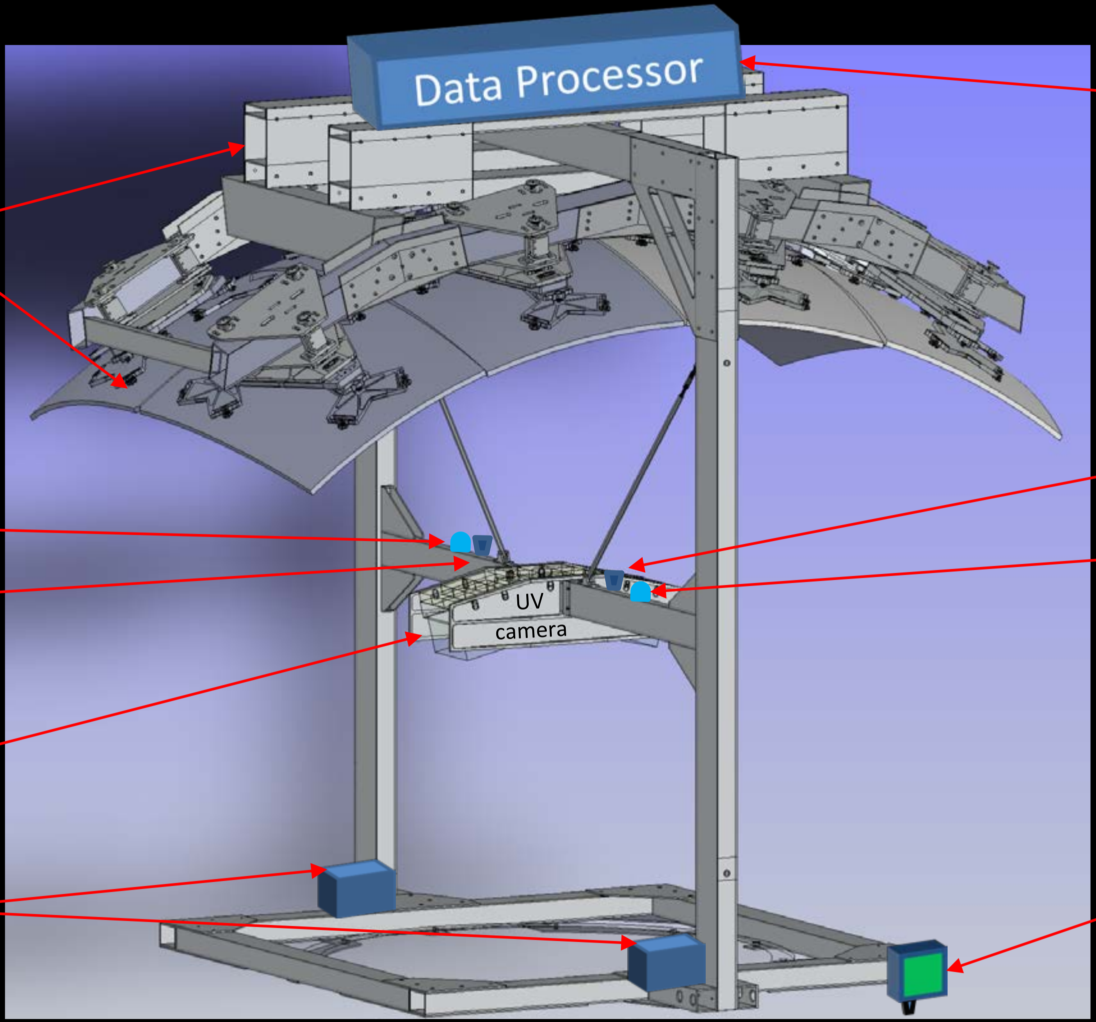
Science solar panels

Cherenkov Telescope (CT)

CSBF solar panels
(4 each side)

Ballast Hooper(2x)

FT and its main sub-systems



Data Processor (DP)
DAQ & Control electronics

Opto-mechanical
(Structure, Schmidt optics)

EMon light sensor2

Health LED1

Health LED2

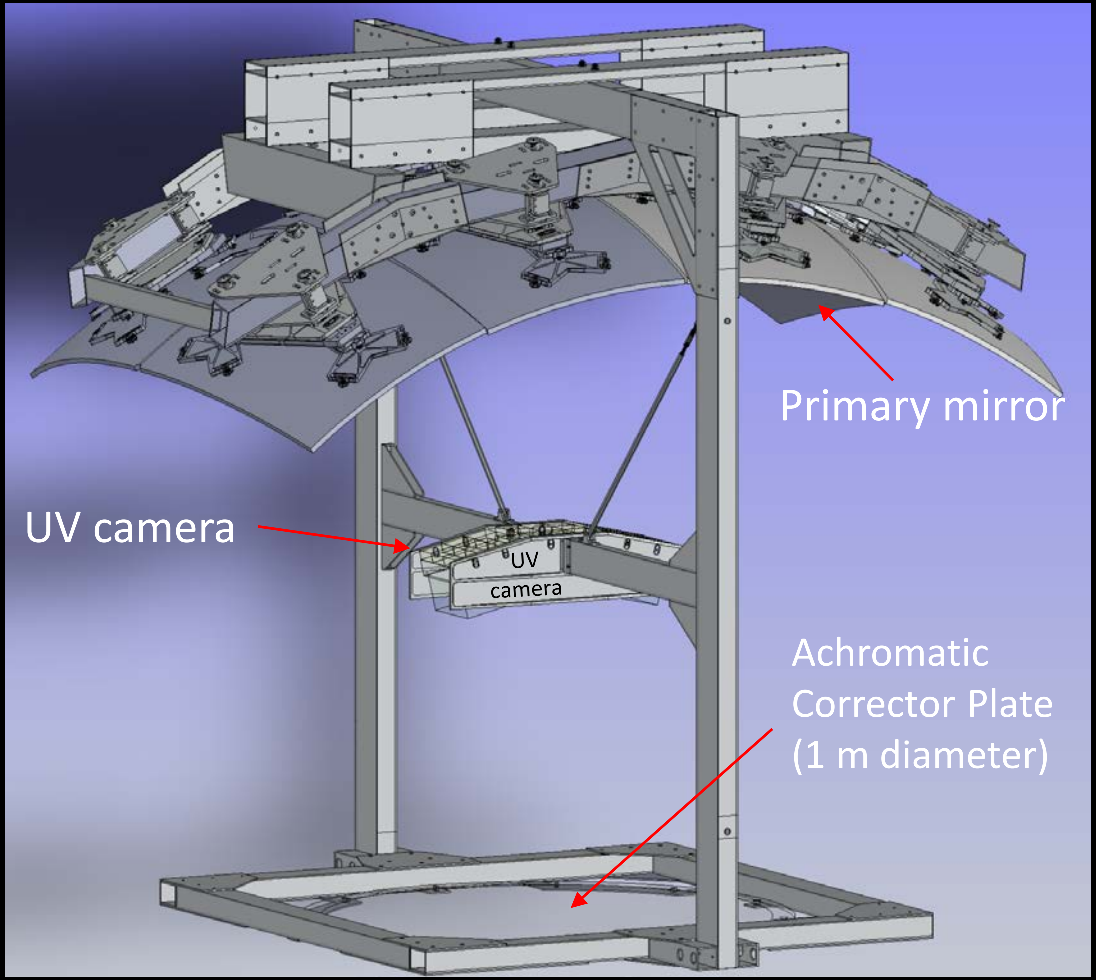
Emon light sensor1

UV Camera

Cover motors

AMon light sensor

FT optics



Schmidt optics

Radius of curvature

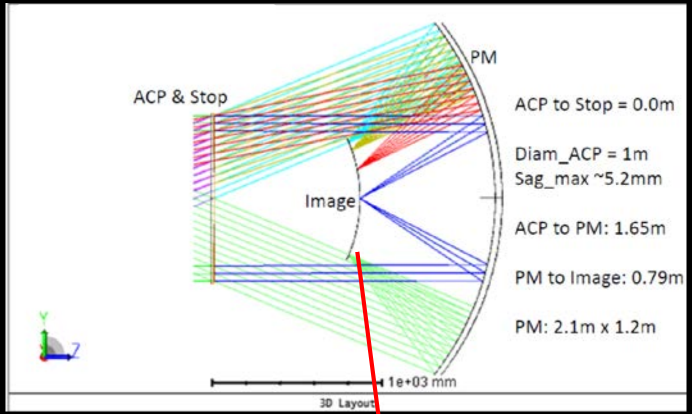
ROC = 1659.8 mm

Effective focal length

EFL = 860 mm

Rectangular FoV: 37.4° x 11.4°

≈ 36 km^2 projected on ground

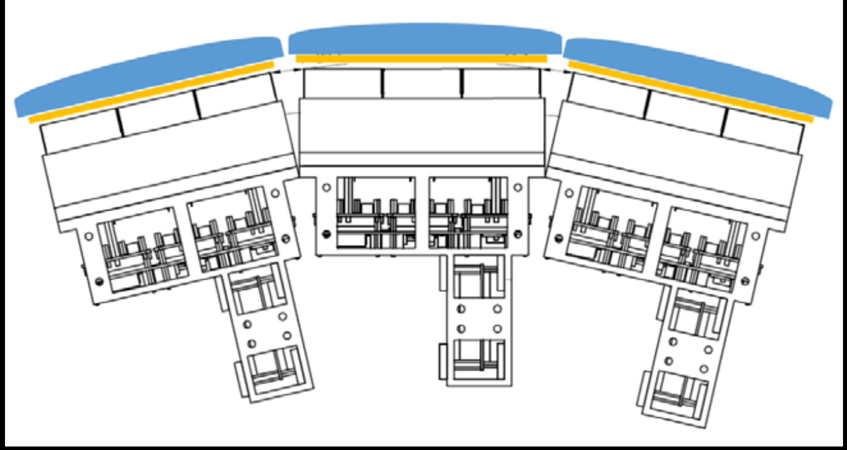


A plano-convex corrector lens is placed in front of each element of the UV camera to preserve the point spread function (PSF).
The overall throughput estimation, including corrector plate, mirror and filter losses is around 0.67.

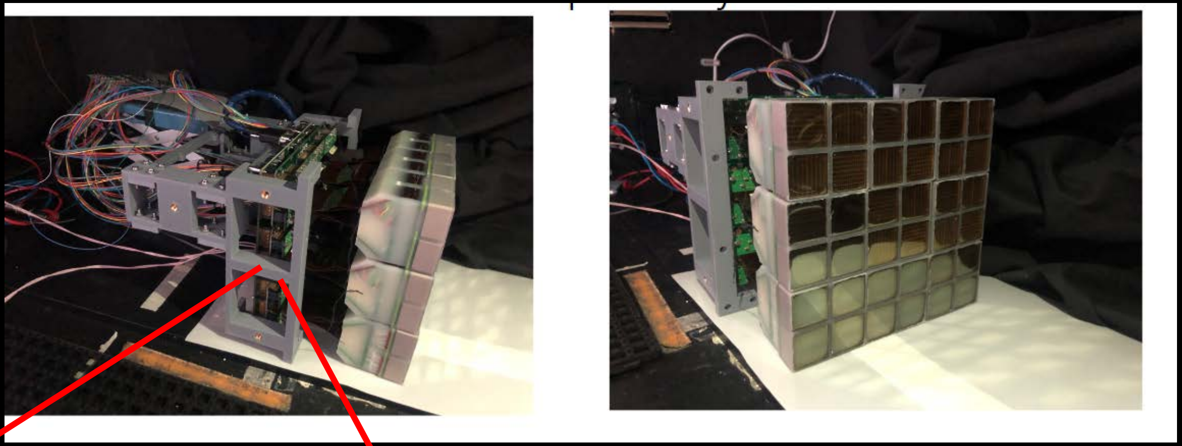
UV camera

UV camera

- 6912-pixel camera
- Counts single photoelectrons (290 nm and 430 nm) with an integration time of 1 µs and double pulse resolution of 6 ns
- Segmented in three modules called Photo Detection Modules (PDMs)
- Each PDM features 9 Elementary cell composed of four 64-pixel MAPMTs
- MAPMTs front-end electronics based on Omega Spaciroc3 ASIC
- UV camera back-end electronics performed by a Xilinx FPGA (Zynq) based board



UV camera



PDM (9 EC)

specifications:

256 pixels

photon counting
(dynamic: linear from 1 to 100 pe)

UV + visible

fast (1 µs GTU, 6 ns resolution)

compact & potted (55 x 55 x 60 mm)

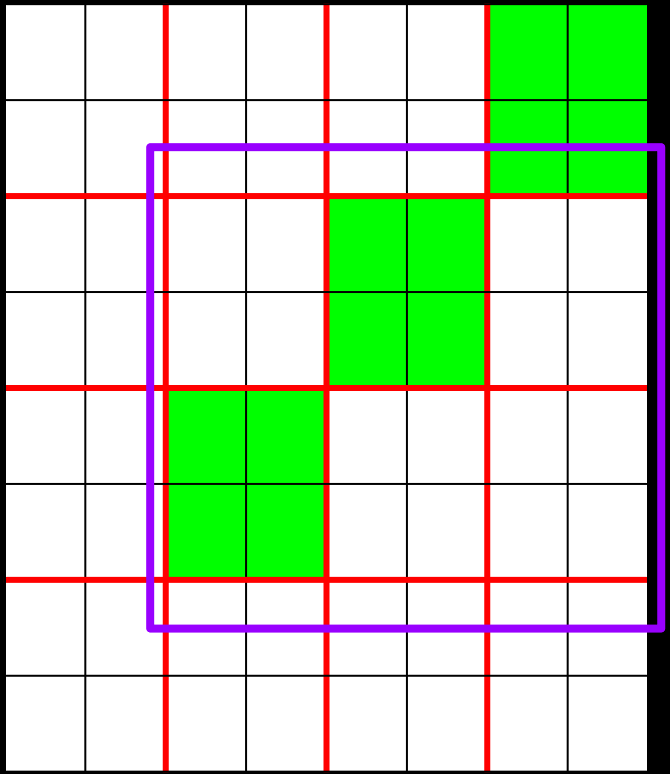
low consumption (< 500 mW)

light (255 g)

Elementary Cell

Zynq board

Trigger



1 PDM

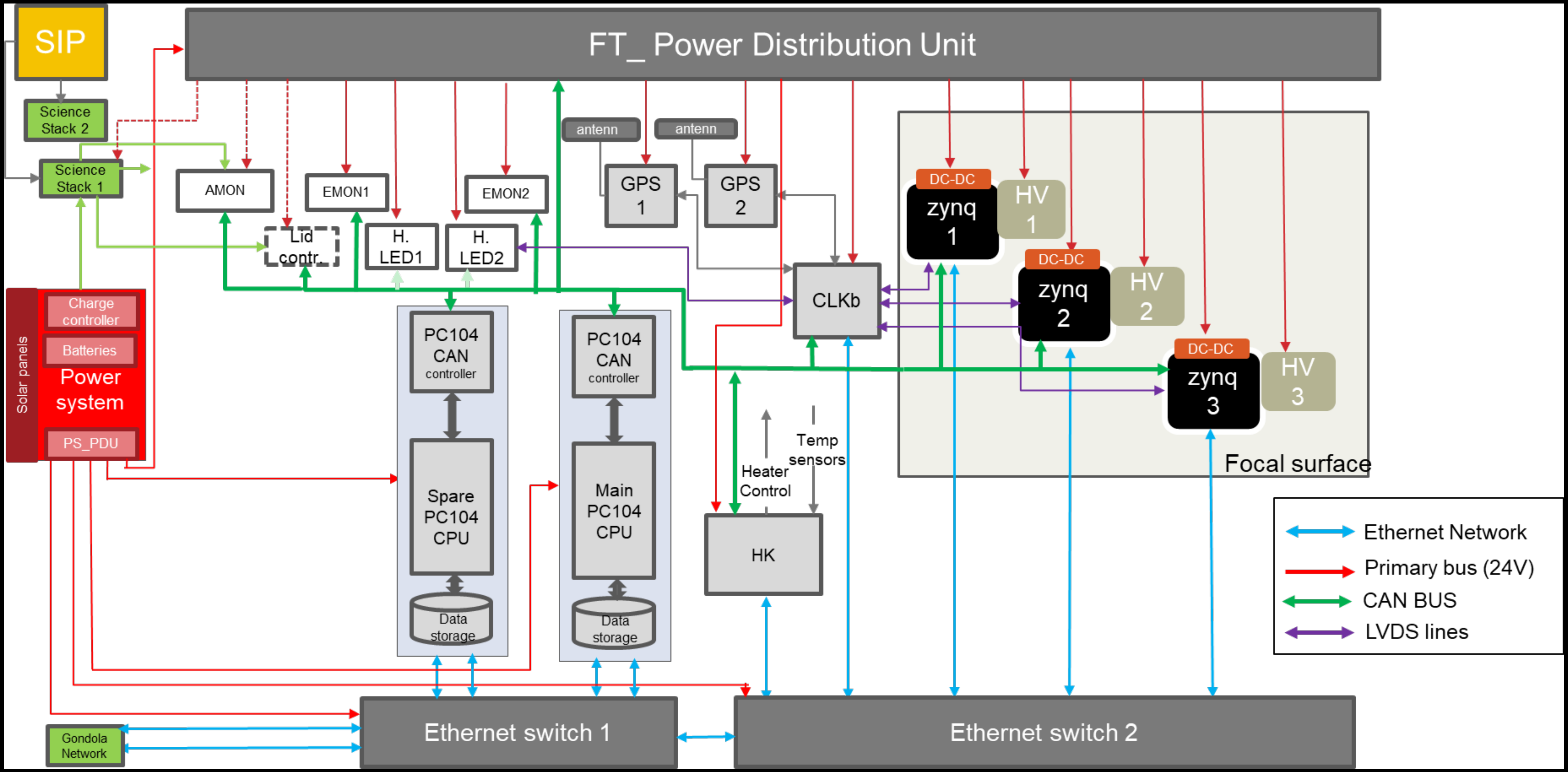
The trigger algorithm implemented should be able to recognize a fluorescence signal lasting a few tens of µs, while keeping the trigger rate on the level of 1 Hz/PDM.
The implemented algorithm:

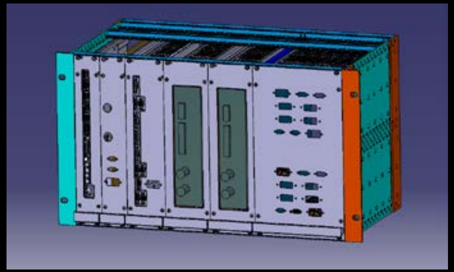
- Break camera into 2x2 MacroPixel grids
- uses an adaptive threshold independent for each cluster of pixels;
- counts the number of active clusters in a certain portion of the PDM (an active cluster is defined as a cluster above its threshold);
- searches for a signal above n standard deviations from the average in any cluster of the focal surface;
- Both the rms and the average are calculated in real time (by averaging over 16ms of data) to take into account varying illumination conditions;

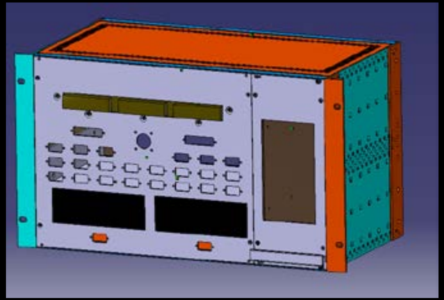
In case of a trigger, the 128 frame buffer (64 frames before the trigger and 64 after it) is stored in memory for each of the three PDMs

G. Filippatos et al., [JEM-EUSO Coll.], *Expected Performance of the EUSO-SPB2 Fluorescence Telescope this Conference*

FT Architecture and Data Processor

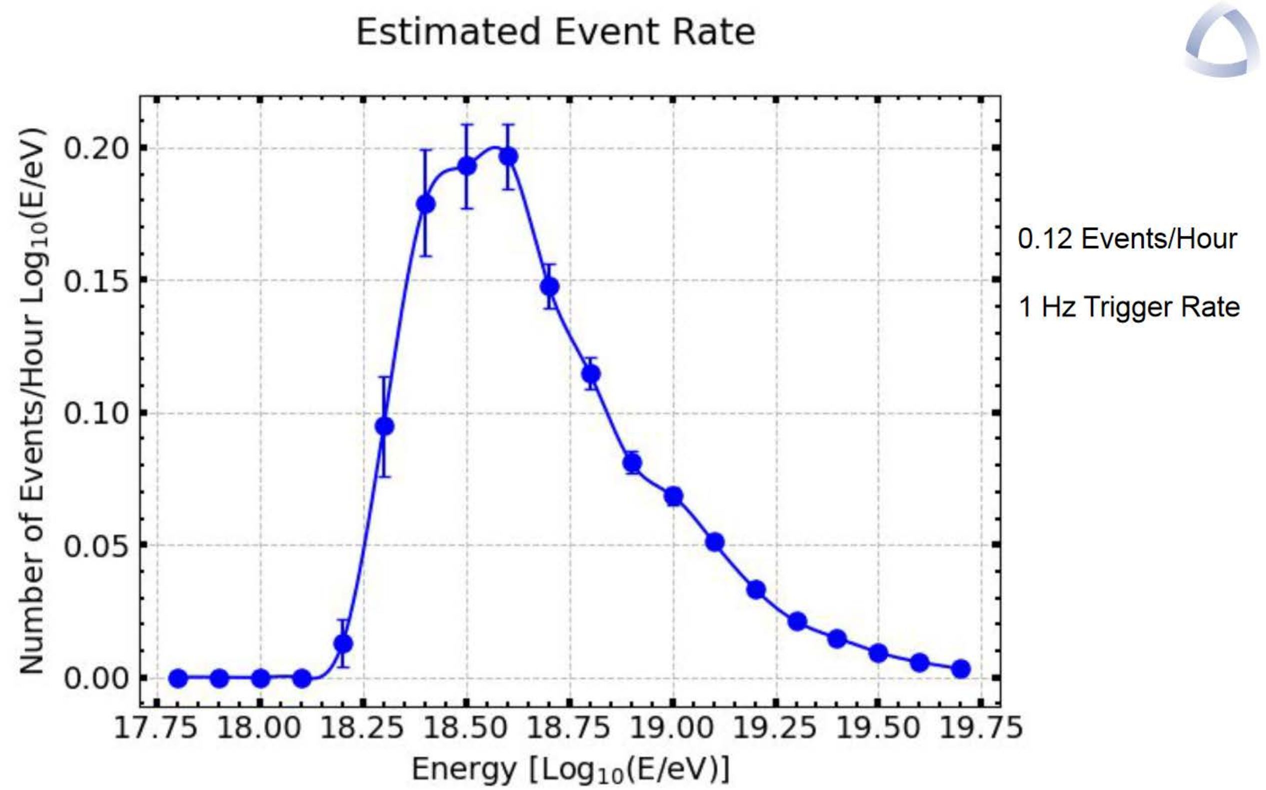






Expected performance
Event Rate Estimation

- Peak energy sensitivity around 6 EeV
- Can expect 1 event every 9 hours
  - For an 80 day flight with 15% duty cycle ~ 32 events
  - For a flight similar to EUSO-SPB1 ~5 events
  - Performance increase of at least 3x over EUSO-SPB1
- Trigger optimization is ongoing
- Pre-flight expectations will continue to be refined as the instrument is assembled and tested



G. Filippatos et al., [JEM-EUSO Coll.], *Expected Performance of the EUSO-SPB2 Fluorescence Telescope*

FT specifications

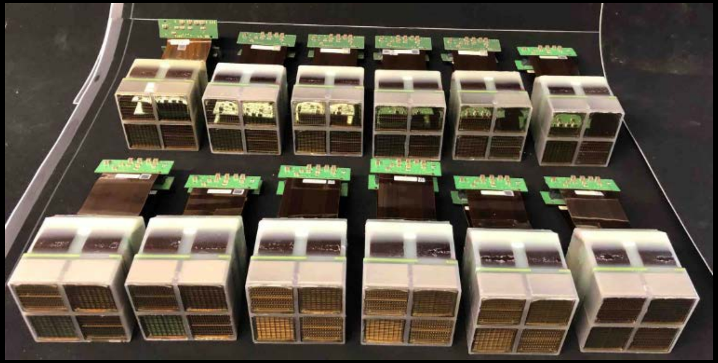
Fluorescence Telescope	
Energy Threshold	$10^{18.2}$ *eV*
Sensor Type	MAPMT (Hamamatsu)
Wavelength Sensitivity	UV 300-420 nm (BG3 filter x QE)
Time Bin	1 μs/bin
Pointing (zenith angle)	nadir
FOV (instrumented)	(37.4x 11.4) deg
Number of Pixels	3x2304=**6912** (3 48x48 PDMs)
Pixel FOV (& size)	0.2x0.2 deg (2.8x2.8 mm)
Optics (modified Schmidt)	Spherical Mirror Glass, ROC 1659.8 mm 6 segments common focus + camera corrector/filter
Entrance Pupil	1 m diameter PPMA corrector plate

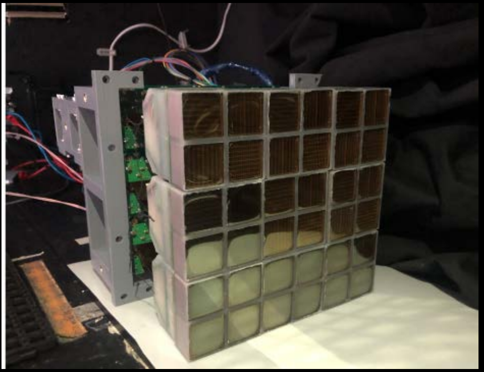
Development Status

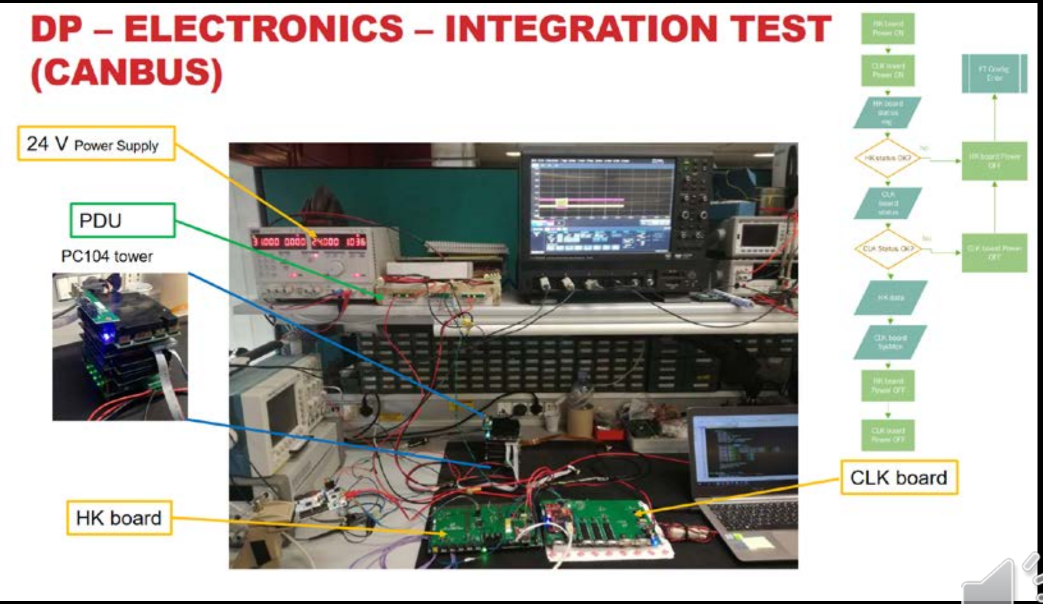
All the components needed to build the telescope have been procured and the construction of its subsystems is now underway.

Extensive laboratory and field testing is planned to characterize and calibrated the FT prior to payload integration.

- TVAC test of the UV Camera and Data Processor
- Optical throughput will be measured for downward and horizontal orientations using a 1 m diameter optical test beam.
- The FT will then be transported to the Utah desert for testing with lasers and other light sources.







Conclusions and outlook

- Detector development in progress
  - On track for a launch in 2023
- Expected peak energy sensitivity at 4 EeV
- Expected to detect 0.12 events per hour
- A 14 day flight >8 events expected
- Sophisticated hardware and software solutions have been developed for the telescope and are applicable to future missions

Thank you for your attention