EUSO-SPB Extreme Universe Space Observatory on a Super Pressure Balloon

EUSO-SPB: in-flight performance

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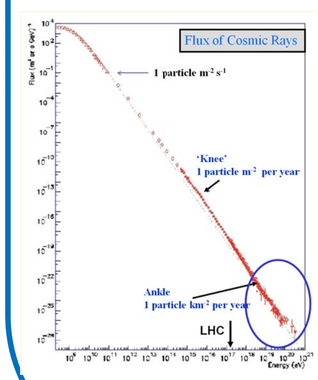
EUSO

Extreme **U**niverse **S**pace **O**bservatory

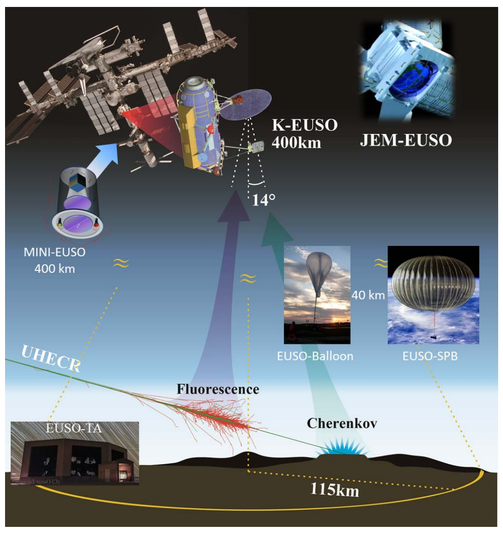
EUSO is a new type of observatory which observes transient luminous phenomena occurring in the Earth's atmosphere.

The main objective of EUSO is to study the Extreme Energy Cosmic Rays, EECR (E > 5×10^{19} eV), the most energetic component of the cosmic radiation.



Observation from space has two main advantages:

1. The target volume is far greater than possible from the ground
2. Full sky coverage



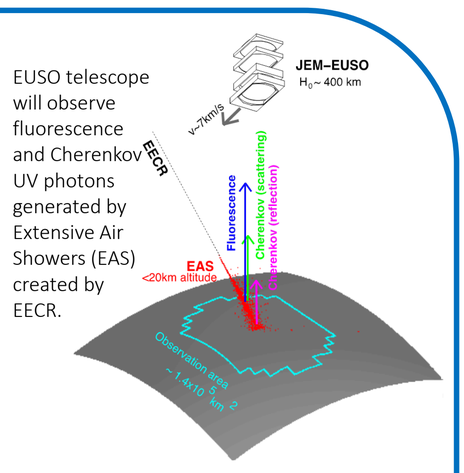
Physics and Astrophysics from E > 5×10^{19} eV, focusing at E~10^{20} eV (and above):

- Identification of EECR sources by high-statistics arrival direction analysis
- Measurement of the energy spectra of individual sources (spectral shape, flux, power)
- Understand and constrain acceleration and emission mechanisms

The telescope is an extremely-fast and highly-pixelized (~3·10^5 pixels) digital camera with a large diameter (2.35 m) and a wide-Field of View (FoV, ±30°). It works in near-UV wavelength (290 - 400 nm) in single-photon counting mode. The telescope consists basically of four parts:

- **Optics**: 3 high transmittance optical Fresnel lenses focusing the arriving UV photons onto the Focal Surface
- **Focal Surface detector:** ~ 5000 Multi Anodic PhotoMultipliers Tubes of 64 pixels
- **Focal Surface electronics**: trigger, data acquisition and controls
- **Mechanical structure**

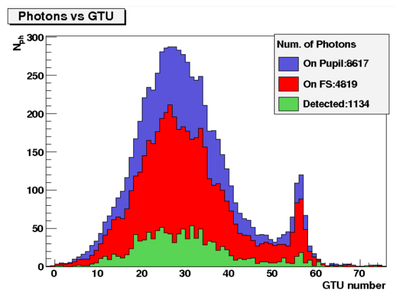
The apparatus is completed by an atmosphere monitoring system (Infra-Red camera and Lidar) and a calibration system.



EUSO telescope will observe fluorescence and Cherenkov UV photons generated by Extensive Air Showers (EAS) created by EECR.

The program

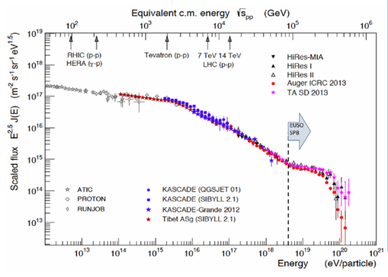
1. **EUSO-TA**: ground detector installed in 2013 at Telescope Array site (USA); currently operational
2. **EUSO-Balloon:** 1st balloon flight from Timmins (Canada) by the French Space Agency; August 2014
3. **EUSO-SPB**: NASA Ultra long duration flight from Wanaka (New Zealand); launch in April 2017
4. **MINI-EUSO**: precursor on the International Space Station approved by Italian and Russian Space agencies; launch in 2019
5. **K-EUSO**: bigger telescope on ISS, approved by Russian Space Agency; launch in 2023



EAS development time ~ 50 - 150 μs

Simulation of the light profile observed at the entrance pupil and through the instrument

EUSO-SPB



Scientific objectives

1. First fluorescence observations of cosmic ray from above
2. Measure UV background light at night from space
3. Search for faint and ultrafast UV signatures in the atmosphere from other phenomena
4. Establish methods and techniques for a future high energy astroparticle space observatory

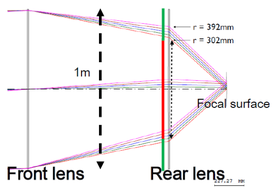
The instrument

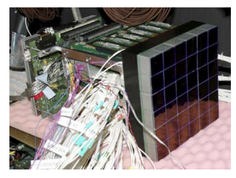
Optics:

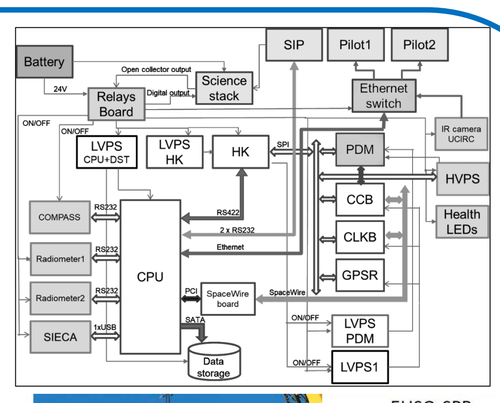
- 2 x Φ 1m Fresnel type lenses
- UV filter (330-400 nm)
- FoV = ±5.5°
- Axis elevation: 26°
- Concave focal surface

Photo Detector Module:

- array of 36 Multi-Anode Photomultiplier Tubes (MAPMTs) of 64 pixels:







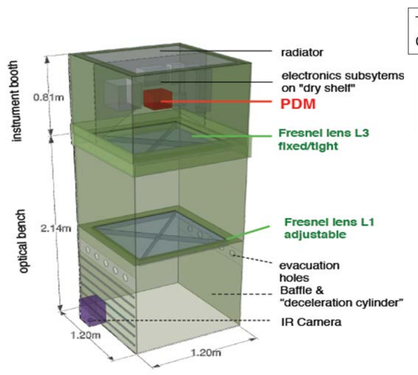
SPB Float Height	110,000 ft = 33.5 km
Weight	
Detector	2250 lbs
Payload	2700 lbs w/ SIP, Antennas, Empty Ballast Hoppers
Dimensions	1.2m x 1.2m x 3m
Power consumption	40 W Day, 70 W Night (assumes 20W PDM heater @ 50%)
Telescope	Refractor with 2 Fresnel lenses
FOV	11. deg (measured w/ stars)
Camera:	2,304 pixels; 36 MAPMTS (Hamamatsu R11265-113-M64-MOD2)
Data volume:	Downlinked ~1-1.5 Gb/day
Recorded	~3 GB/Day w/ 10 hour dark run
	with trigger rate of 0.2 Hz
Energy threshold	for h=33 km ~3 EeV
Ground equivalent Trigger Aperture	
	250 km^2sr @ 3 EeV to ~500 km^2 sr @ 10 EeV

Electronics:

- readout performed by one ASIC per MAPMT : 2304 channels in total
- multiple trigger levels to filter out noise and identify events of interest

Auxiliary instruments:

- infrared camera (UCIRC)
- Silicon photomultiplier Elementary Cell Add-on camera (SiECA)



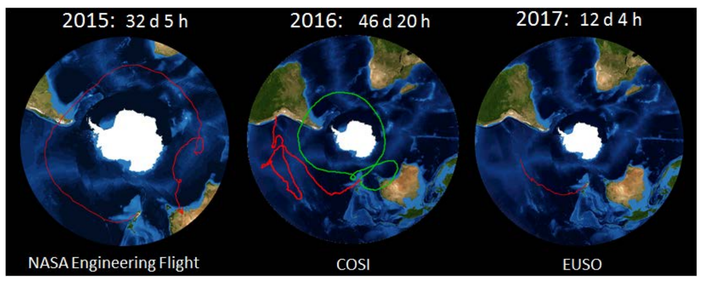
EUSO-SPB Payload and Major Components

The flight

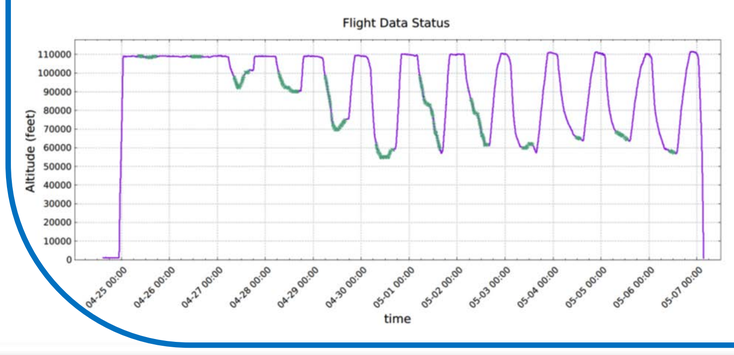
The launch occurred on April 24th 23:30 UTC. Unfortunately the balloon developed an anomaly that lead to an early termination of the mission 12 days after launch the entire flight train had to be "valved down" into the ocean about 300 km SE of Easter Island.

A 24/7 shift schedule for EUSO-SPB1 instrument monitoring and operations was setup with 6 centers in Europe (France, Germany, Italy), RIKEN Japan, and Colorado US.

During the flight 40 hours of PDM data were recorded over 11 nights.



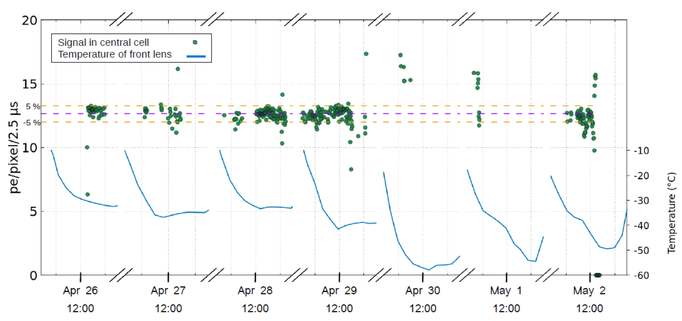
The trajectories of the NASA super pressure balloon test flights launched from Wanaka NZ.



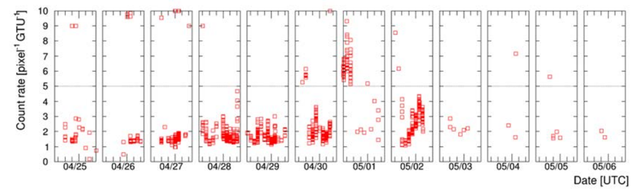
Altitude profile of the 2017 mission. The thicker lines denote the dark moonless periods when data was collected.

The data download bandwidth was reduced when 1 of the 2 links failed. 30 hours of the data recorded on board were downloaded.

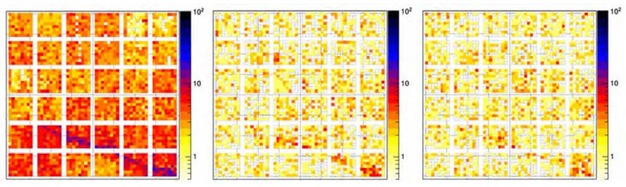
Preliminary data analysis



The response of the central cell of the EUSO-SPB1 PDM to flashes from the Health LED (dots). The dashed lines indicate 5% about the mean. The lower curves show the temperature measured at the outside of the front Fresnel lens at the optics entrance aperture. Some gaps in the data occurred because the LED was turned off to avoid RF pickup from an onboard radio beacon that was enabled when the balloon dropped below 21 km.



Preliminary measurement of the night time background light levels recorded during the mission. The units are photoelectrons/pixel/2.5 μs.



A direct cosmic ray traveling through the PDM camera.
The 3 panels correspond to 3 consecutive 2.5 ms time bins.

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JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 People