The Probe of Extreme Multimessenger Astrophysics (POEMMA) on a Balloon with Radio

George Filippatos for the JEM-EUSO Collaboration

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Collaboration

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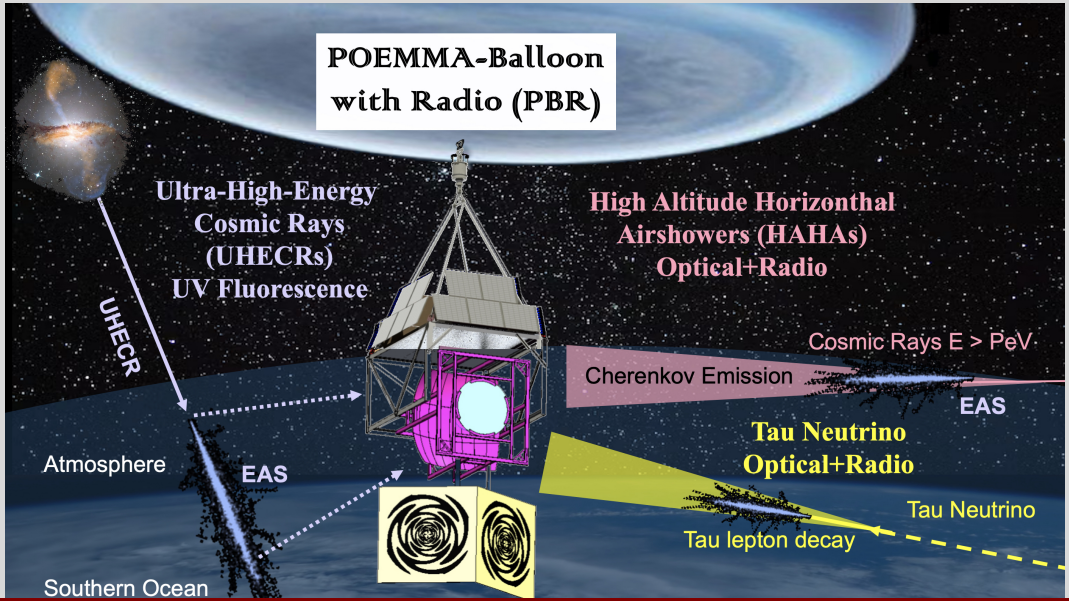
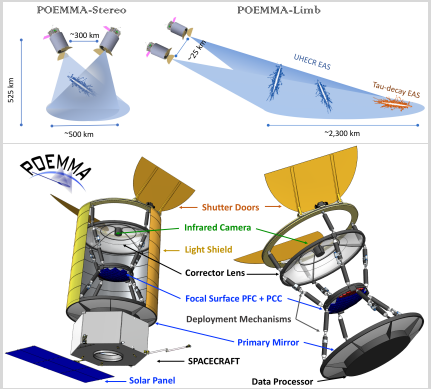
PRELIMINARY

51 members, 22 institutions, 8 countries


POEMMA-Balloon
with Radio (PBR)
Ultra-High-Energy
Cosmic Rays
(UHECRs)
UV Fluorescence
UHECR
High Altitude Horizonthal
Airshowers (HAHAs)
Optical+Radio
Cosmic Rays E > PeV
Cherenkov Emission
EAS
Tau Neutrino
Optical+Radio
Tau Neutrino
Tau lepton decay
Atmosphere
EAS
Southern Ocean

The Probe Of Extreme Multimessenger Astrophysics (POEMMA)

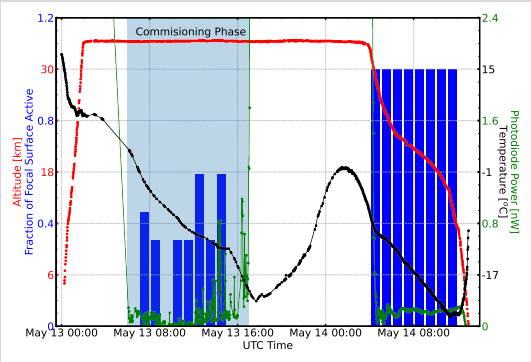


- Conceptual design for a NASA Astrophysics Probe-class mission[1]
- 2 sattiliettes flying in formation in low Earth orbit
- Large ($45° \times 45°$) FoV, hybrid focal surface for fluorescnce and Cherenkov observations
- 2 observation modes, stereo optimized to detect UHECRs and limb optimized to detect astrophysical ν_τ

[1] A.V. Olinto et al. 2021

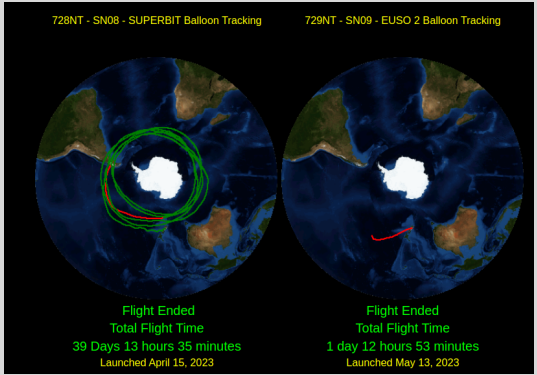
Building on the experience of EUSO-SPB2 (2023)

- Payload housing 2 optical telescopes to prototype the two portions of POEMMA's focal surface
- Flight terminated after 1.5 days due to a leak in the balloon
- Instruments worked as expected, but not enough time to accomplish main science goals



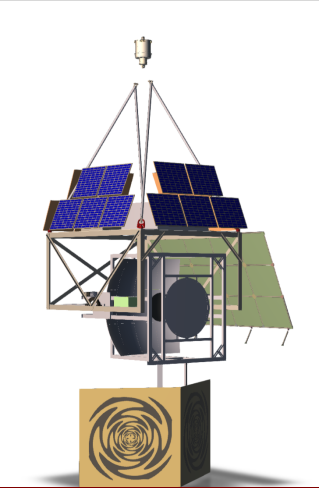
Super Pressure Balloons

- Mantain constant pressure throughout day/night cycles
- Allow for mid-lattitude flights with dark periods of observations and sunlihgt for battery charging
- Utilize semi-annual stratospheric wind pattern to circumnavigate
- 5 launches from Wānaka NZ
  - 32 Days (2015)[1], 46 Days (2016)[1], 12 Days (2017)[2], 39 Days (2023)[1], 1.5 Days (2023)[2]



[1] Recovered on land
[2] JEM-EUSO collaboration payload

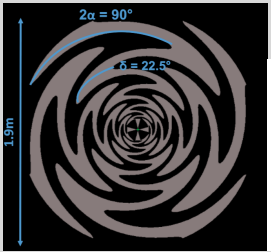
Payload Overview

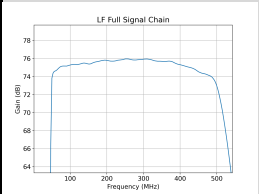


- 3,000 lbs of science (5,500 lbs total payload weight), 33.5 km float altitude
- 1.1 m entrance diameter Schmidt telsescope
  - Ability to point from -90°(nadir) to $+12°$ in zenith
  - Azimuthal rotational control
- Hybrid focal surface
  - MAPMTs for fluoresnce observation
  - SiPMs for Cherenkov observation

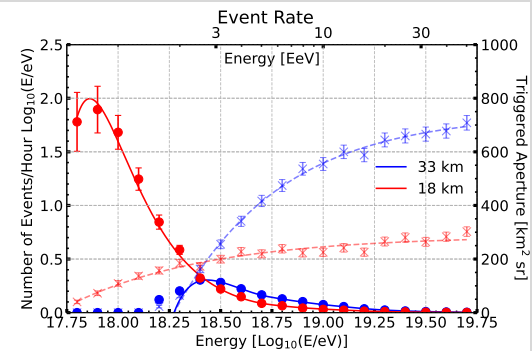
Radio Instrument

- Two 2×2 m sinuous antenna canted at 120°
- 50-500 MHz frequencey range
- Capable of self triggering, or recieving triggers from optical instrument
- Rotates with main telescope
- Modeled off of the the PUEO low frequencey instrument design





Observing Mode 1: Ultra-High Energy Cosmic Rays (UHECRs) Observations

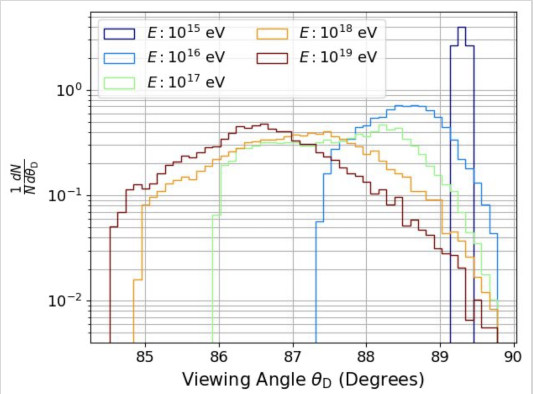


Simulated apperture for EUSO-SPB2

- **Telescope pointing down towards the Earth**
- 144 MAPMTs, with 9,216 total channels with a $25^\circ \times 25^\circ$ FoV
- 1 μs integration, BG-3 filter (280-420 nm)
- Sensitive to EAS with $E \gtrsim 10^{18}$ eV
- Requires cloudless, moonless conditions for observations
- $\approx$ 1 UHECR expected per 8 hours of observation

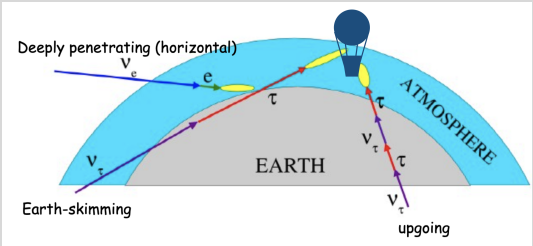
Observing Mode 2: High Energy Cosmic Ray Observations

- **Telescope pointing near horizontal, above the limb of the Earth**
- Sillicon Photomutipliers, 100 MHz digitization over optical wavelengths. $12^\circ \times 6^\circ$ FoV
- Sensitive to EAS with $E \gtrsim 10^{15}$ eV
- ≈ 1 cosmic ray expected per minute of observation
- Sensitive to energies around the knee in the cosmic ray energy spectrum



Simulated angular distributions for PBR at different EAS energies

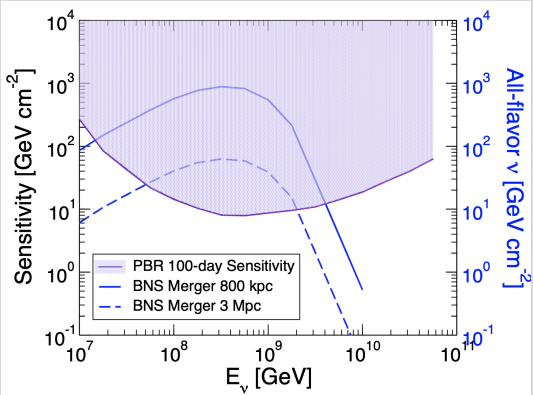
Observing Mode 3: Earth-Skimming ν_τ Observations



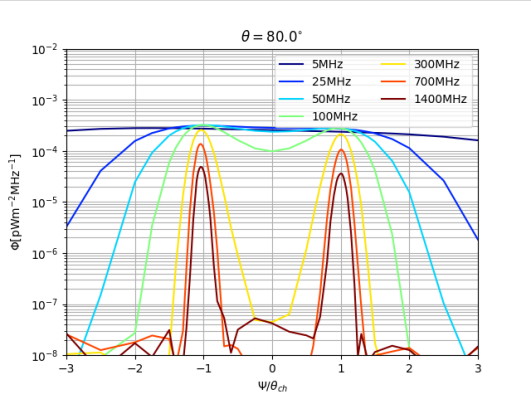
- **Telescope pointing near horizontal, below the limb of the Earth**
- Sensitive to showers induced by τ created by a ν_τ interacting in the Earth's crust
- Expected ≈ 0 events per flight from diffuse cosmogenic background
- Fluoresnce camera has some sensitivity to UHECRs in this observing configuration

Astrophysical transient Targets of Opportunity

- Integrated exposure is not competeitve with ground based experiments that can run for years
- Instantaneous exposure is larger than most ground based detectors due to the nature of the observation
- Ability to point detector enables follow up of astrophyiscal transient events, including BNS mergers, GRBs, etc.

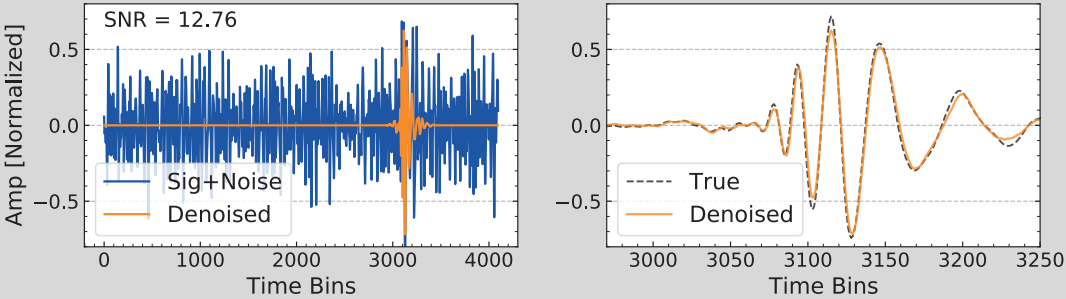


Simultaneuos Radio and Optical Measurements



- Optical measurement is degenerate in distance from shower axis and shower energy
- POEMMA breaks this degeneracy with two eyes observing the shower
- Radio spectrum contains information about distance from the shower axis
- Combining with optical measurements leads to a better constraint on the shower energy shower direction (azimuth) and potentially shower maximum

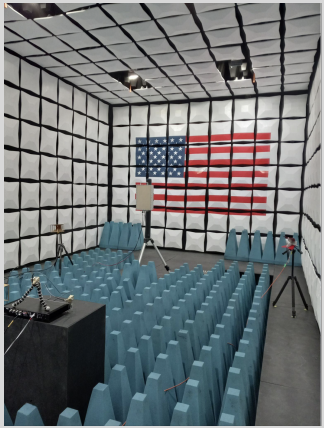
Radio Denoising



Machine learning based techniques developed for identifying faint signals. Example above for IceTop Enhancement Prototype. More details in F. Schroeder's talk on Thursday.

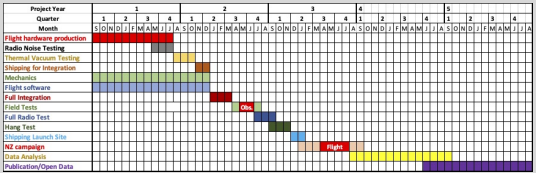
Radio Noise from the rest of Payload

- Much of payload designed without radio noise in mind
- Mitigation planned including absorbing fabric around main telescope
- Motors needed for rotation planned to operate with radio instrument turned off
- Pre-flight measurements planned using anechoic chambers



Current Status

- Awaiting results of funding proposal
- Design well underway
- Proccurment of components and prototyping has begun
- 2027 flight application submitted



Proposed schedule to begin September 2024

Summary

- POEMMA Balloon with Radio is a proposed ultra-long duration stratospheric balloon mission with a targeted launch of 2027
- PBR will aim to measure cosmic rays via fluorescnce and optical Cherenkov and search of astrophyiscal ν_τ
- Hybrid focal surface (MAPMTs and SiPMs) will prototype instrumentation for POEMMA
- Novel technique of simultaneuos measurements of the radio and optical Cherenkov compnent of EAS will help constrain shower characteristics

Thank you for your attention