



# The High-Altitude View of the Most Extreme Phenomena in the Universe

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COLUMBIA UNIVERSITY  
IN THE CITY OF NEW YORK

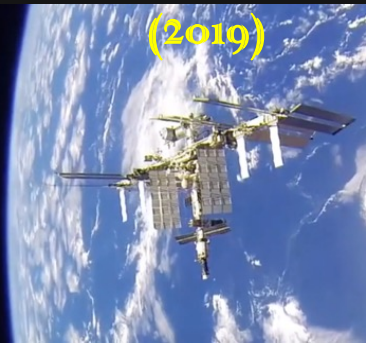
# POEMMA-Balloon + Radio

POEMMA = Probe Of Extreme Multi-Messenger Astrophysics

EUSO = Extreme Universe Space Observatory

**Mini-EUSO**

(2019)



**EUSO-Balloon**

(2014)



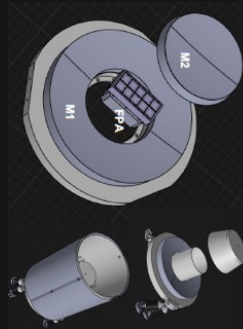
**EUSO-SPB2**

(2023)



**Terzina**

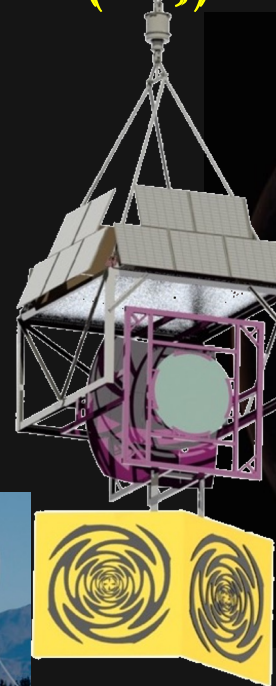
(2026)



**POEMMA-Balloon**

**+ Radio (PBR)**

(2027)



**POEMMA**

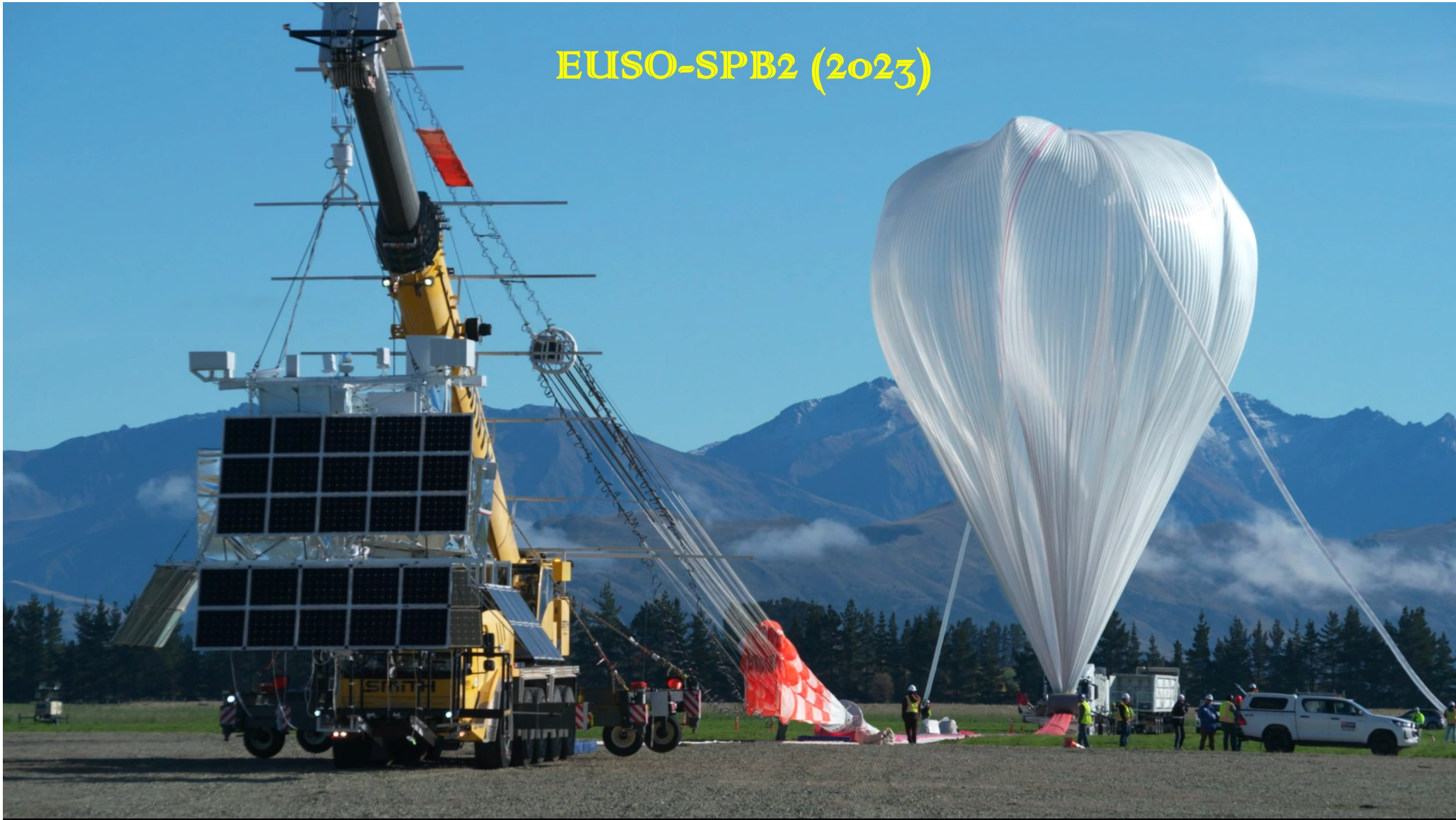


**EUSO-SPB1 (2017)**





# EUSO-SPB2 (2023)





# 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 Neutrino

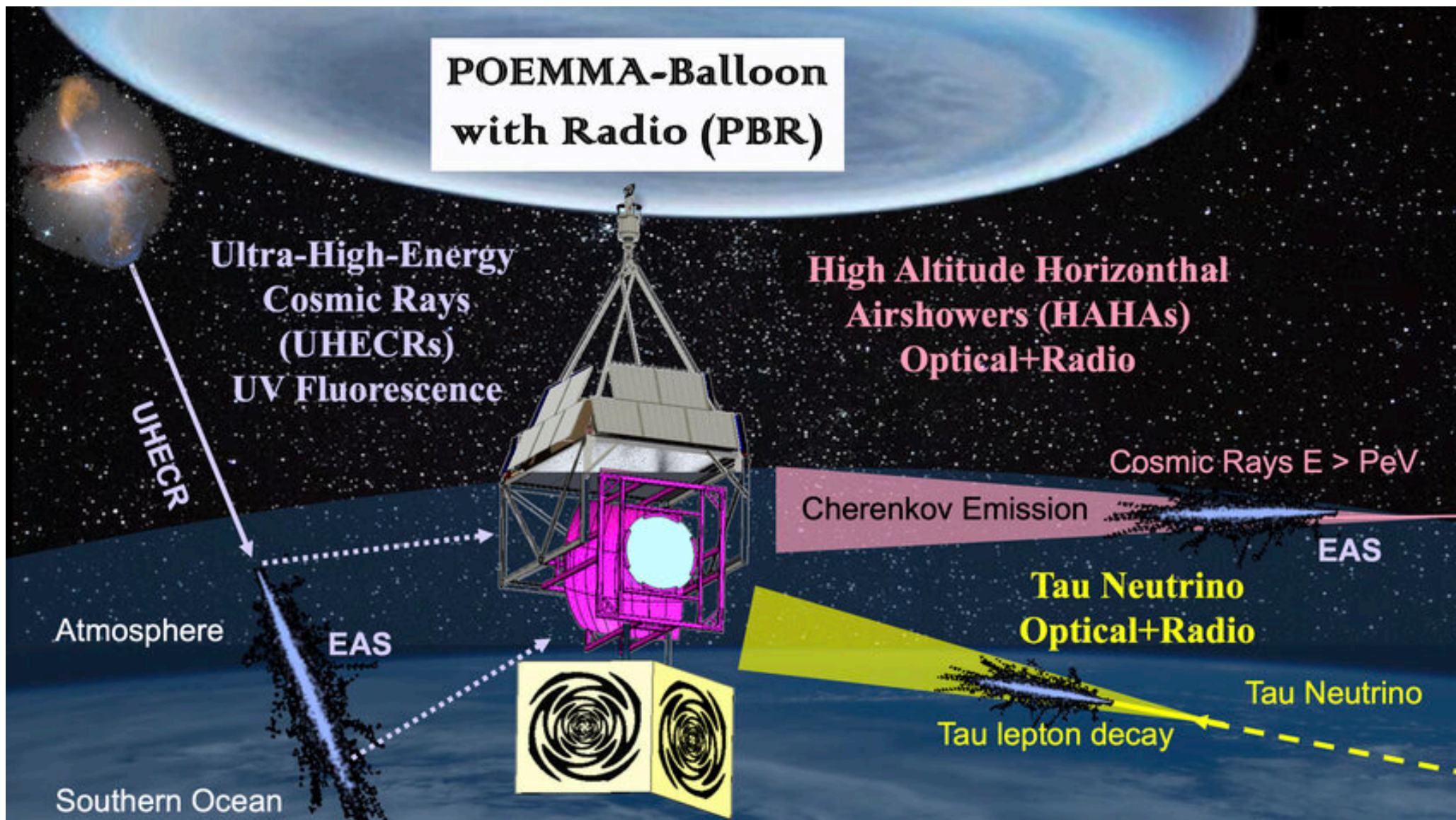
Tau lepton decay

UHECR

EAS

Atmosphere

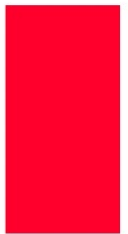
Southern Ocean





# The PBR team

- Part of the JEM-EUSO collaboration
- Summary
  - 89 Members
  - 27 Institutions
  - 8 Countries

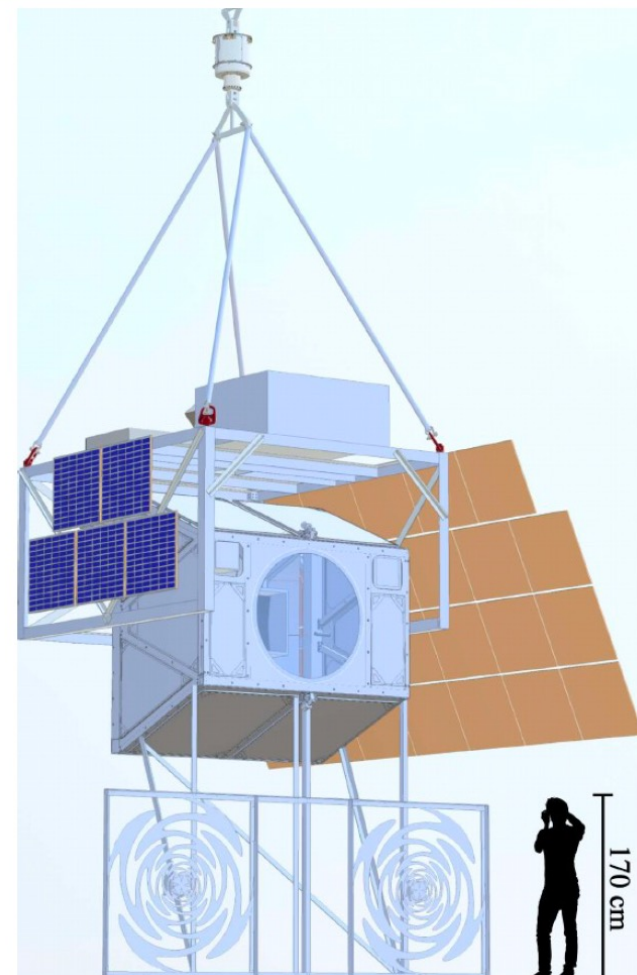






# PBR Instrument

- Payload of NASA **SPB** with launch from Wanaka, NZ
- Target date: Spring, **2027**
- Flight duration: more than **20 days**
- 3000lbs of science
  - 1.1m diameter Schmidt Optic Telescope with Hybrid focal surface
  - 2 radio antennas
  - 1 IR Camera (cloud monitoring)
  - 1  $\gamma$ /X-Ray detector (early shower development)
- Pointing:
  - 360° in azimuth via NASA provided rotator
  - Nadir to 10° above horizon in zenith

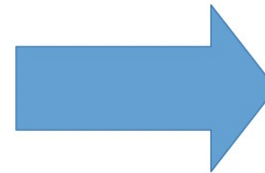
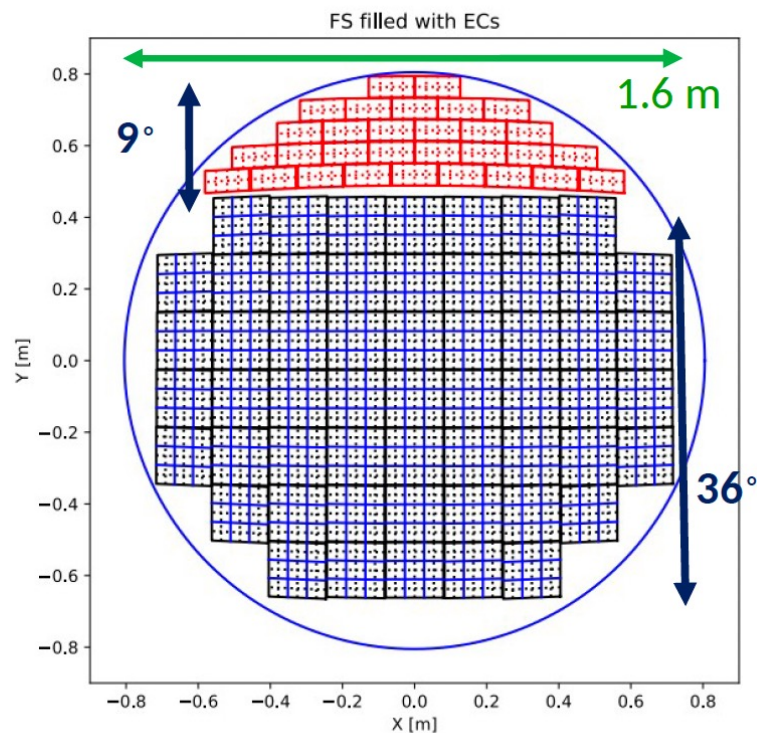




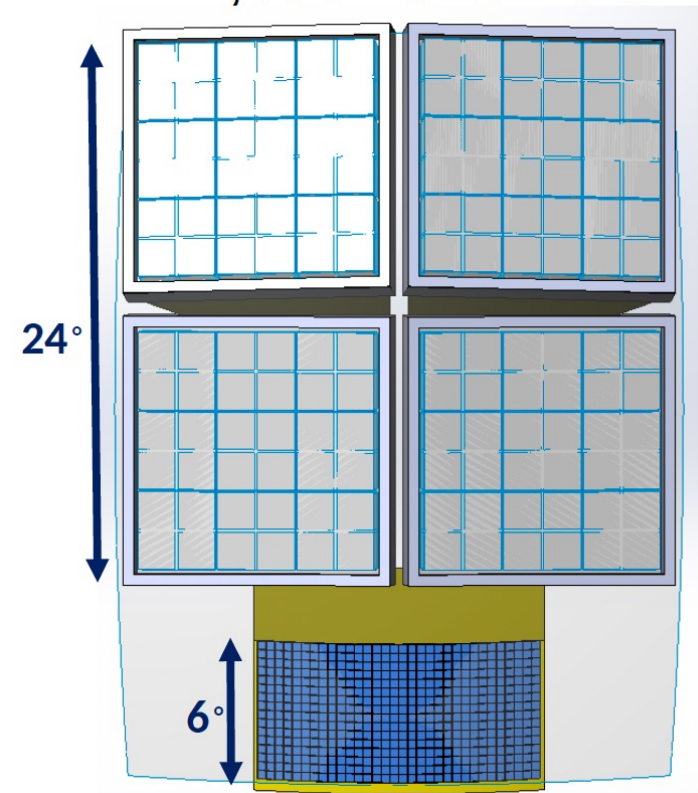
# Hybrid Focal Surface

- Down scale (~8%) design of POEMMA's FS

140,000+ channels



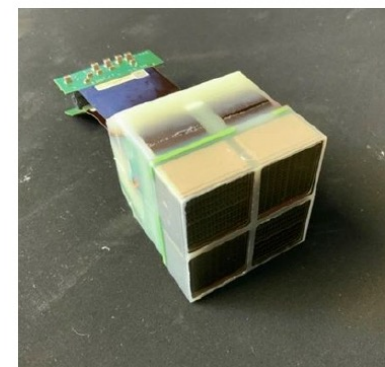
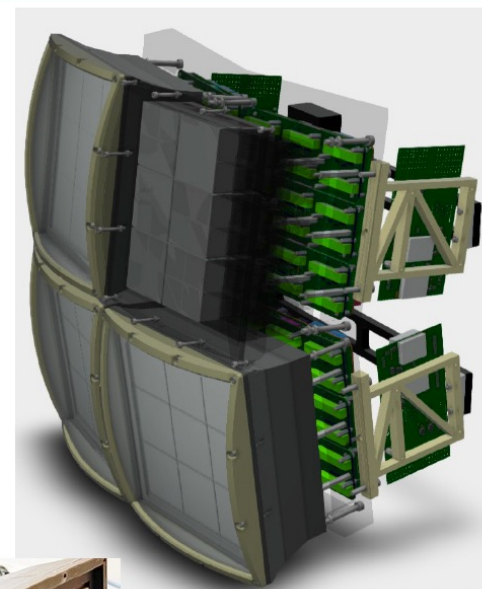
11,000+ channels





# Fluorescence Camera

- Optimized for EAS detection via fluorescence (UHECR)
- 4 Photo Detection Modules with 2304px each (MAPMTs): **9216px**
- 24x24deg FoV
- 290-430nm detection window (BG3 filter)
- Integration time of **1 $\mu$ s**
- Single photo electron counting with double pulse resolution of 10ns
- Integration channel for 8 pixel available to extend dynamic range
- More details in Francesco's talk







# Hybrid Focal Surface

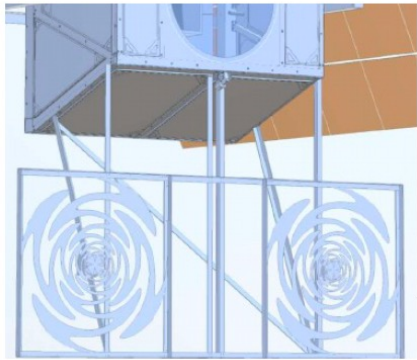


- Optimized for EAS detection via cherenkov (VHEN and CR)
- 4 rows of SiPM matrices: **2048px**
- 12x6deg FoV
- Bi-focal for event selection
- 320-900 nm detection window
- Integration time of **10ns**
- More details in Valentina's talk

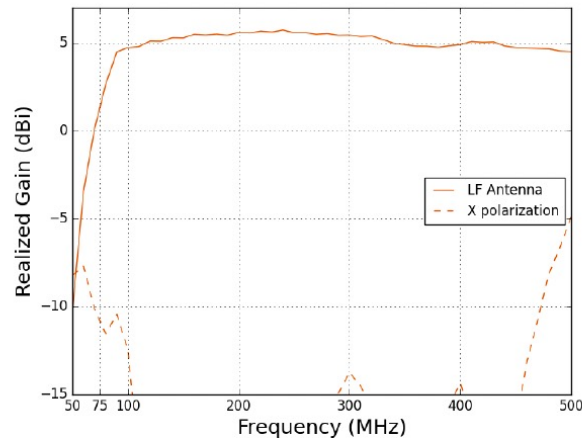




# The Radio Instrument



Sinuous antenna design from PUEO



- 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
- Expected energy threshold  $E > 10^{18}$  eV
  - Forced trigger same threshold as CC



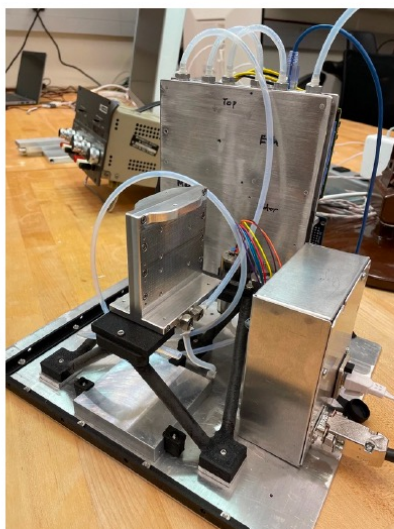
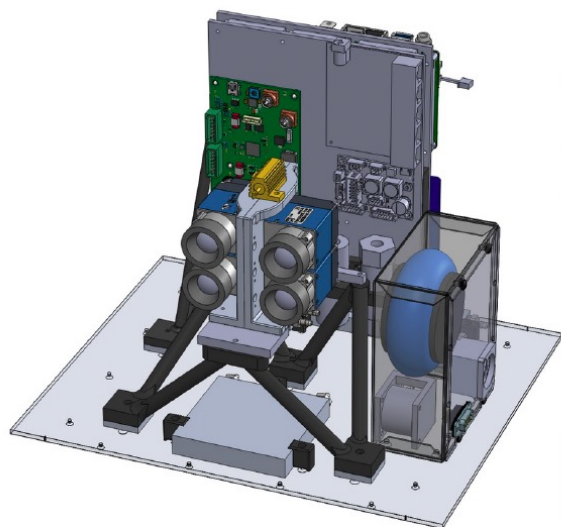


# IR Camera & $\gamma$ /X-Ray/Particle Detector



## UCIRC 3

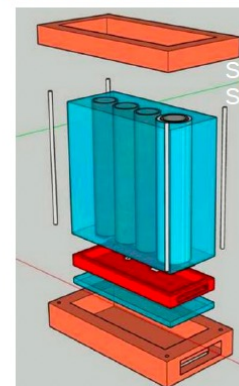
- Observing cloud coverage in telescope FoV
- 4 cameras
  - 9, 10.5 and 12.5 micron bands
  - Unfiltered 8 to 14 microns



## $\gamma$ /X-Ray/Particle Detector

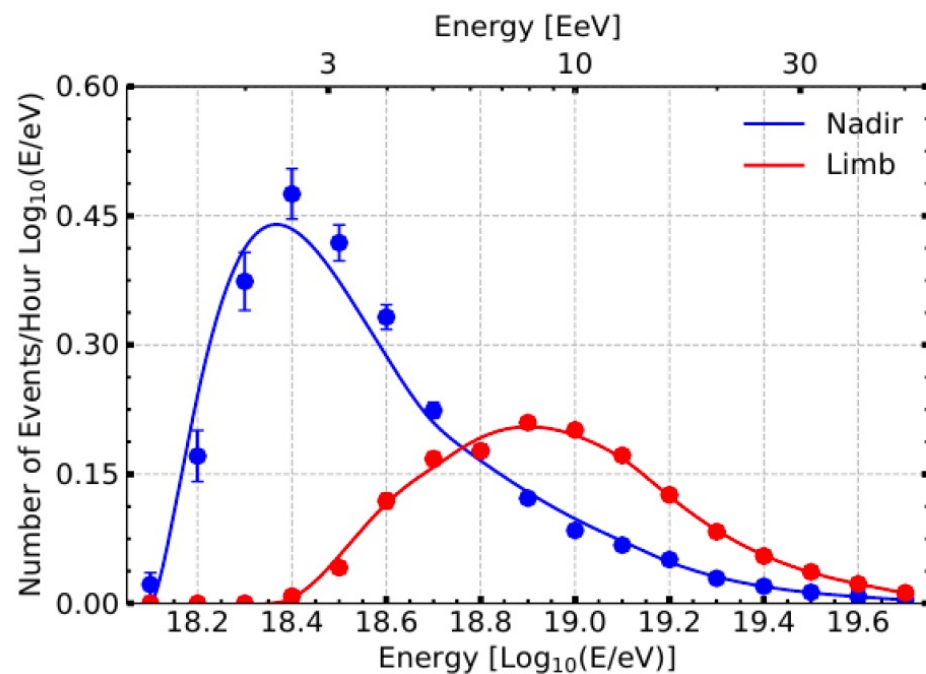
- X-ray measurements (10 - 300 keV)
  - Significant geometry factor for the PBR instruments to be within the EAS cascade development: unique shower measurements
- Gamma detector (0.1 – 4 MeV)
  - TLEs, ToO, GRBs
- Charged particles
  - Particle correlation for CC and FC (part of EAS, ToO)

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



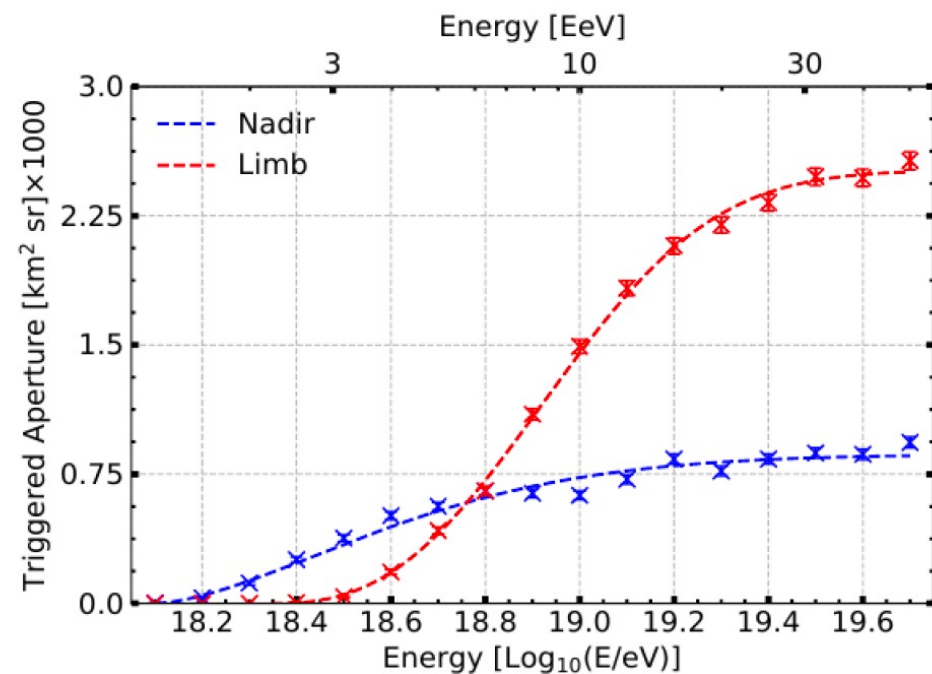


# UHECR observation



## 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)

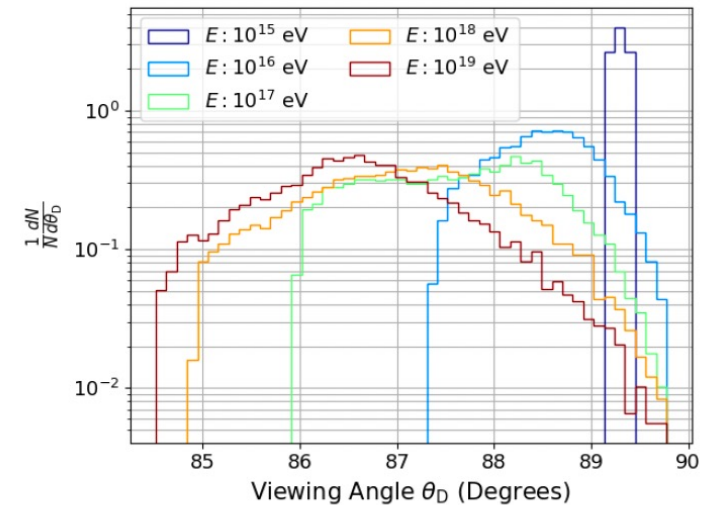
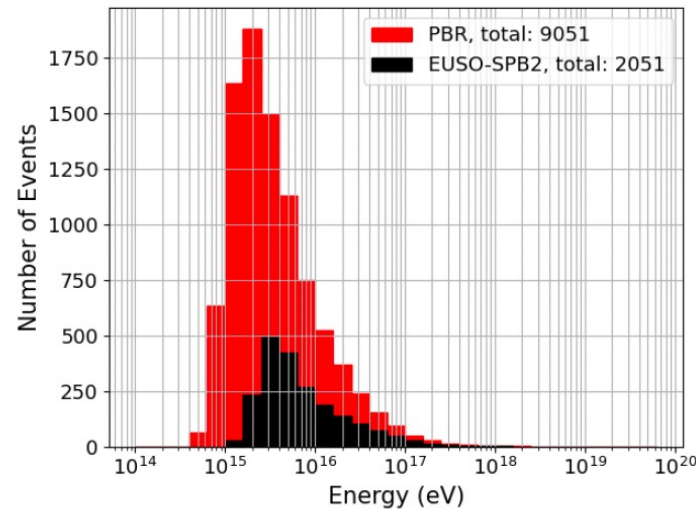
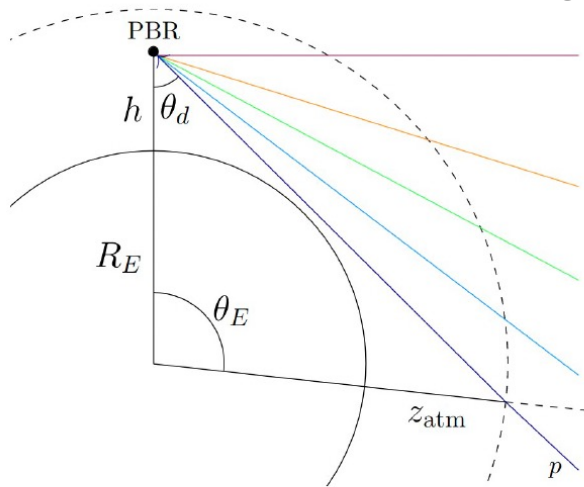




# HAHAs



## High Altitude Horizontal Air-showers - PEV Cosmic Rays



- 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

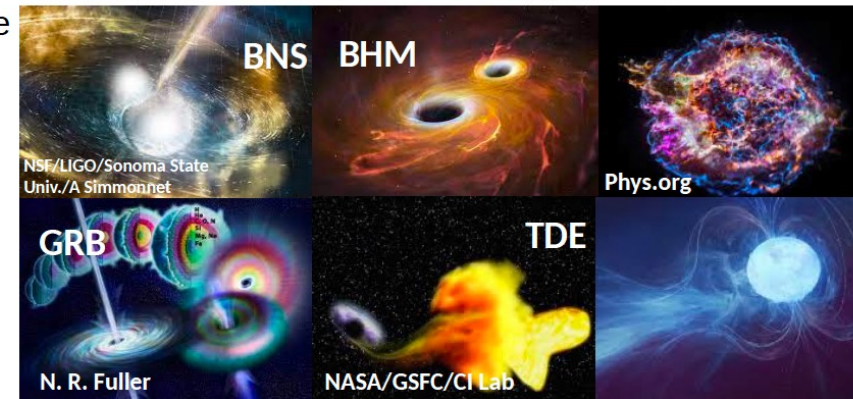
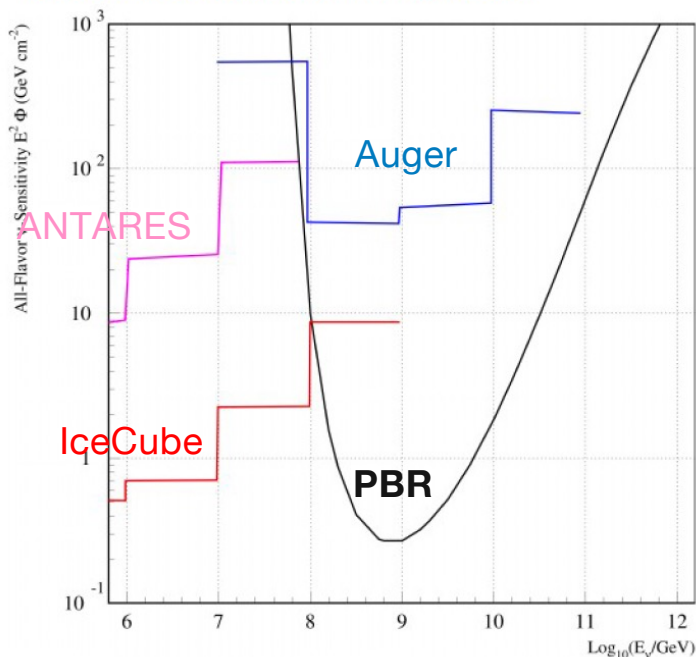
➡ **~60+ events/h**

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

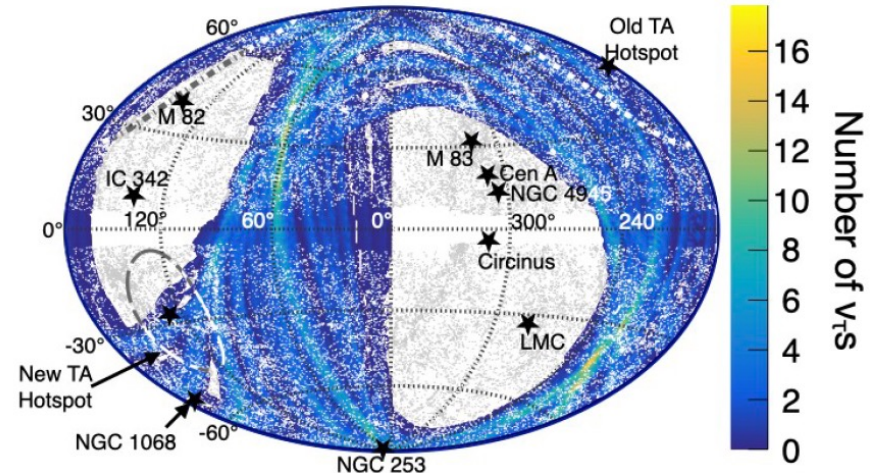


# Target of Opportunity

- PBR only very limited sensitivity to diffuse neutrino flux, BUT can observe transients by pointing
  - Galactic SN, BNS/BH/NS merger, flaring Blazar/AGNs, TDEs, GRBs, ...
  - Steady sources (e.g. TA hotspots)



- Models are fluences (integrated over time)
- Accounting for Sun/Mond effect but no balloon motion currently





# SUMMARY



- POEMMA Balloon (PBR) is the **successor** of the **EUSO-SPB2** mission and an advanced **precursor** of the dual satellite mission POEMMA or the new proposed M-EUSO
- Preparations have started for a launch from Wanaka, NZ **2027**
- First combined measurement of Cherenkov and Radio (from above)
- First UHECR observation from above via fluorescence
- Observation of High Altitude Horizontal Air-shower (HAHAs)
- Neutrino search from Target of opportunity
- Raise TLR for POEMMA/M-EUSO (first hybrid focal surface)



## The JEM-EUSO Collaboration

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*Thank You!*