



POEMMA-Balloon with Radio, towards a space-based Multi- Messenger Observatory

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for the JEM-EUSO Collaborations

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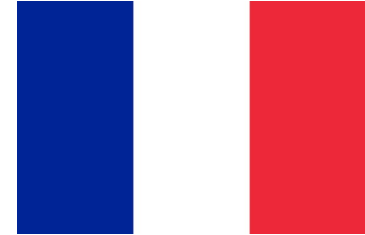
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³Colorado School of Mines

⁴INFN Napoli



The PBR team

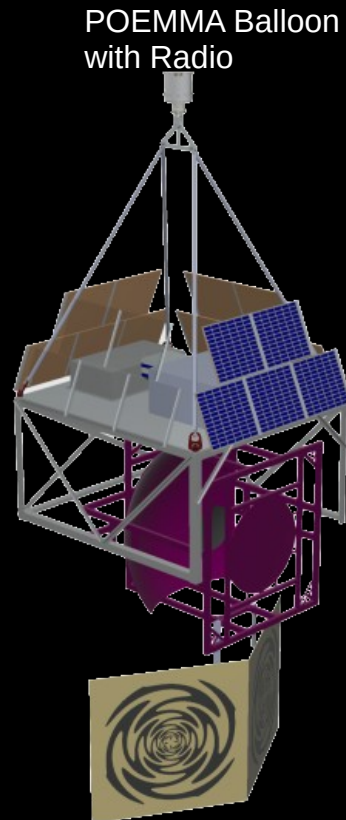
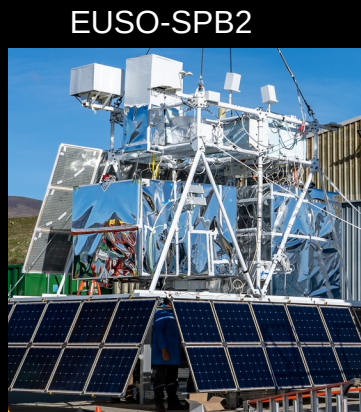


8 Countries
26+ Institutions
60+ Members





Progression



POEMMA-Balloon with Radio (PBR)

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

High Altitude Horizontal
Airshowers (HAHAs)
Optical+Radio

Tau Neutrino
Optical+Radio

UHECR

Cosmic Rays $E > \text{PeV}$

Cherenkov Emission

EAS

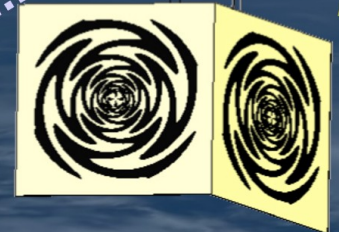
Atmosphere

EAS

Tau lepton decay

Tau Neutrino

Southern Ocean





PBR Science Goals



- **Science Goal 1**

Observe, for the first time, the fluorescence emission of EASs produced by UHECRs from sub-orbital altitudes

- **Science Goal 2**

Observe a large number of high-altitude horizontal air-showers (HAHAs)

- **Science Goal 3**

Search for astrophysical neutrinos from a Target-of-Opportunity (ToO) following multi-messenger events

- Raise Technical Readiness Level of major components to Level 6 as required for probe class space missions



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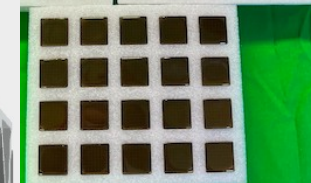
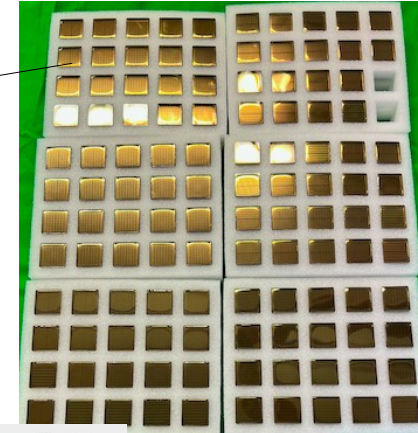
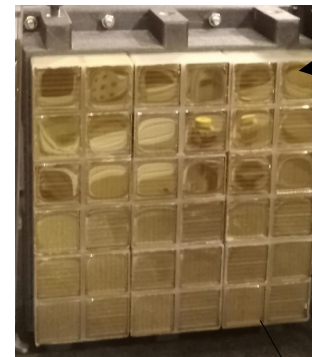
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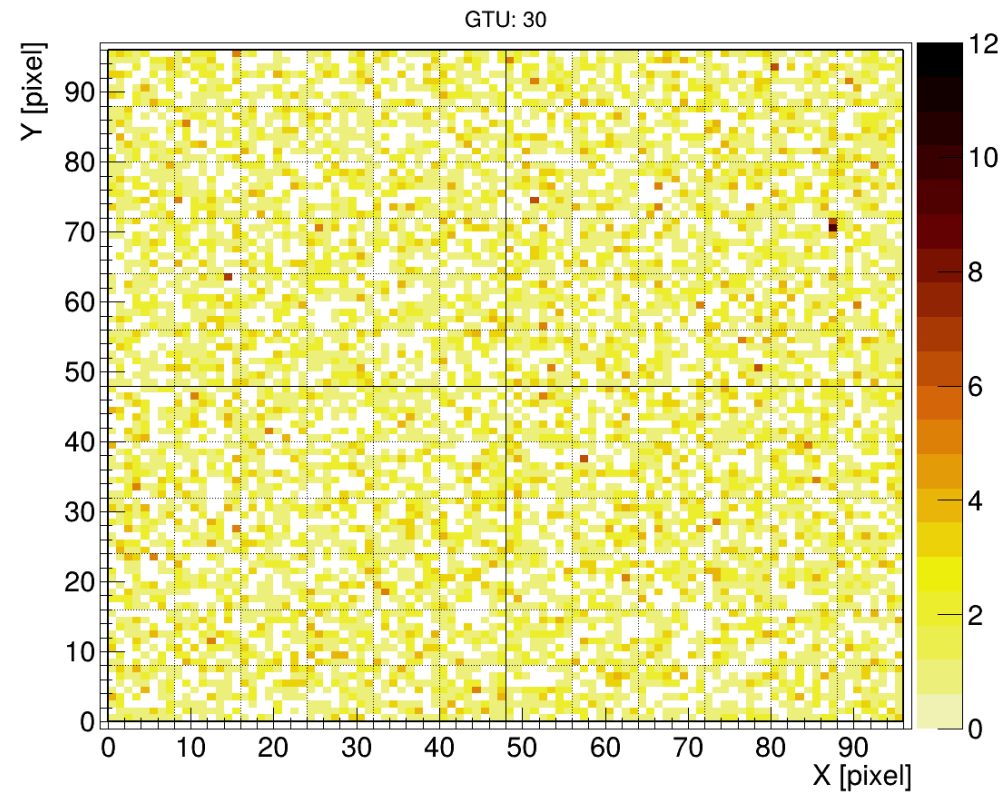
- Optimized for EAS detection via fluorescence (UHECR)
- 4 Photo Detection Modules with 2304px each (MAPMTs): **9216px**
- 24x24° FoV
- 290-430nm detection window (BG3 filter)
- Dual **photon counting** and **charge integration** digitization
- Integration time of **1 μ s**, 128 frame readout
- PDMs triggered independently, readout in parallel

EUSO-SPB2 PDM



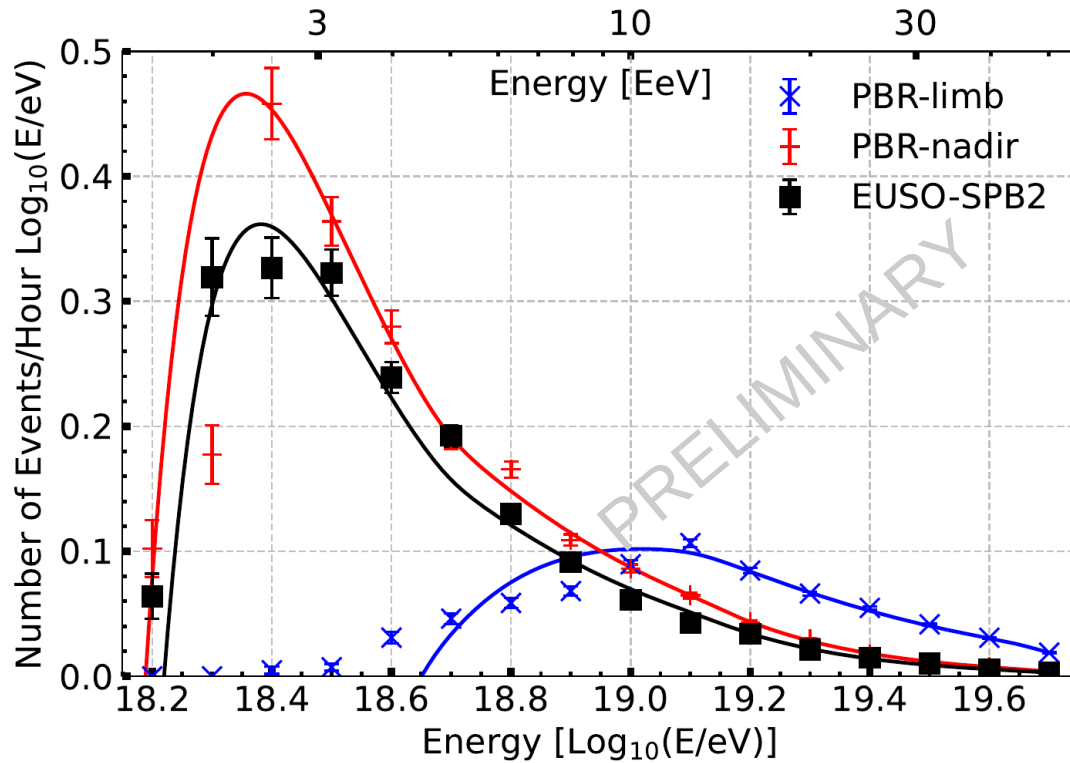


UHECR observation (FC)



- p-shower with energy 20EeV and zenith angle of 57°

UHECR observation (FC)



Nadir

- Event rate: 0.23 evt/h (1.15 per night)
- Energy threshold (Peak): 1.8EeV (2.2EeV)

Limb

- Event rate: 0.07 evt/h (0.35 per night)
- Energy threshold (Peak): 4EeV (~10EeV)



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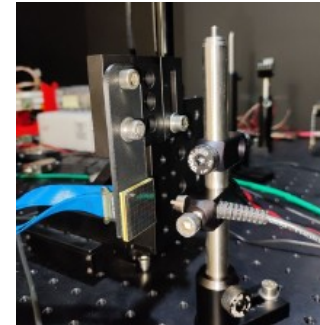
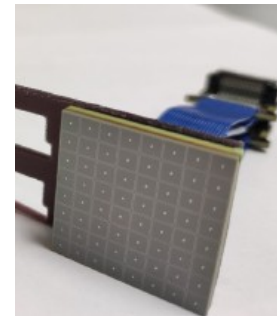
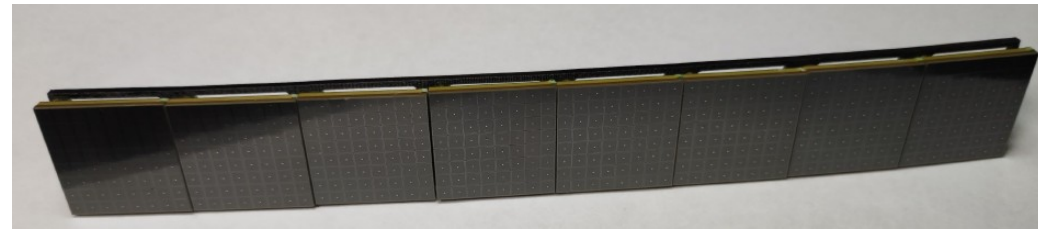
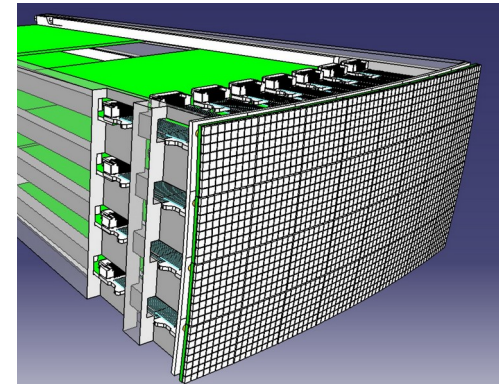


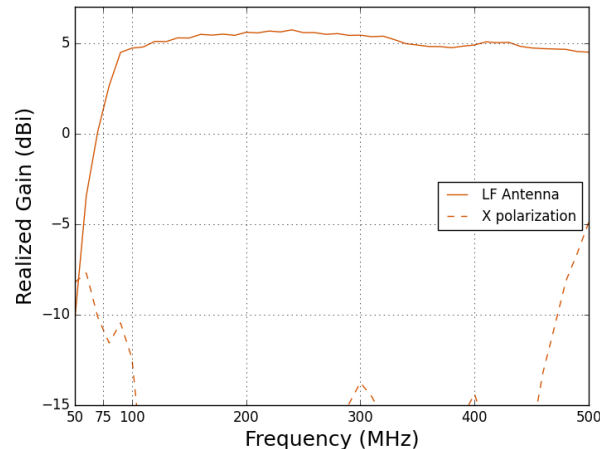
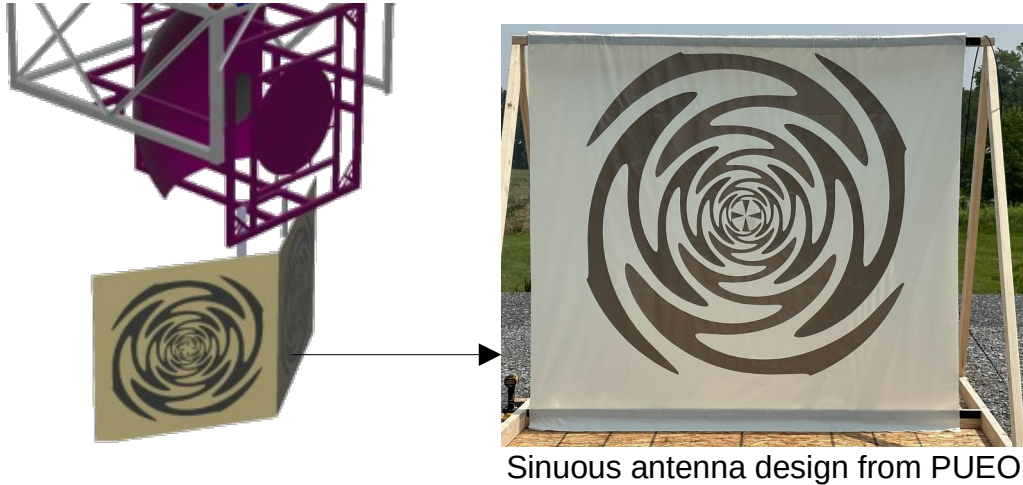
The Cherenkov Camera (CC)



- Optimized for EAS detection via cherenkov (VHEN and CR)
- 4 rows of 8 SiPM matrices
- 8x8 channels per SiPM with 3x3 mm pixel size: **2048 pixels**
- Pixel FoV: 0.2°
- Field of view: 12° (h) x 6° (v)
- Sampling frequency of **5ns**
- Wavelength range 320 - 900nm
- Bi-focal optics for a better background rejection

PBR CC Design

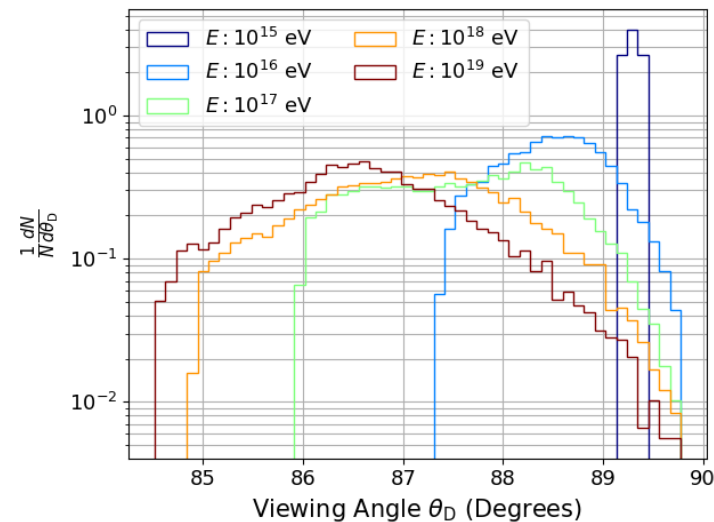
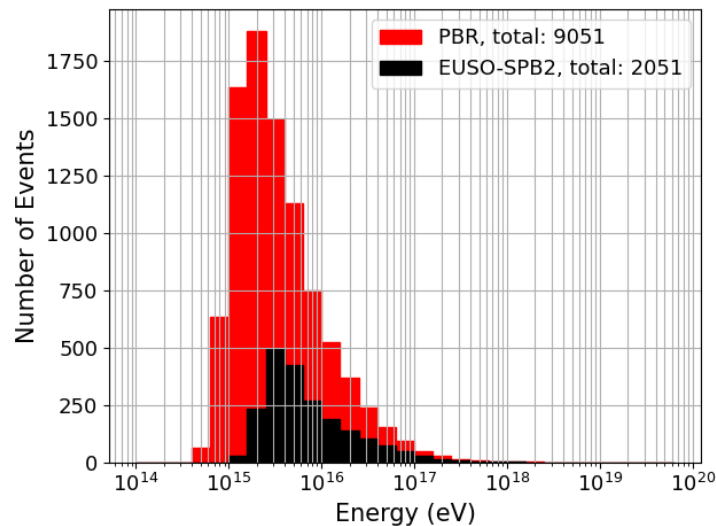
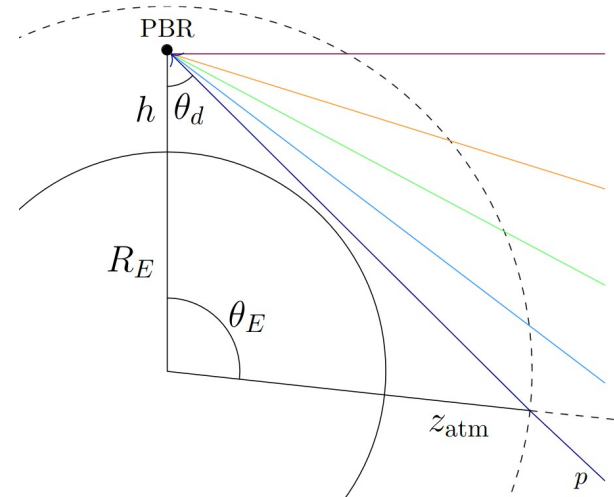




- Two 2 by 2m dual-polarized Sinuous antennas
- Based on PUEO-LF instrument
- Frequency range: 50-500MHz
- 60 x 60deg field of view
- Overlapping with CC
- Canted at 120° from one another
- Expected energy threshold $E > 10^{18} \text{eV}$
 - Forced trigger same threshold as CC



HAHAs observation (above the limb)



By A. Cummings

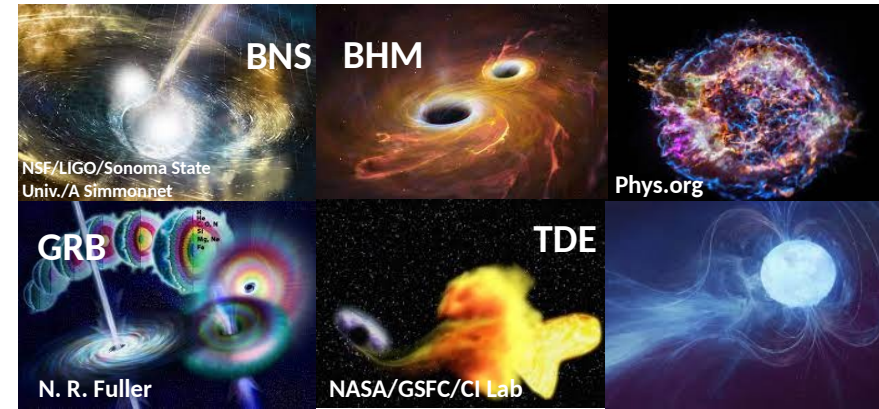
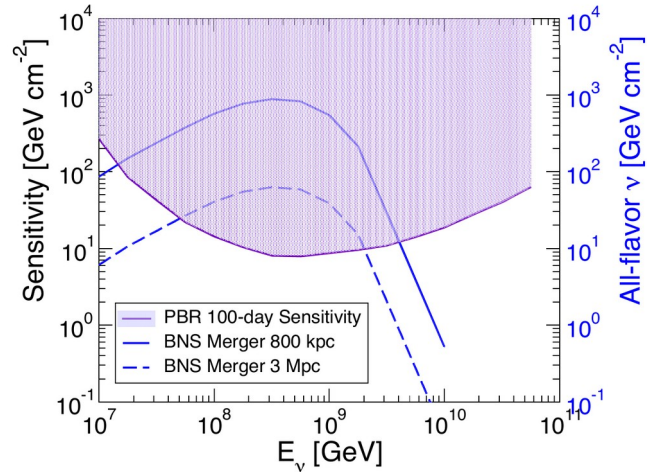
- Guaranteed signal with significant statistics (similar signature to neutrino event)
- Simulation study using EASCherSim*
- Energy threshold of 0.4 PeV (max sensitivity 2PeV)
- Angular acceptance is energy dependent
 - Geometric energy filter

➔ ~60+ events/h

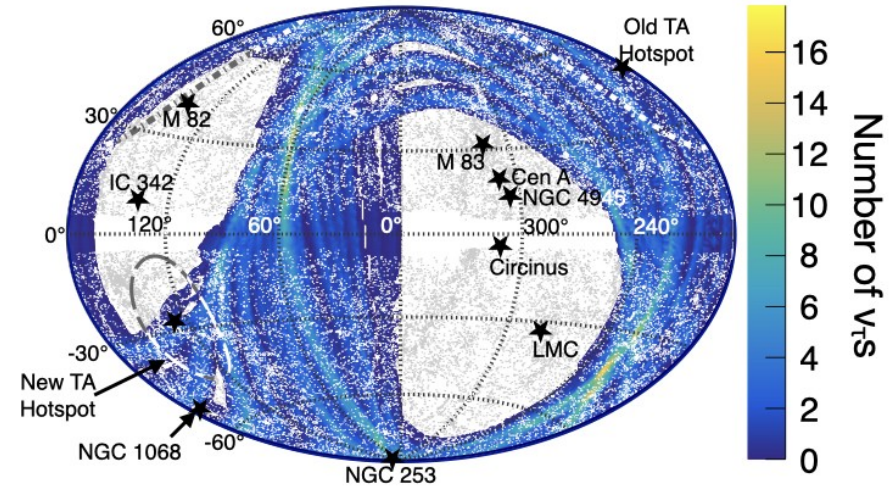
*<https://gitlab.com/c4341/easchersim>

ToO observation (below the limb)

- PBR has very limited sensitivity to diffuse neutrino flux, but can observe transients by pointing (similar to POEMMA and EUSO-SPB2)



- Models are fluences (integrated over time)
- Accounting for Sun/Moon effect but no balloon motion currently
- Flight date of Apr 6 2027 (realistic launch date)



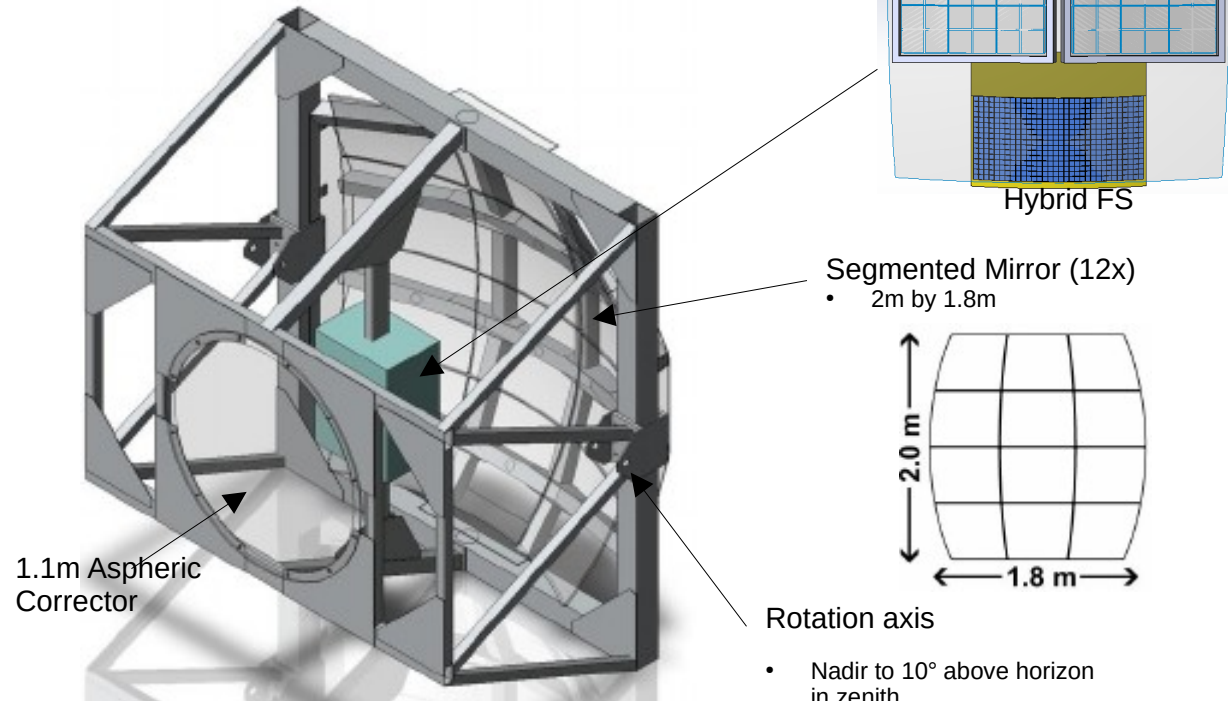
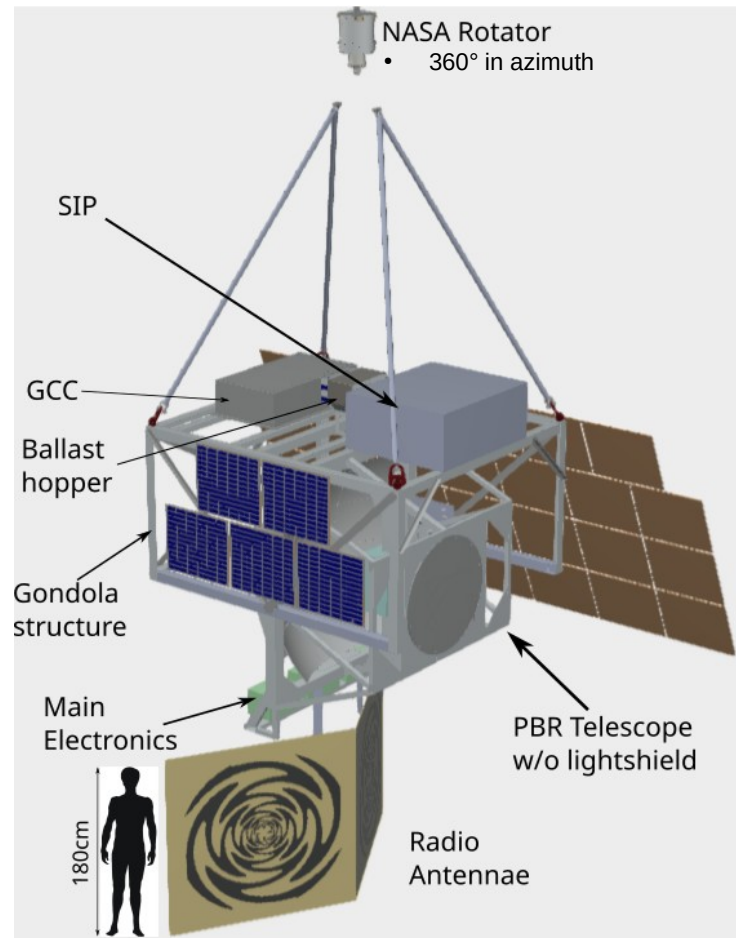
By T. Venters



PBR Instrument



- 3000lbs of science
 - 1.1m diameter Schmidt Optic Telescope
 - 2 radio antennas
 - IR Camera & γ /X-Ray/Particle Detector



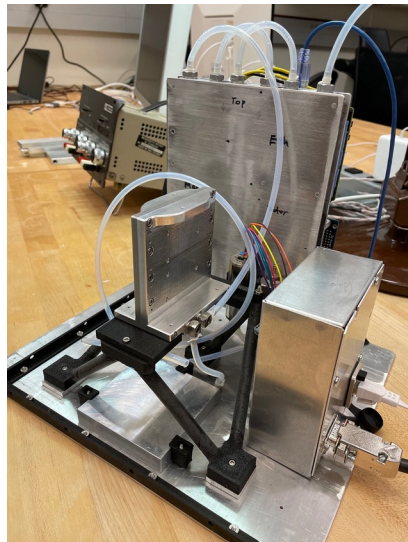
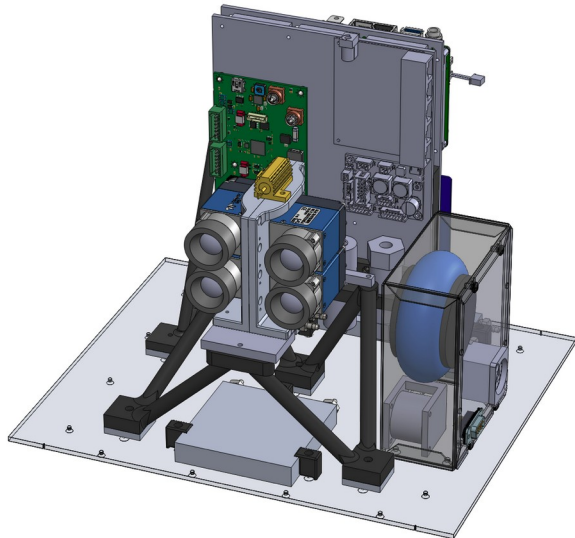


IR Camera & γ /X-Ray/Particle Detector



UCIRC 3

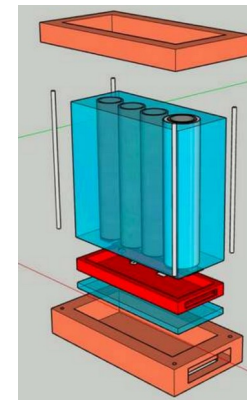
- Observing cloud coverage in telescope FoV
- 4 cameras
 - 9, 10.5 and 12.5 micron bands
 - Unfiltered 8 to 14 microns



γ /X-Ray/Particle Detector

- X-ray measurements (10 - 300 keV)
 - Significant geometry factor for the PBR instruments to be within the EAS cascade development: unique shower measurements
- Gamma detector (0.1 – 4 MeV)
 - TLEs, ToO, GRBs
- Charged particles
 - Particle correlation for CC and FC (part of EAS, ToO)

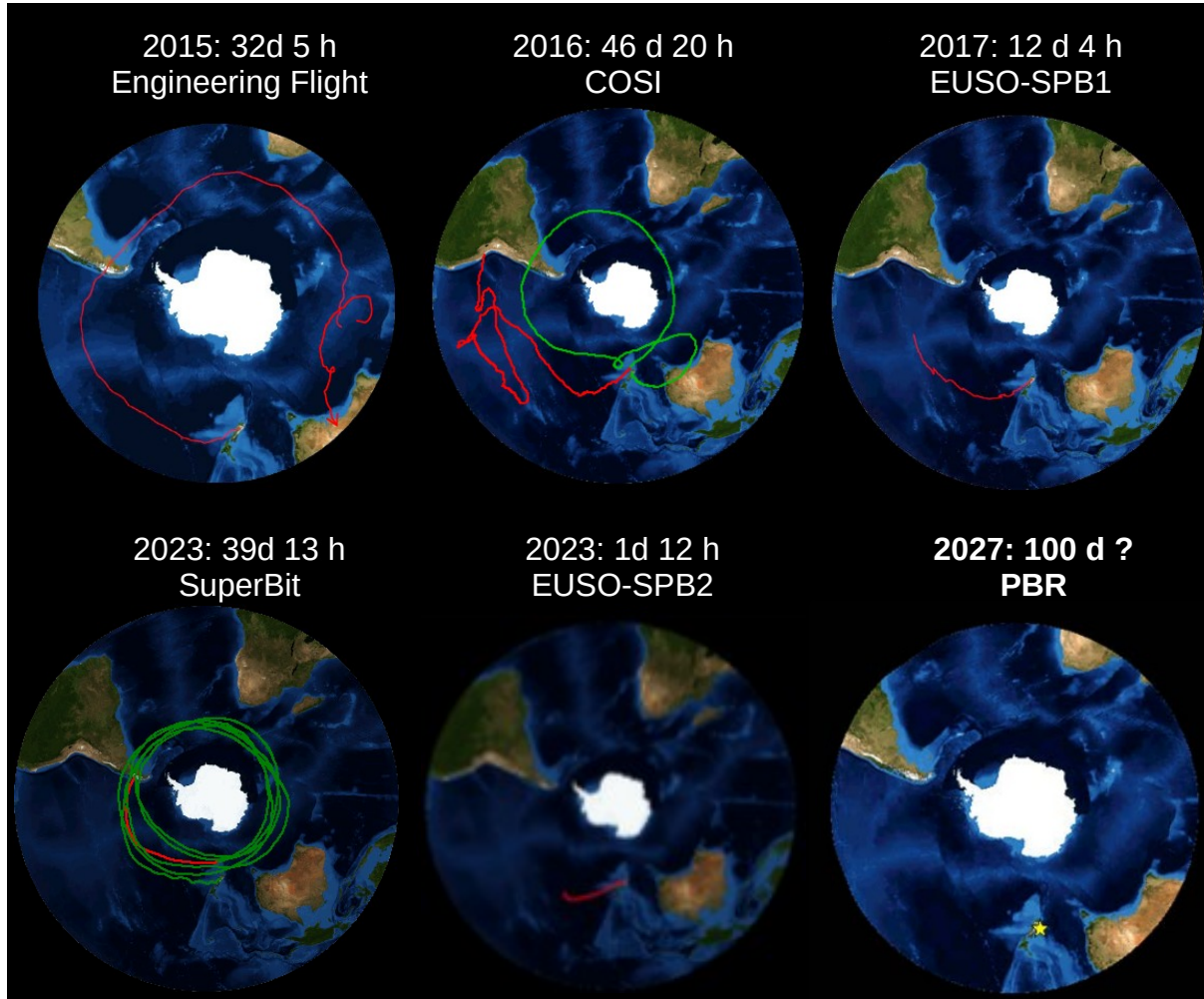
CsI scintillation detector + SiPM (Gamma)
SiPM with crystal (X-ray)





The Mission

- Payload of NASA **SPB** with launch from Wanaka, NZ
- Target date: Spring, **2027**
- Up to **100 days** flight
 - 500h of operation (~20% duty cycle)
 - Min 14 days (70h)





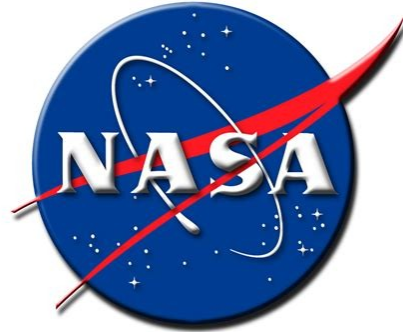
Summary & Conclusion



- POEMMA Balloon (PBR) is the **successor** of the **EUSO-SPB2** mission and an advanced **precursor** of the dual satellite mission POEMMA
- Preparations have started for a launch from Wanaka, NZ **2027**
- Goals:
 - UHECR observation from above
 - Observation of High Altitude Horizontal Air-shower (HAHAs)
 - Neutrino search from Target of opportunity
 - First combined observation of optical Cherenkov and radio signal
 - Raise TLR for POEMMA (first hybrid focal surface)



Acknowledgments



The authors would like to acknowledge the support by NASA award 80NSSC22K1488 and 80NSSC24K1780, by the French space agency CNES and the Italian Space agency ASI. The work is supported by OP JAC financed by ESIF and the MEYS CZ.02.01.01/00/22_008/0004596. We acknowledge the NASA Balloon Program Office and the Columbia Scientific Balloon Facility. We also acknowledge the invaluable contributions of the administrative and technical staffs at our home institutions.