Cherenkov Telescope on-board the EUSO-SPB2 Mission for the Detection of Very High Energy Neutrinos

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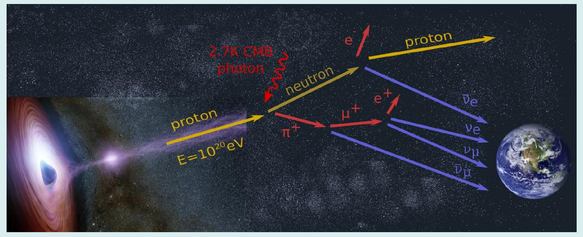
Scientific Motivation

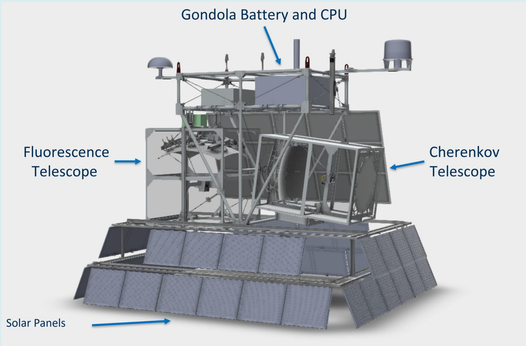
Very-High-Energy (VHE) neutrinos (E > 10 PeV) can address a broad range of major scientific drivers in astroparticle physics:

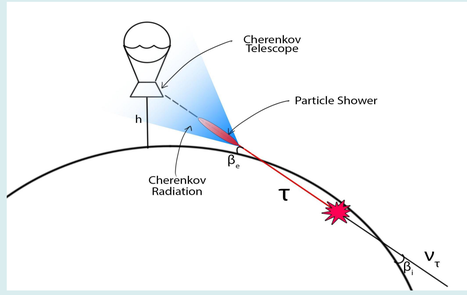
- What are the most energetic particles in the Universe?
- Where and how do they gain their incredible energies?
- How did the universe evolve?



EUSO-SPB2 Mission

The Extreme Universe Space Observatory on a Super Pressure Balloon II (EUSO-SPB2) is a second-generation stratospheric balloon instrument, carrying a Fluorescence Telescope for the detection of Ultra High Energy Cosmic Rays (UHECRs, E > 1 EeV) and a Cherenkov Telescope for Very High Energy (VHE, E > 10 PeV) earth-skimming tau-neutrinos. EUSO-SPB2 is a pathfinder mission for space-based missions such as the Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) and is expected to be launched from Wanaka, NZ in Spring 2023. A rendering of the SPB2 payload along with the concept of earth-skimming technique is shown below.



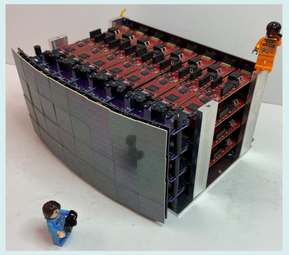


Cherenkov Camera

The Cherenkov telescope (CT) on-board EUSO-SPB2 will probe, for the first time, a volume of 10° above and below the limb of the Earth. The CT science objectives are:

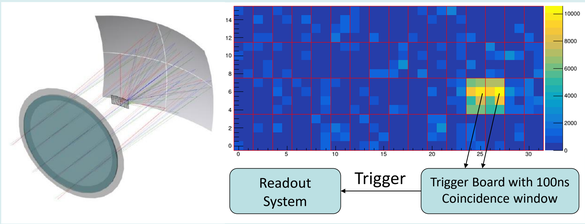
- Identifying sources of cosmic rays above the horizon and VHE neutrinos below the horizon
- Studying the Night-Sky-Background (NSB) and classifying the known and unknown of background
- Perform target of opportunity searches in response to international multi-messenger alerts

Cherenkov Telescope Specs	
Number of Pixels	512 (0.4° Pixel size)
Field of View	6.4° × 12.8°
Photosensors	SiPM Hamamatsu (S14521-6050CN)
Wavelength Sensitivity	300-900 nm
Optics	Schmidt catadioptric system



Bifocal Optics and Trigger Logic

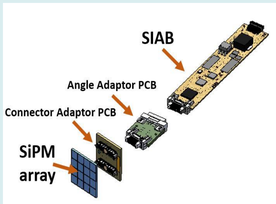
The CT primary mirror is segmented into four identical mirrors with an aperture area of 0.785 m^2. The mirrors are tilted in a way that a parallel light pulse from outside of the telescope produces two spots in the camera with a horizontal offset of 12 mm, or 2 pixels. Trigger Board Receives one trigger signal from each 8 pixels and forms a 100ns coincidence between each two adjacent signal to generate a trigger for the readout system.



Front-end electronics

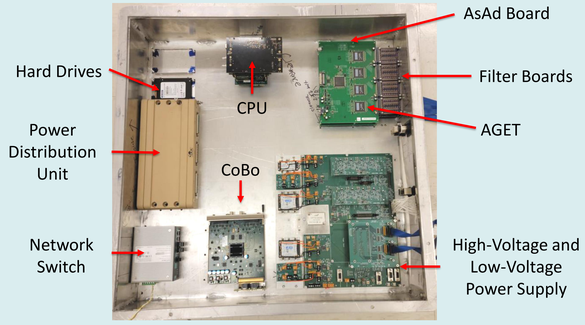
The front-end of camera consists of 32 Sensor Interface / Adapter Board (SIAB) which each one includes:

- Two Music chips for shaping the SiPM signals, adjusting the bias voltage and providing current output per pixel.
- One 24-bit ADC to digitize the SiPM currents.
- One microcontroller for slow control of the camera.



Data Acquisition

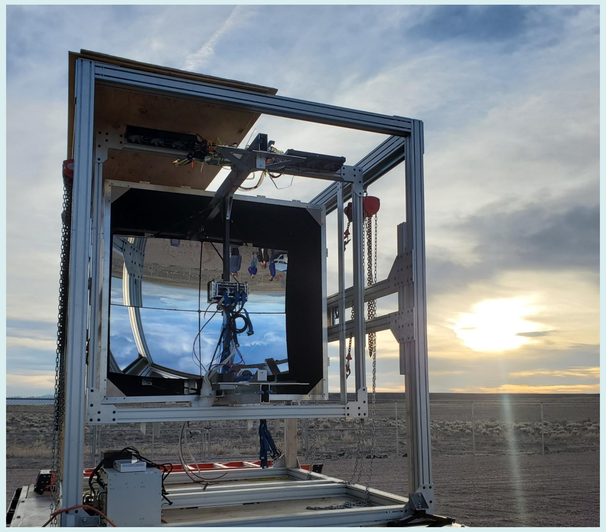
- Digitization: 2 AsAd (ASIC Support & Analog-Digital conversion) board, each with 4 onboard AGET (ASIC for General Electronics for TPC) chips managed by a Concentration Board (CoBo).
- Sampling rate: 100 MS/s with overall deadtime of 1.44 ms
- Digitizer Resolution: 12-bit ADC
- Readout window length: 5.12 µs



Field Test in Utah

We integrated the Cherenkov camera and its electronics into the telescope structure in the flight configuration and tested all the communication and functionalities of the electronics components. Besides, we operated the telescope in Delta, Utah and collected data in three scenarios:

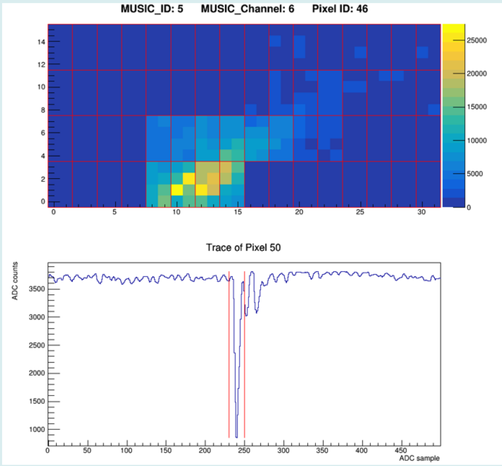
1. Health LED Flasher
2. Laser Track
3. Air showers by pointing the telescope upwards



Observed Air Shower

We operated the telescope for several hours by pointing it upwards and recorded multiple air shower tracks, which an example of it is shown below.

- The top plot shows a snapshot of the camera with the color representing the integrated ADC counts over 200 ns.
- The bottom plot shows the trace of the signal in one pixel and the red lines show the integration window.



Summary

- The camera focal plane and the readout electronics have been completed and tested successfully in the lab and the field.
- The slow control and data acquisition software is tested and is being finalized.
- Telescope detection performance has been evaluated under different scenarios by observing air showers during field test.

References

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