

The Payload for Ultrahigh Energy Observations (PUEO)

2025-2026 Flight and Experiment Overview



Lucas Beaufore
The Ohio State University





PUEO: A Brief Introduction



Payload for **U**ltrahigh **E**nergy **O**bservations

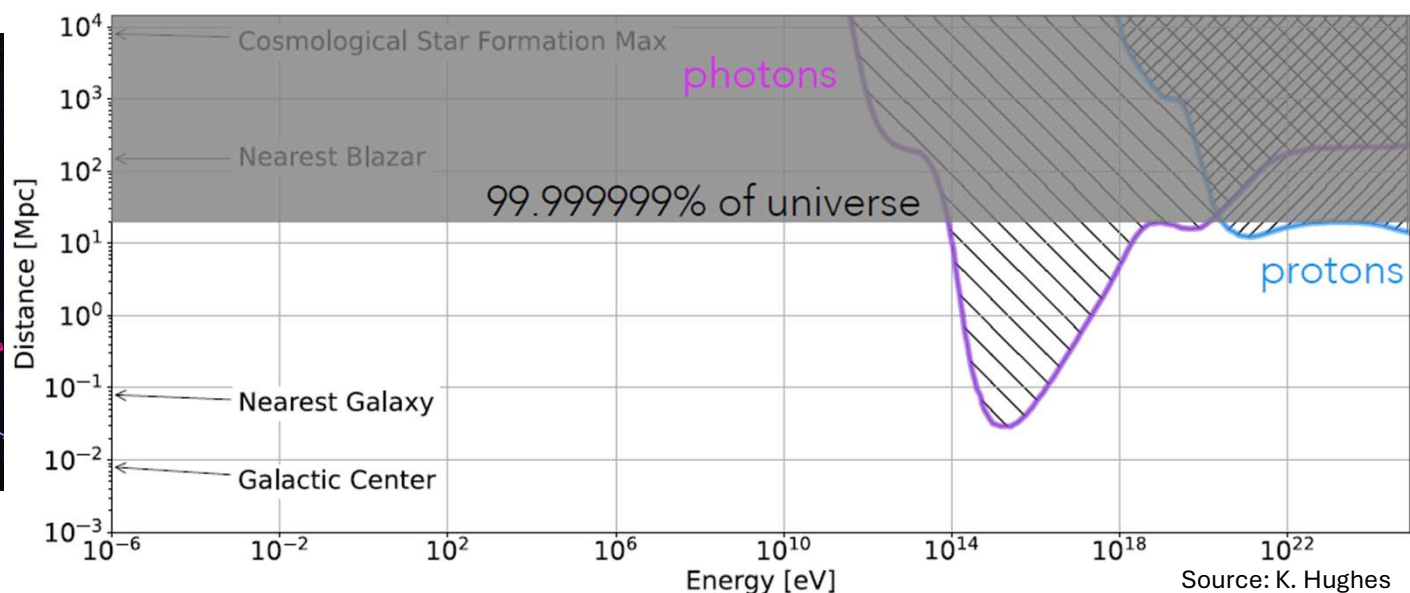
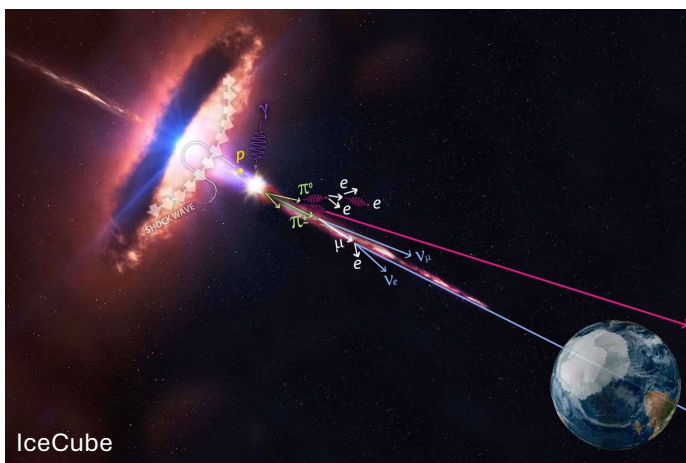
- Science goal of detecting ultrahigh energy (UHE) >1 EeV neutrino interactions in Antarctic ice using radio detection techniques.
- NASA Long-Duration Balloon payload, achieved a ~ 23 day flight in the 2025-2026 Antarctic Summer
- Successor to the ANITA I-IV (2006-2016) balloon missions.



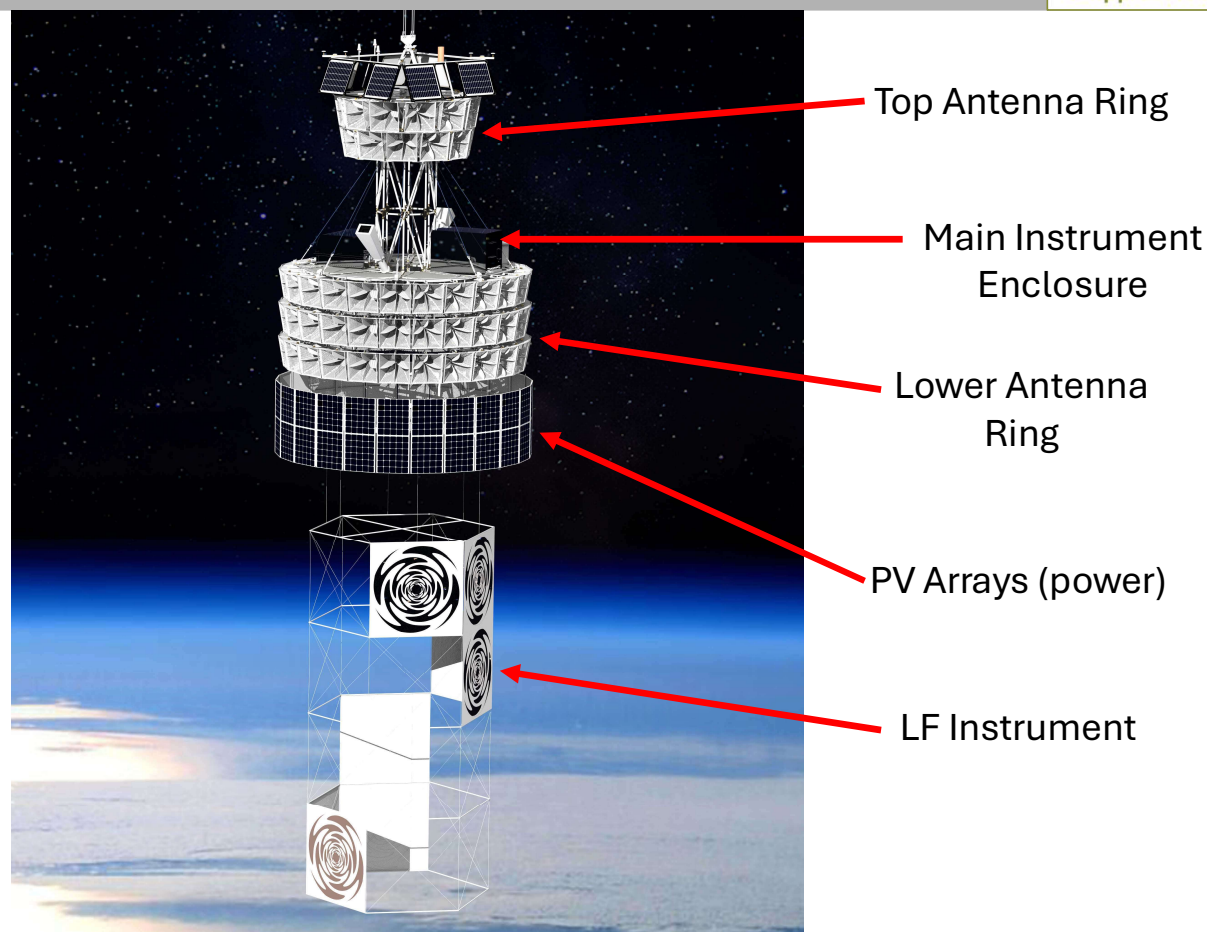
What is PUEO looking for?

We want to study the distribution and nature of the sources of the highest energy particles in the universe!

Neutrinos are uniquely well-suited messengers for this purpose.



- Main instrument antennas
 - 96 Quad-ridged horns
 - Dual polarized
 - Arranged into 4 rings
 - 2π (full) azimuthal coverage
 - 300-1200 MHz band
- Low frequency instrument
 - 8 Sinuous antennas
 - Dual polarized
 - 50-500 MHz band
 - Made of conductive fabric

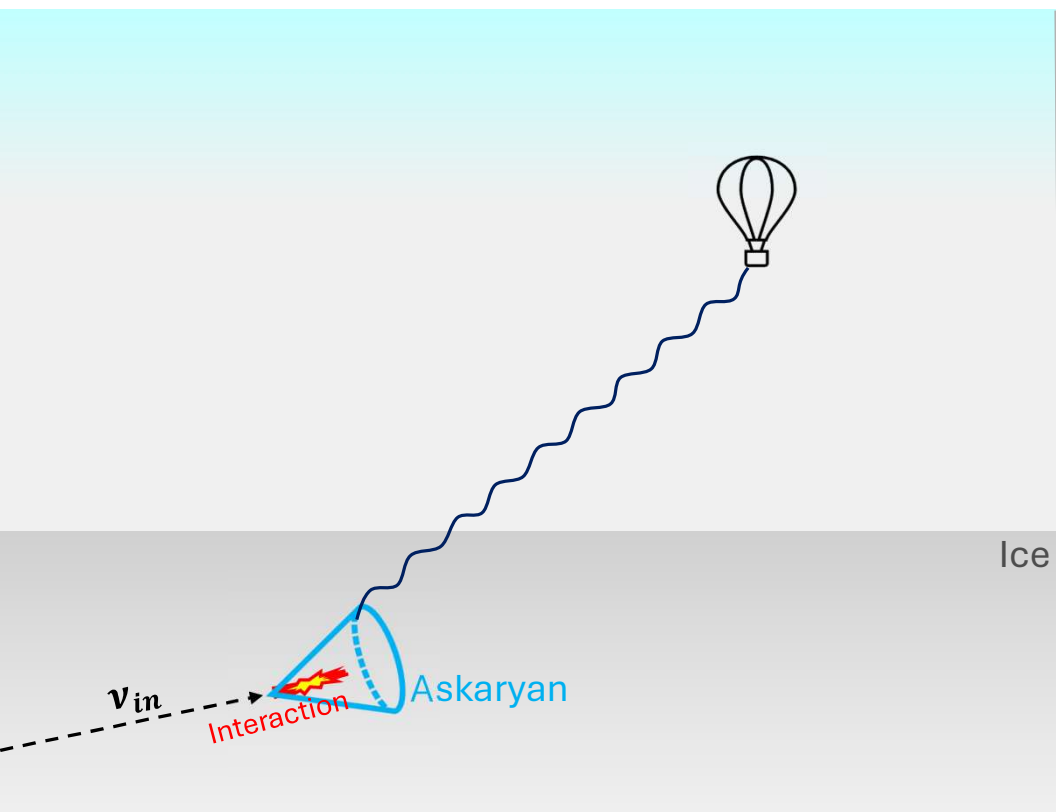


Improvements over ANITA

- 300 MHz high-pass antennas vs 200 MHz
 - Anthropogenic noise below 300 MHz
 - Smaller antennas → more collecting area
- Longer baselines between antennas
 - Improved pointing and background rejection
- Improved DAQ and trigger system
 - Phased array trigger → higher effective SNR
 - Enabled by use of RFSocCs (8 channels @ 3 GHz)
- LF instrument
 - Better sensitivity to air showers from CRs or taus
- Improved navigation/orientation suite



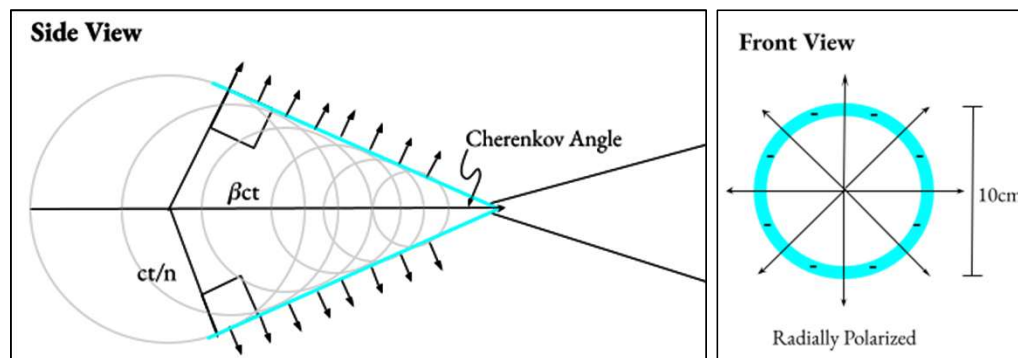
Method 1: Askaryan emission in ice



When a UHE neutrino interacts in the ice, the resulting shower emits Askaryan radiation at the Cherenkov angle.

This radiation will add coherently in radio (with power $\sim E^2$) if the width of the shower is less than radio wavelength.

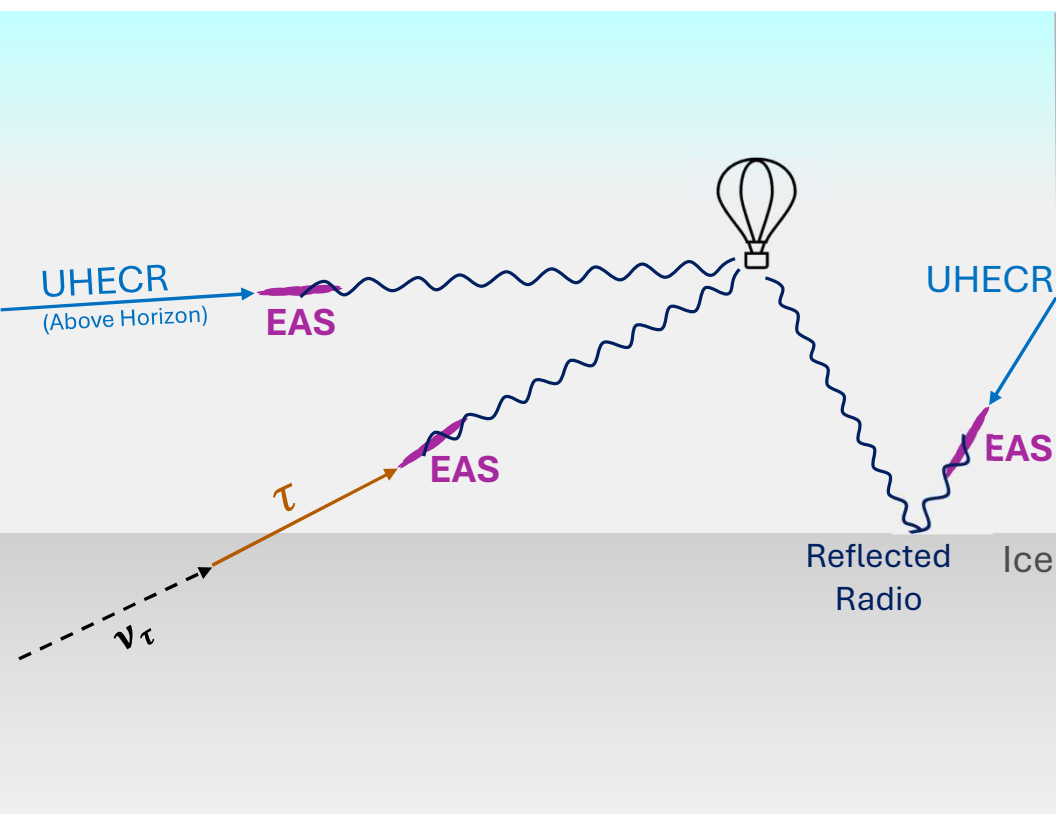
The radio emission is radially polarized, which is useful for reconstructing the direction of the shower.



Credit: Rachel Scrandis

How does PUEO see these particles?

Method 2: Geomagnetic emission in air showers

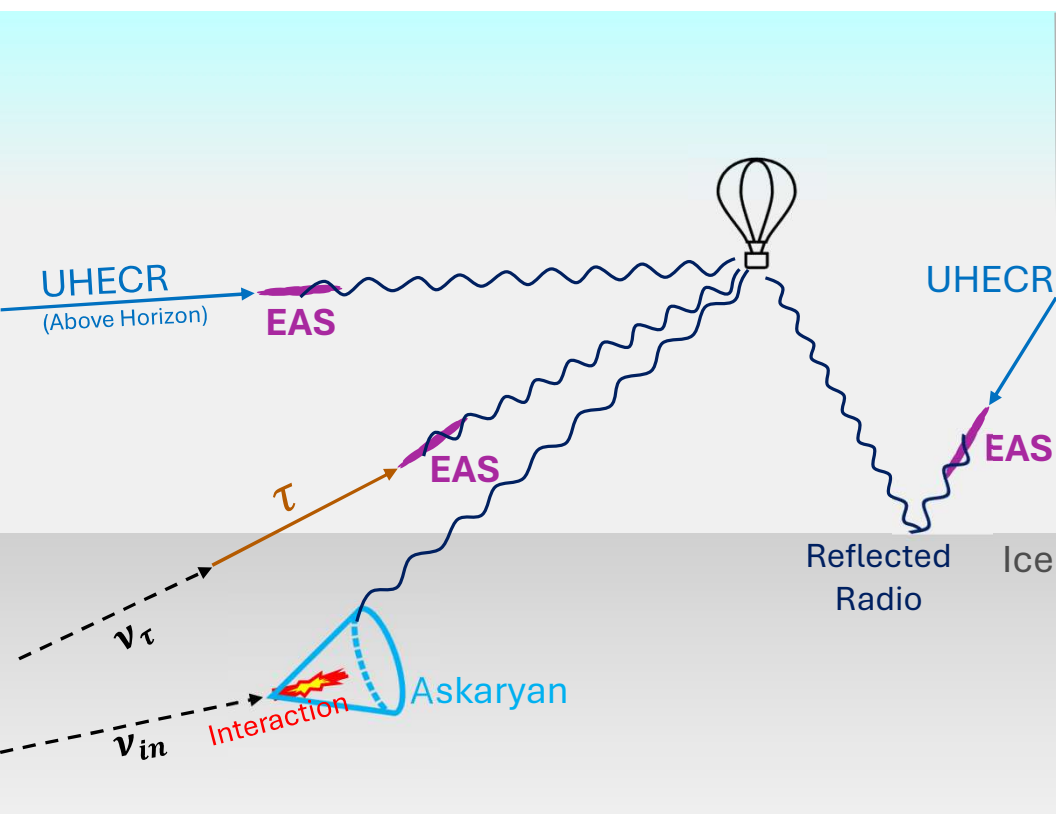


PUEO can also detect the radio that is produced by geomagnetic emission in air showers.

Tau neutrinos interacting in the Earth produce tau particles, which then decay and produce an Extensive Air Shower (EAS).

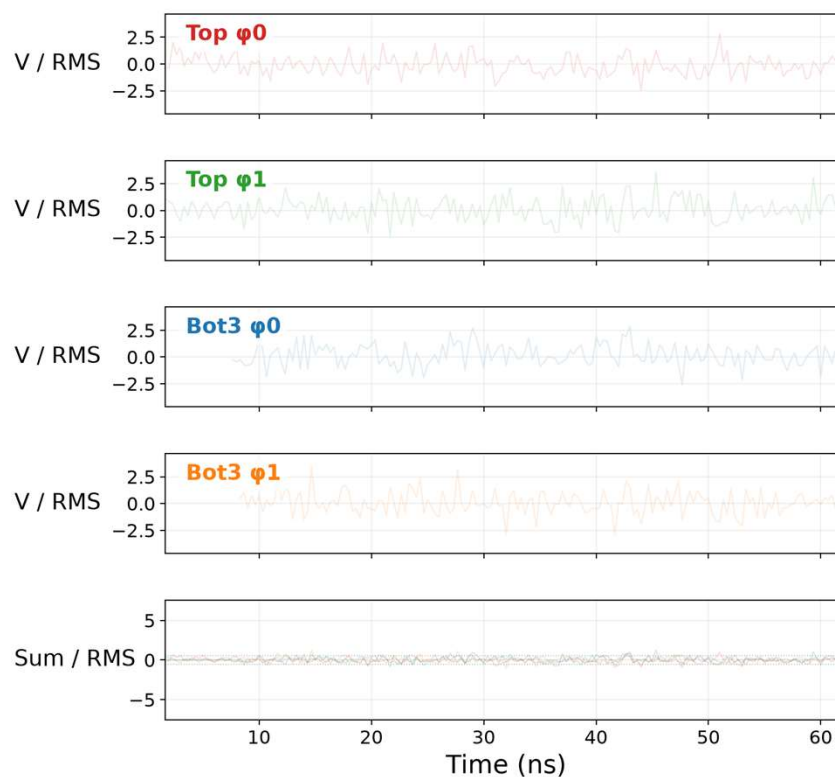
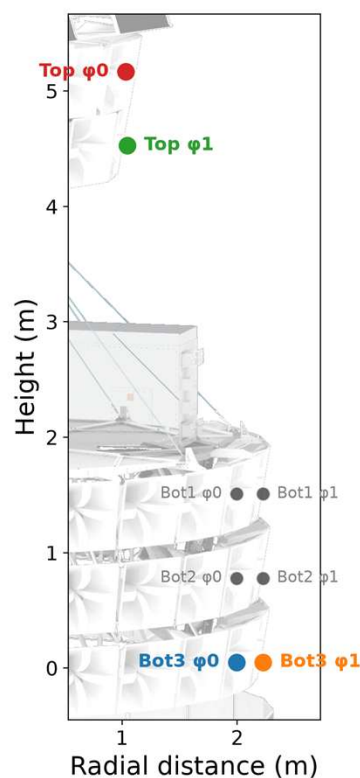
EASs can also be produced by UHE cosmic rays.

Differentiation Between Radio Sources



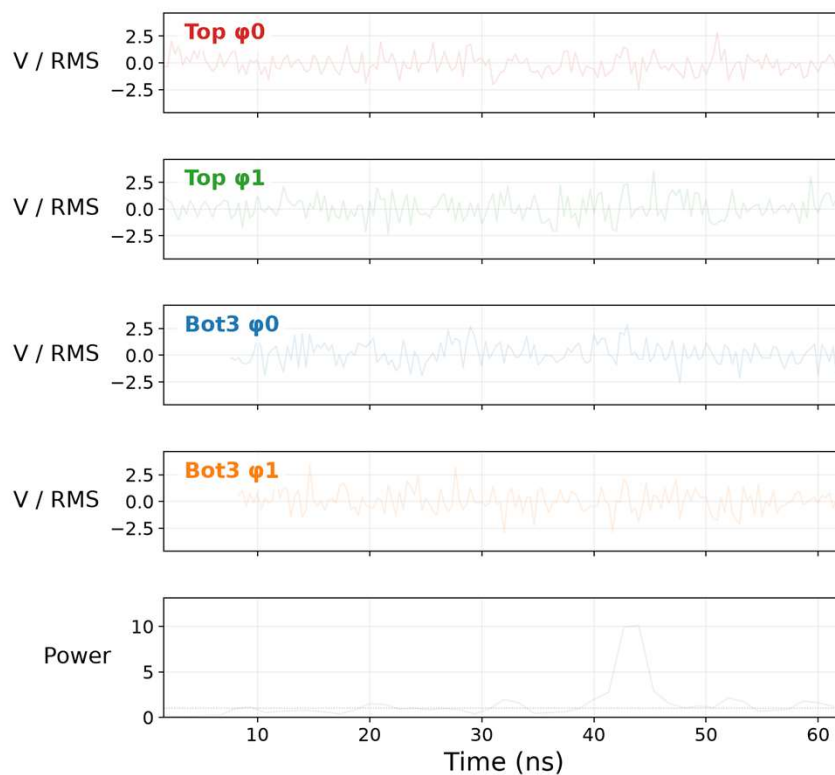
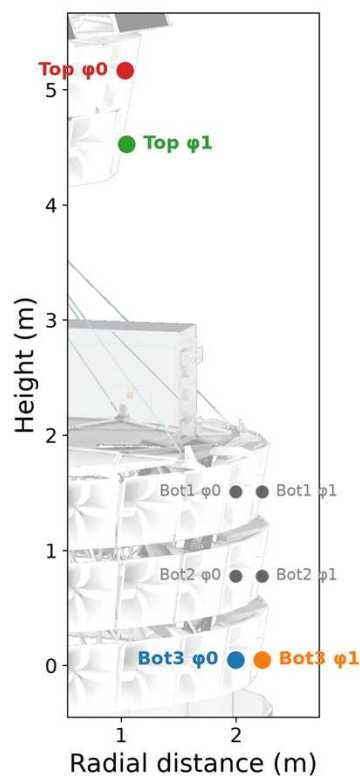
- **In-ice Askaryan**
 - Below horizon
 - Vertically polarized
- **UHECR induced EAS**
 - Above horizon
 - Horizontally polarized
- **Tau-neutrino induced EAS**
 - Below horizon
 - Horizontally polarized
- **UHECR induced EAS (reflected)**
 - Below Horizon
 - Horizontally polarized
 - *Polarity flip relative to other EAS showers*

PUEO Delay-and-Sum Beamforming



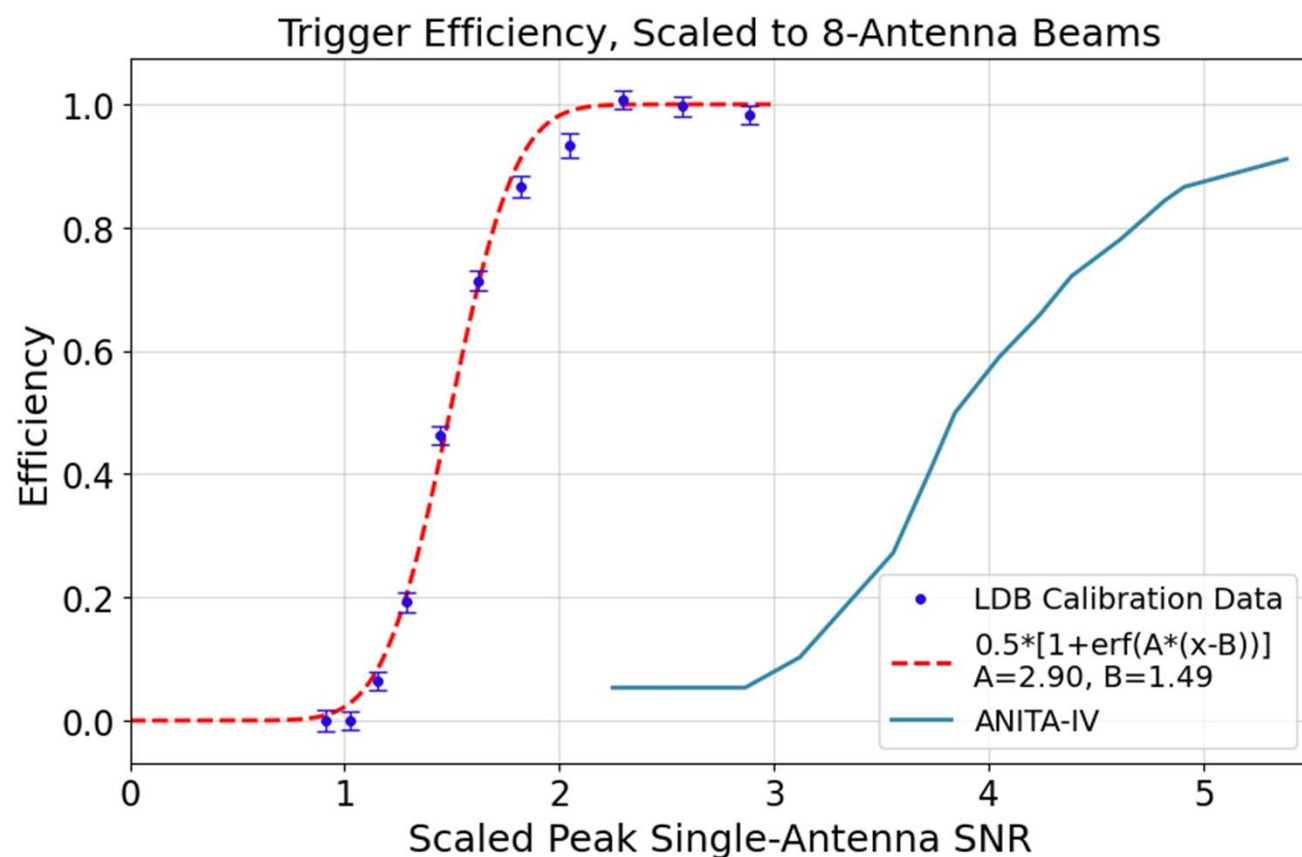
- With multiple antennas, you can use interferometry to greatly lower your trigger thresholds.
- 1152 precomputed “beams” of antenna delays are used in PUEOs trigger to search different arrival directions.

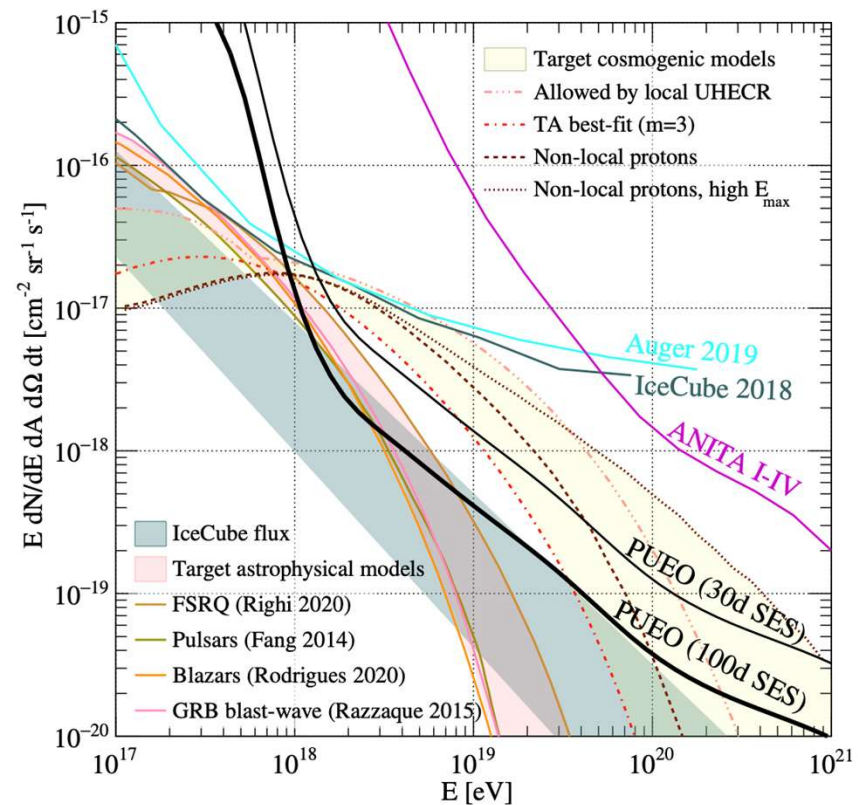
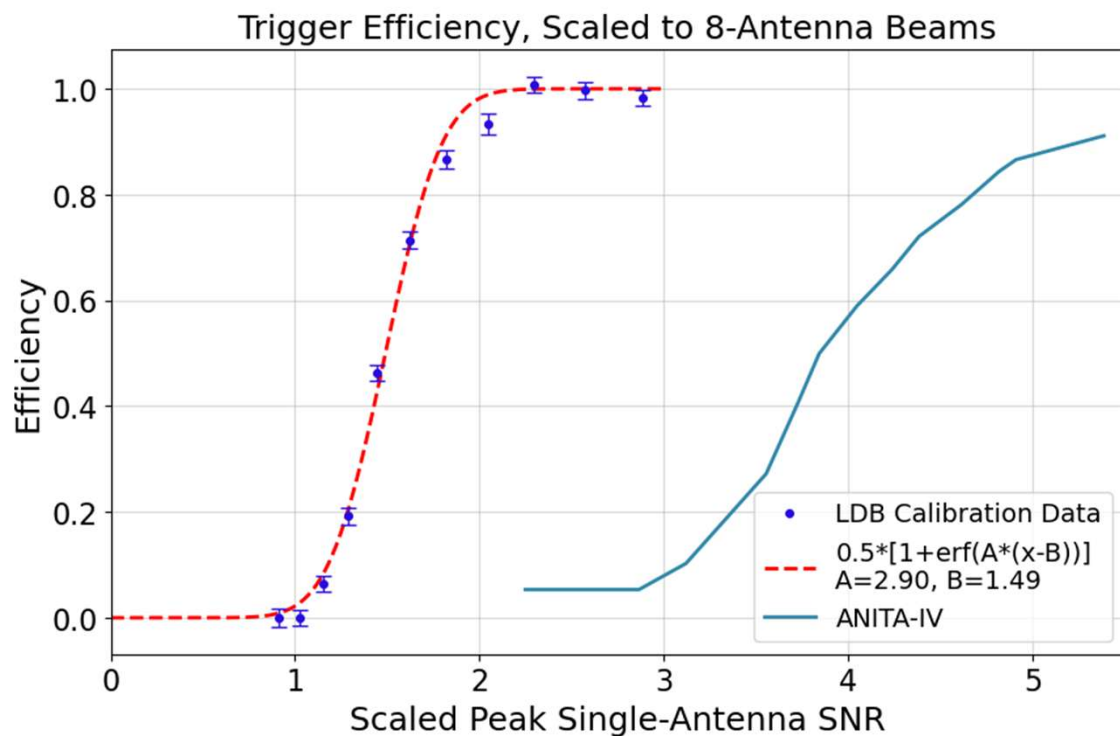
PUEO Power Trigger



- With multiple antennas, you can use interferometry to greatly lower your trigger thresholds.
- 1152 precomputed “beams” of antenna delays are used in PUEOs trigger to search different arrival directions.

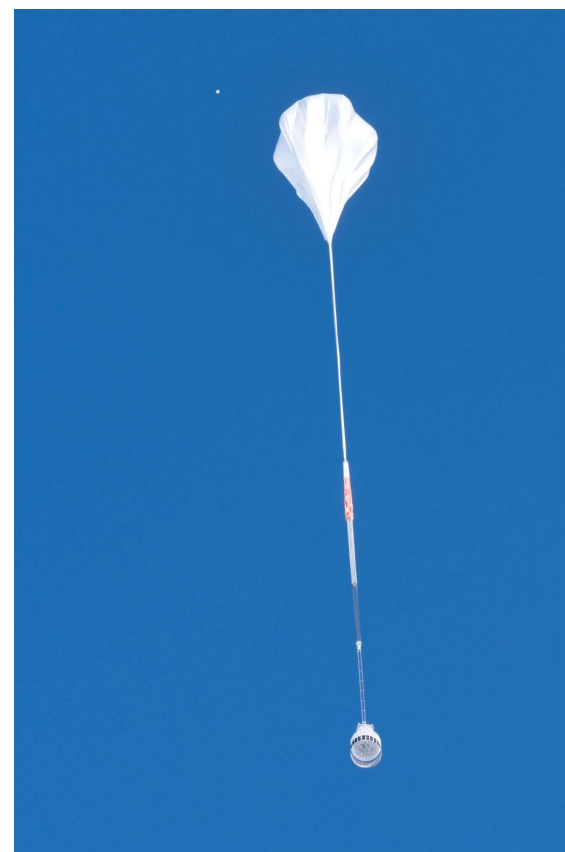
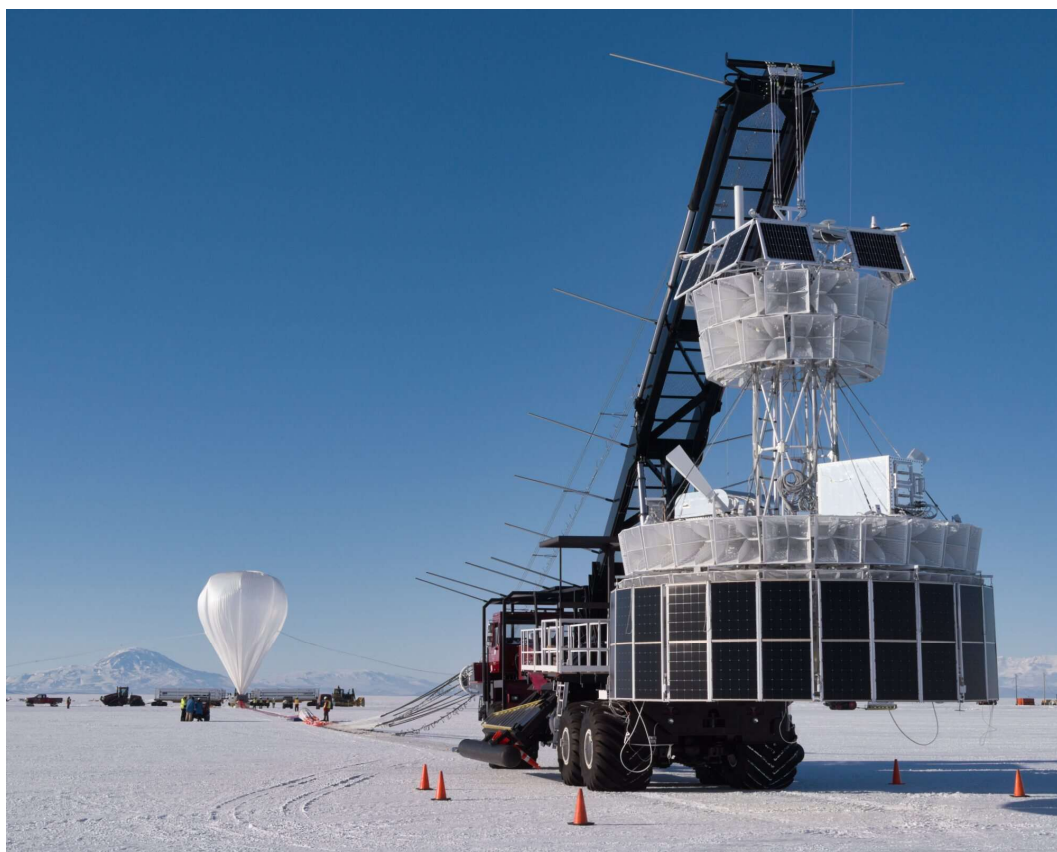
- RFSocCs digitize signals from the antennas to 12 bits
- Real-time digital processing
 - Low-pass filter at ~750 MHz
 - Tunable dual-biquad notch filters (*unused in flight*)
 - Matched filter for RF chain
 - Automatic gain control
 - 12-to-5 bits, then beamform
- Trigger thresholds adjust to maintain a constant event rate





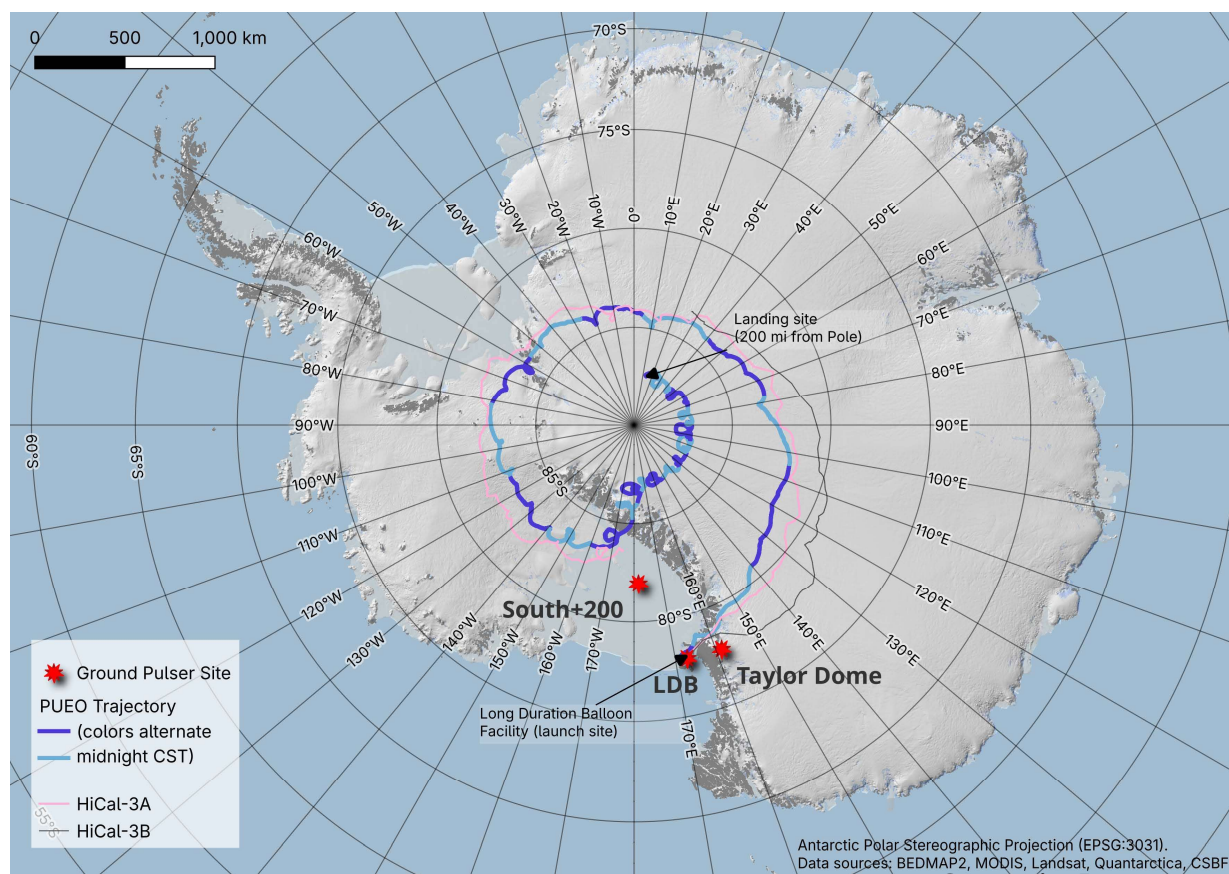
Antarctic Deployment: Ice Team







PUEO Flight

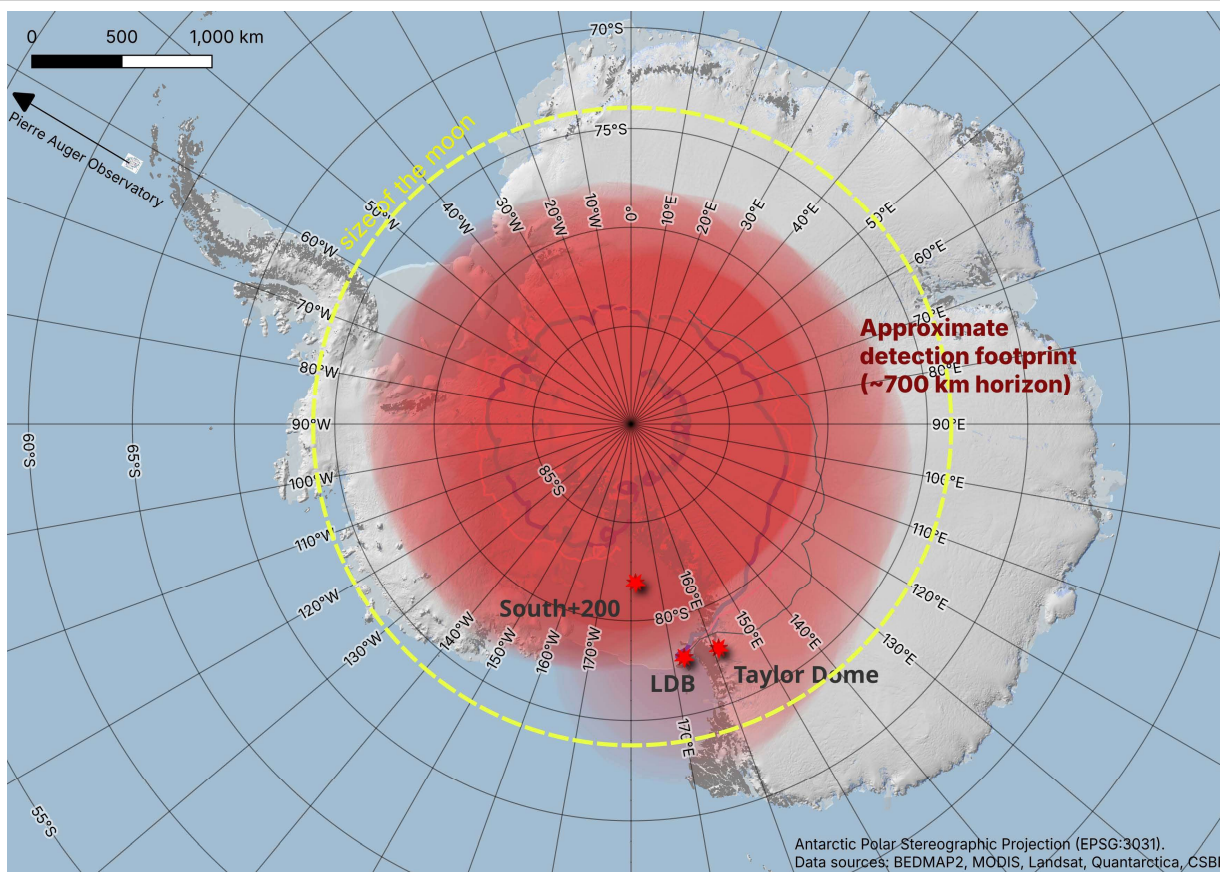


Cosmin Deaconu

- Dec 20, 2025 - Jan 12, 2026.
- ~ 53% data taking livetime. This was due to running in a duty cycle for thermal management.
- Terminated within range of Arctic Truck recovery dispatched from Pole.



Where PUEO Looked



Cosmin Deaconu

- PUEO had a successful 23-day flight!
- All data was successfully recovered.
- Calibration and analysis is underway and going well!

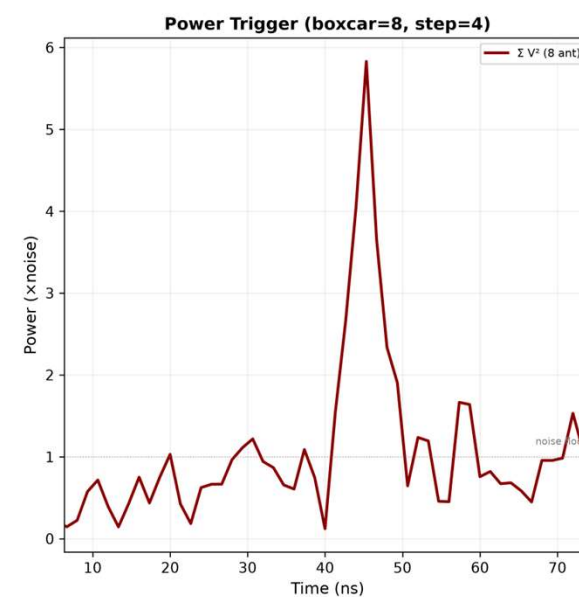
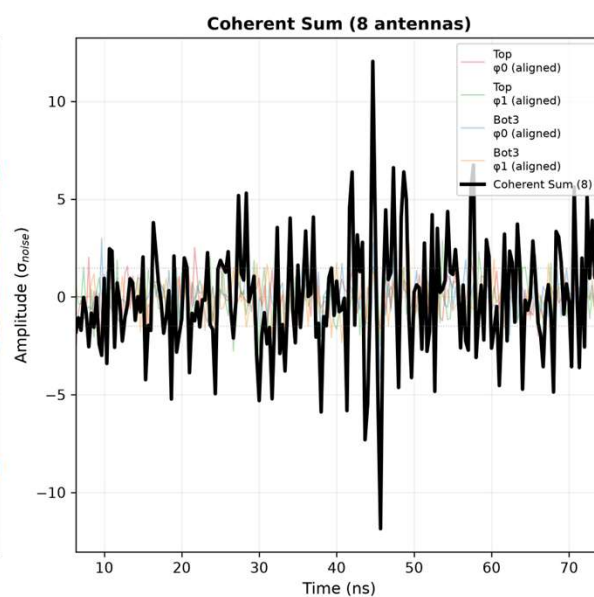
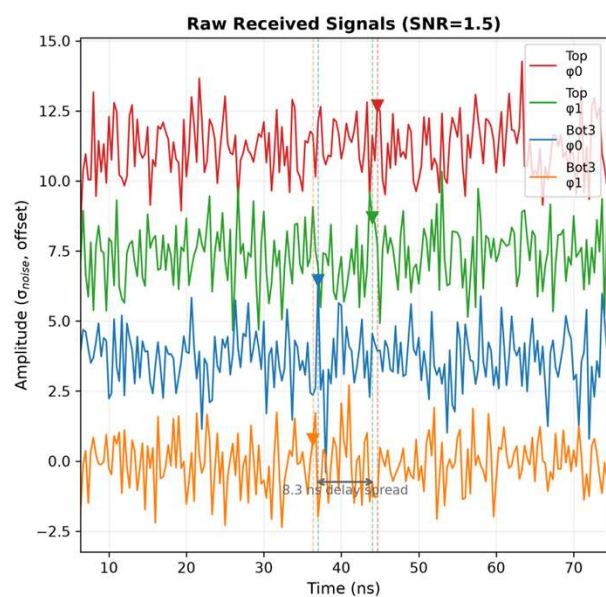


PUEO is grateful to be selected as a NASA Pioneers mission funded by NASA grants #80NSSC20K0775 and #80NSSC20K0925. We would like to particularly thank the staff at the Columbia Scientific Balloon Facility, the National Science Foundation, and the Antarctic Support Contractor, whose talented and tireless efforts made PUEO possible.





Backup



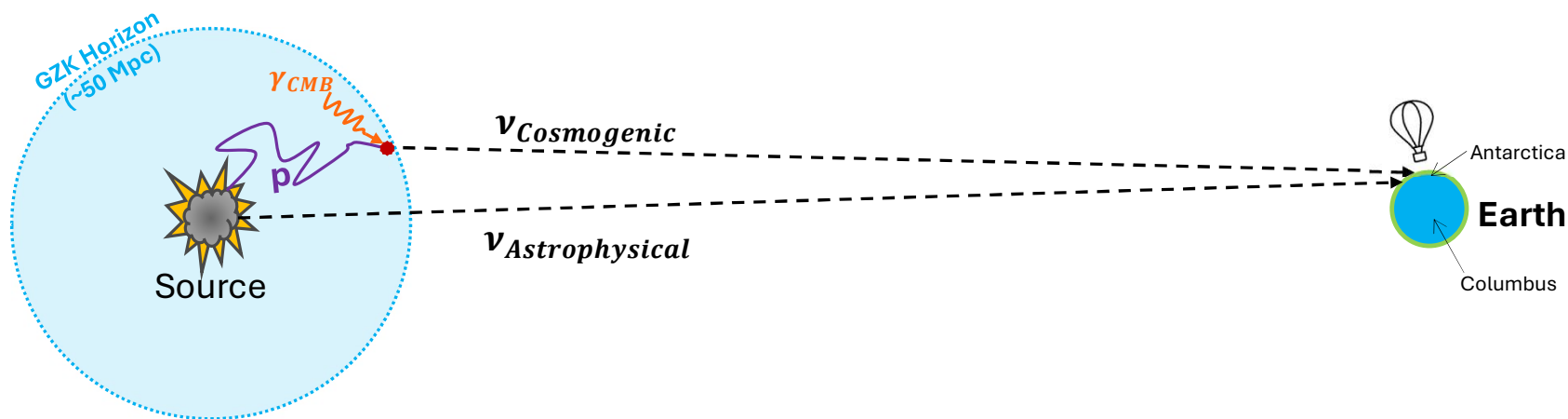
Source: Dan Southall

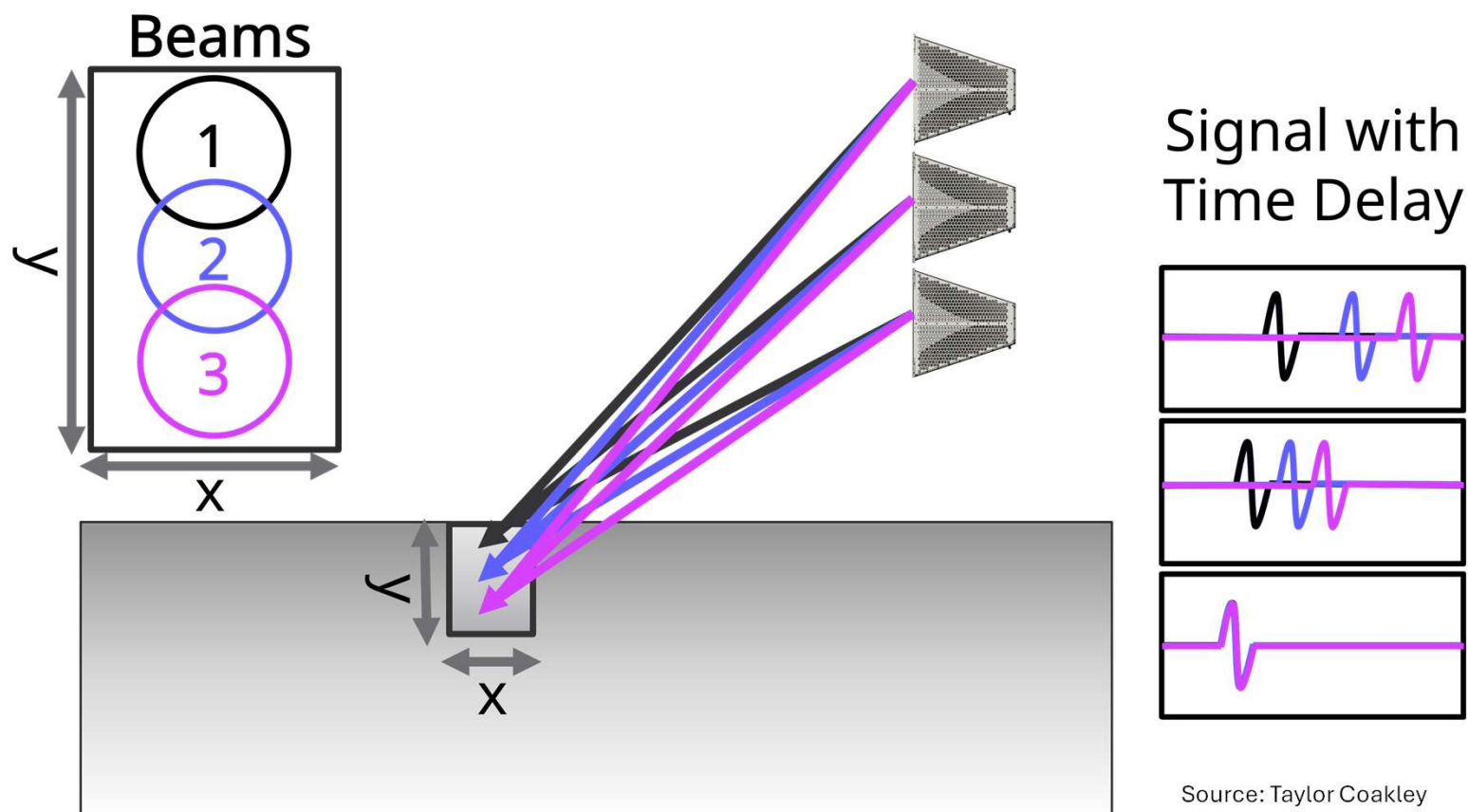
Astrophysical

UHE neutrinos produced directly by their astrophysical sources.

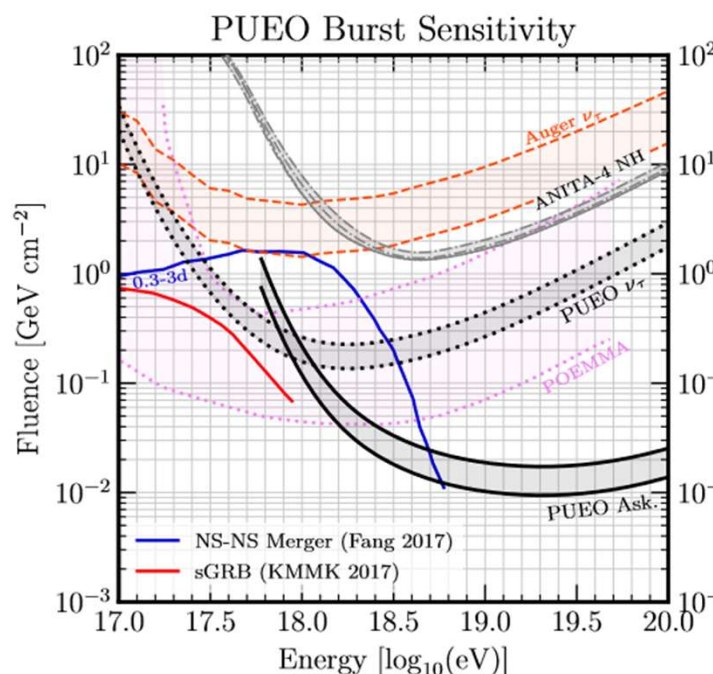
Cosmogenic

UHECR with energies above ~ 50 EeV interact with the CMB, producing neutrinos.

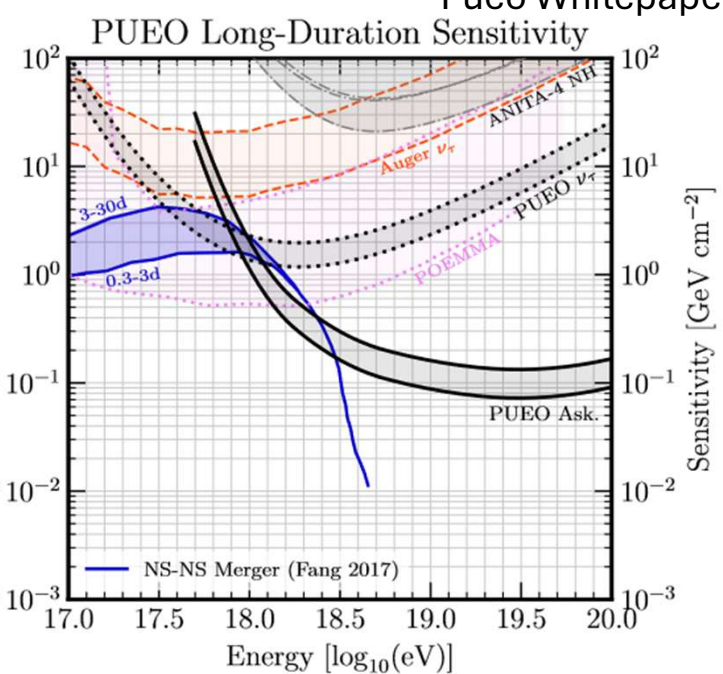




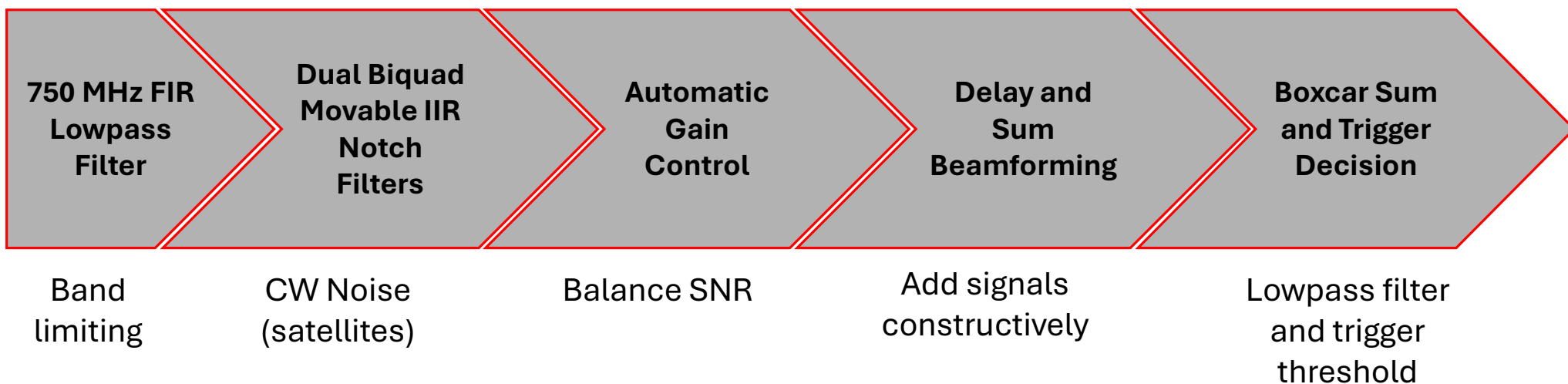
PUEO's large instantaneous aperture makes it ideal for transient searches within its field-of view!



Burst sensitivity is for transients lasting a few hours.



Long duration sensitivity is for transients lasting around the same length as the flight, so effective area is averaged over the full flight.



- Sensitive to the lower frequency (50-500 MHz) components present in air showers
 - Overlaps frequency range with main instrument, providing independent measurement
- Enhanced measurement of tau-neutrino induced EASs
- Measurements of cosmic ray induced EASs
 - Understanding neutrino signal background
 - Opportunity to better characterize events like the ANITA “mystery events”

