

POEMMA Balloon with Radio

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POEMMA-Balloon with Radio (PBR)

Ultra-High-Energy
Cosmic Rays
(UHECRs)
UV Fluorescence

High Altitude Horizontal
Airshowers (HAHAs)
Optical+Radio

Cosmic Rays $E > \text{PeV}$

Cherenkov Emission

EAS

Tau Neutrino
Optical+Radio

Tau lepton decay

Tau Neutrino

Atmosphere

EAS

Southern Ocean

Heritage: from balloons toward space

- ▶ PBR builds on a decade of JEM-EUSO fluorescence-detector flights:
 - ▶ EUSO-Balloon (2014, Timmins) and EUSO-SPB1 (2017, Wanaka)
 - ▶ EUSO-SPB2 (2023, Wanaka) – fluorescence + Cherenkov telescopes
 - ▶ PBR (Wanaka, targeted 2028) adds pointing optics and a radio detector
 - ▶ Working towards an eventual orbital detector (such as POEMMA)



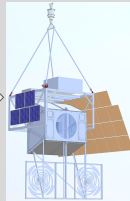
2014



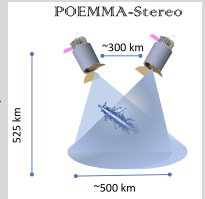
2017



2023



2028*



Future

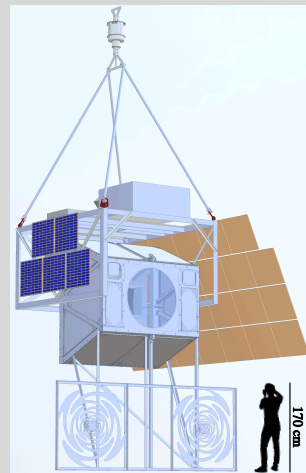
Mission & payload

Flight

- ▶ Super Pressure Balloon (18.8 MCF), >20-day flight
- ▶ ~3000 lb (1360 kg) science payload
- ▶ Pointing: 360° azimuth, nadir to 10° above horizon
- ▶ Southern mid-latitude flight – recovery not guaranteed

Instrument

- ▶ 1.1 m Schmidt telescope, hybrid focal surface
- ▶ Fluorescence Camera (FC) – UHECRs, $E \gtrsim 10^{18}$ eV
- ▶ Cherenkov Camera (CC) – VHECRs & ν , $E \gtrsim 10^{15}$ eV
- ▶ Radio Instrument – 60–500 MHz
- ▶ Ancillary detectors and instruments



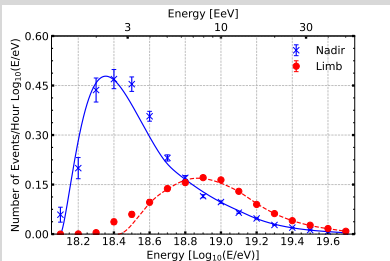
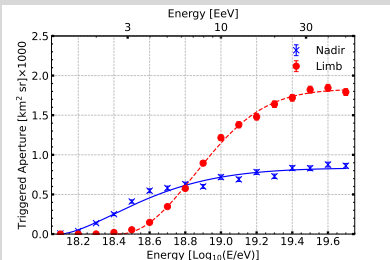
Fluorescence Camera

- ▶ Hybrid focal surface shared with the Cherenkov Camera
- ▶ **Microsecond** time sampling (GTU $\approx 1 \mu\text{s}$) – images the fluorescence track
- ▶ Multi-anode photomultiplier tubes
 - ▶ Single photon counting
- ▶ 9,216 total channels
- ▶ 4th generation instrument
 - ▶ Extensive flight heritage

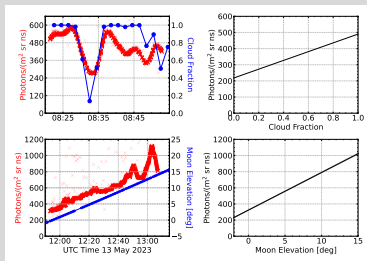
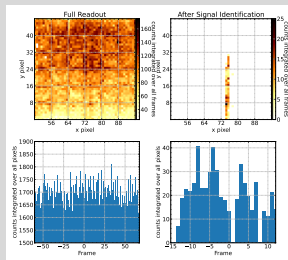


PBR simulated performance

JCAP 07 (2026) 001



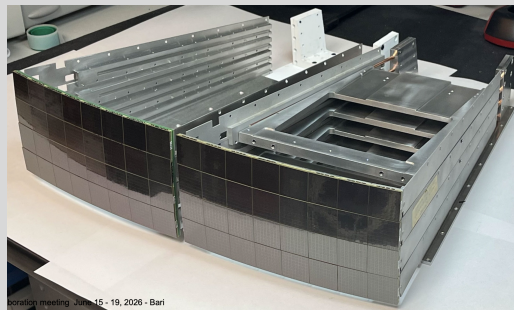
EUSO-SPB2 data



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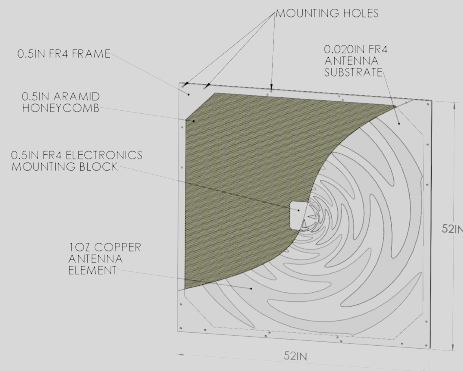
Cherenkov Camera

- ▶ SiPM focal surface for fast Cherenkov signals
- ▶ **Tens-of-nanosecond** integration
- ▶ 2,048 total channels
- ▶ Builds off experience of EUSO-SPB2
 - ▶ Heavily modified electronics
 - ▶ Custom ASIC + FPGA readout
- ▶ Bi-focal triggering to reject background signals



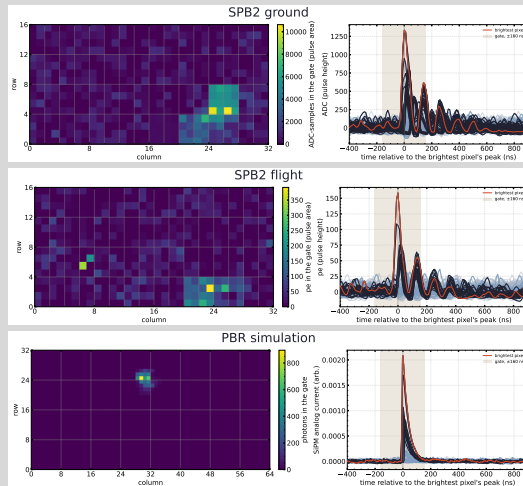
Radio Instrument

- ▶ Two dual-polarization sinuous antennas
 - ▶ 60–500 MHz band
- ▶ Built off of the PUEO low frequency instrument
 - ▶ Successful Antarctic flight in 2025–2026
- ▶ Enables hybrid optical + radio measurement of horizontal air showers and tau-neutrino showers
 - ▶ First of its kind measurement
- ▶ Verifies neutrino signal, constrains primary shower parameters



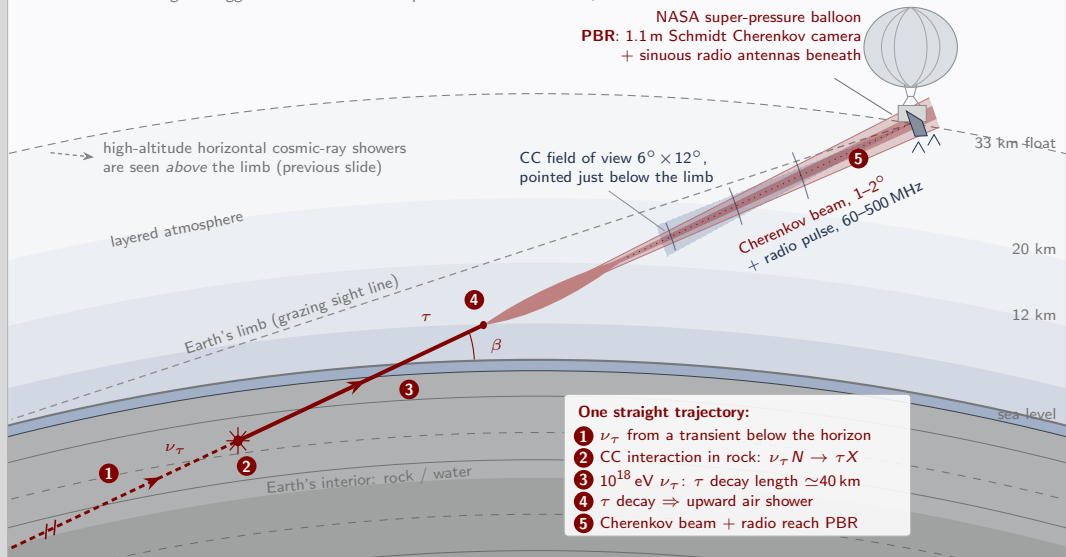
High-altitude horizontal air showers

- ▶ Near-horizontal showers develop high in the rarefied atmosphere, viewed above the Earth's limb
- ▶ Beamed Cherenkov light gives a **tens-of-ns** pulse confined to a few pixels
- ▶ Same optical signature as a τ -lepton shower from an Earth-skimming ν_τ – validates the neutrino search
- ▶ EUSO-SPB2 recorded such events both on the ground and in flight (2023)
- ▶ Possible mass sensitivity around the knee in the CR energy spectrum



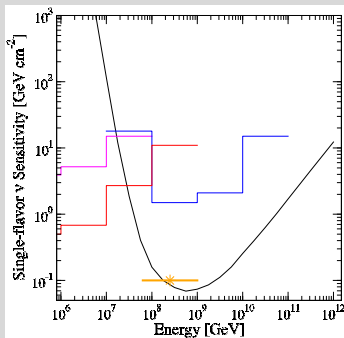
Vertical scale and angles exaggerated: the true limb depression at 33 km is 5.8° , not the $\sim 18^\circ$ drawn.

NASA super-pressure balloon
PBR: 1.1 m Schmidt Cherenkov camera
+ sinuous radio antennas beneath

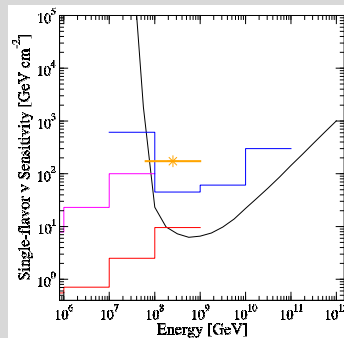


Neutrino sensitivity

1000-s ToO burst



20-day dark-sky observation

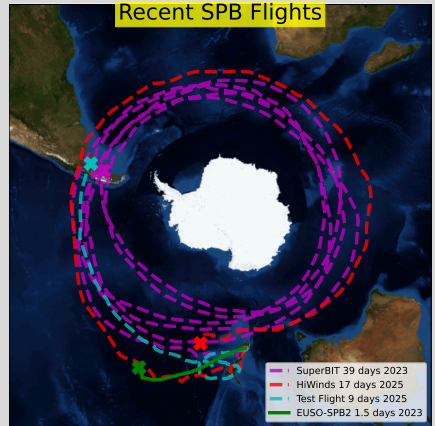


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Single-flavor 90% CL ν_τ sensitivity of PBR. Orange: modeled fluence for a burst of BSM messengers as a possible explanation for KM3-230213A-like events. Upper limits from IceCube (red), Auger (blue) and ANTARES (magenta).

Summary

- ▶ PBR is a novel payload with ambitious science goals
- ▶ Attempting first-of-its-kind measurements requires an innovative design
- ▶ All major subsystems built and tested; integration is well underway
- ▶ (Ultra)Long-duration flight from Wanaka, New Zealand targeted for 2028
- ▶ More details available in the design paper (J. Adams et al. JCAP07(2026)001)



Acknowledgements

8 countries · 43 institutions · 123 members

The PBR team, part of the JEM-EUSO Collaboration

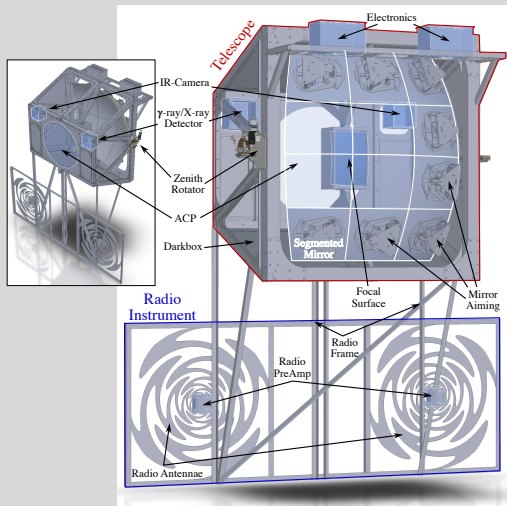
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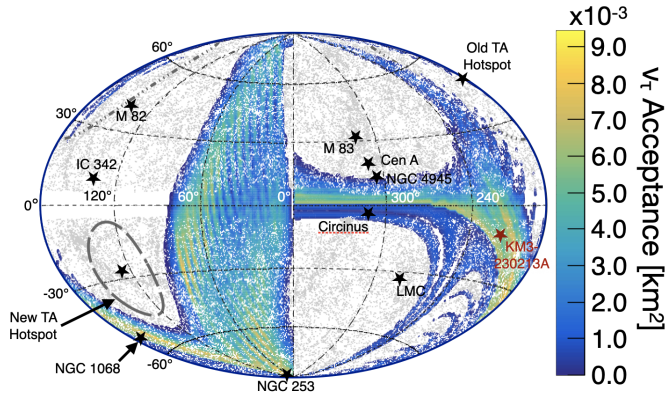
Thank you!

Extras

The instrument in detail



PBR sky coverage



ν_T acceptance at 10^9 GeV in Galactic coordinates

20-day flight following historical wind patterns, launched April 6, 2027 (new moon)

Black stars: nearby sources and TA hotspots; red star: KM3-230213A

PoS(ICRC2025)980

FC Aperture estimation

- ▶ Sampled over a 100 km disk
- ▶ 0° – 80° zenith
- ▶ 100,000 showers per energy
- ▶ Iron, oxygen, helium and protons
- ▶ Weighted by the composition measurements of Auger
- ▶ Converted to an expected event rate via the Auger spectrum

