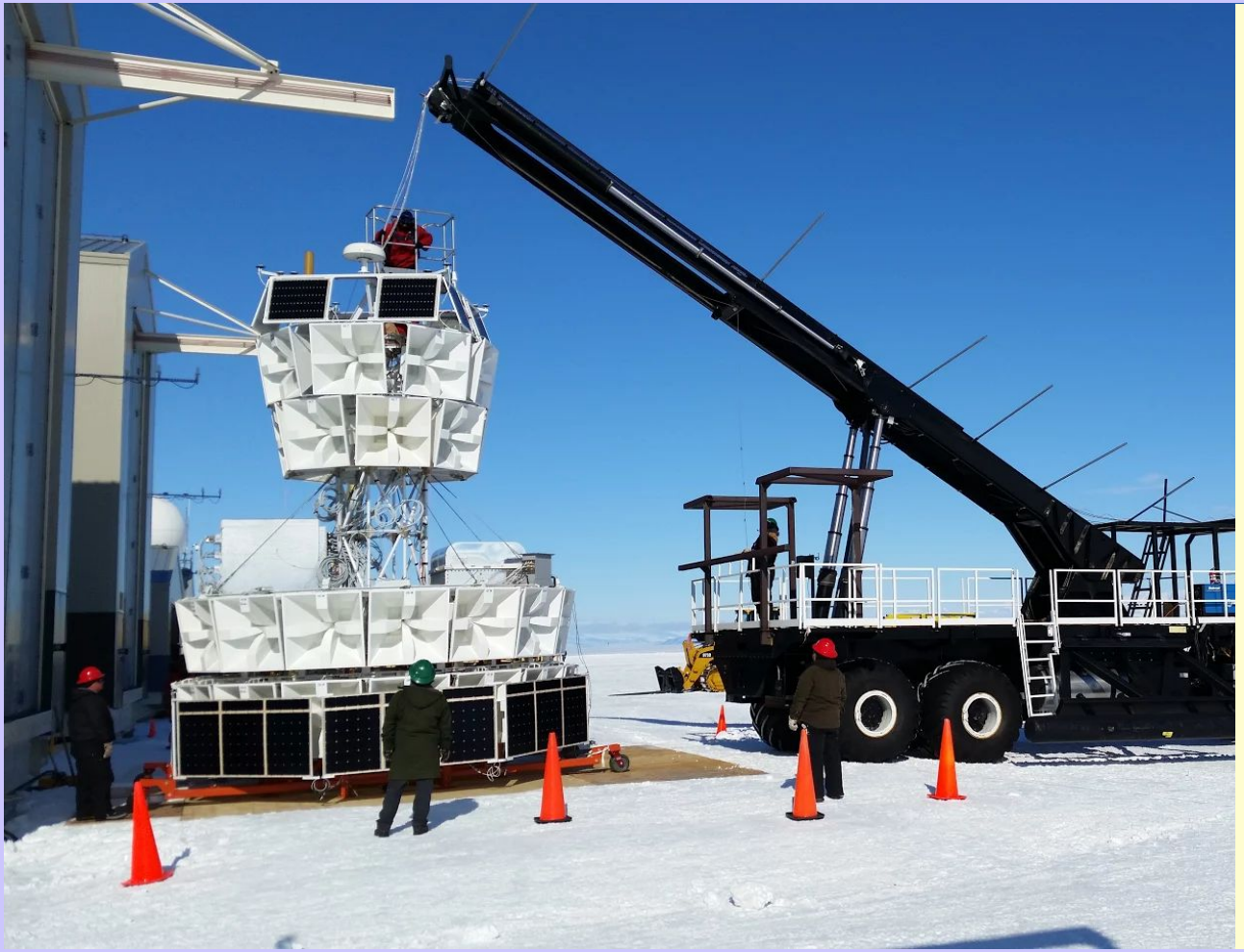
The fourth flight of the ANITA experiment

DPF Fermilab 2017
Andrew Ludwig

Outline



Ultra high energy neutrinos

ANITA instrument

- Neutrino detection
- Cosmic ray detection

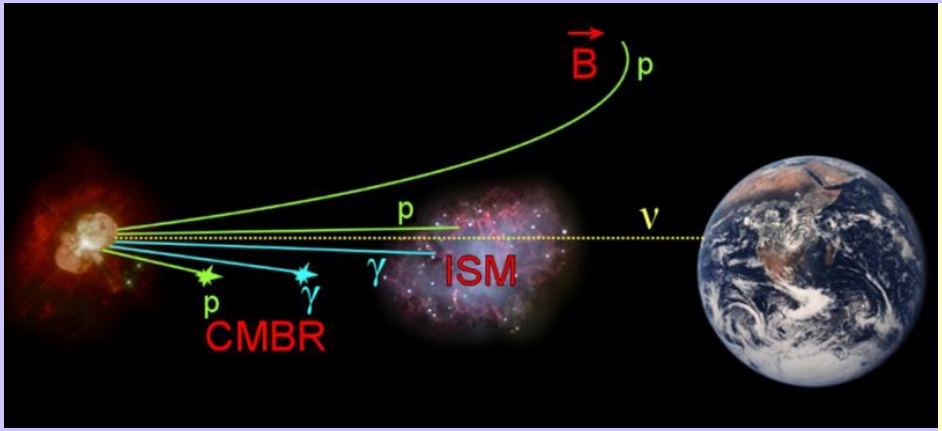
Previous ANITA results

ANITA-4 flight

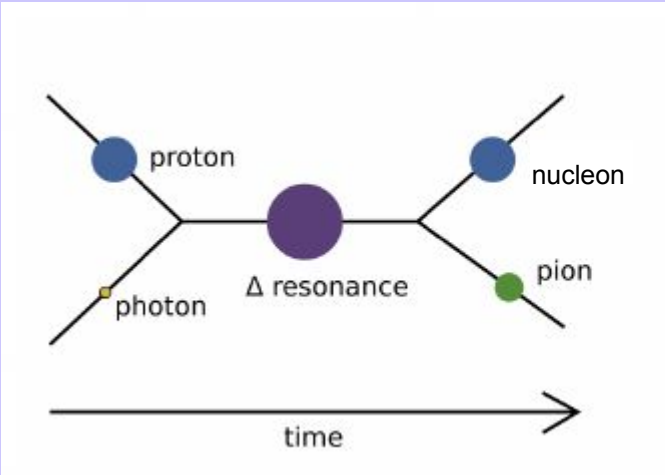
- Improvements
- Data

Next steps

Ultra high energy (UHE) neutrinos



credit: J. Nam



GZK process (credit: W. Bietenholz)

UHE defined as > ~10^{18} eV

Neutrinos make great messengers

One source of UHE neutrinos is the GZK process:

Protons with energy > $10^{19.5}$ eV will interact with CMB photons in a Δ^+ resonance:

$$p^+ + \gamma_{\mathrm{CMB}} \rightarrow \Delta^+ \rightarrow \pi^0 + p^+$$
$$p^+ + \gamma_{\mathrm{CMB}} \rightarrow \Delta^+ \rightarrow \pi^+ + n$$

Charged pions decay into a muon and neutrino that will decay and produce more neutrinos:

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\downarrow$$
$$\mu^+ \rightarrow \overline{\nu_\mu} + e^+ + \nu_e$$

The ANtarctic Impulsive Transient Antenna (ANITA)

48 antennas

- Dual polarization
- Directional
- 200 - 1200 MHz band

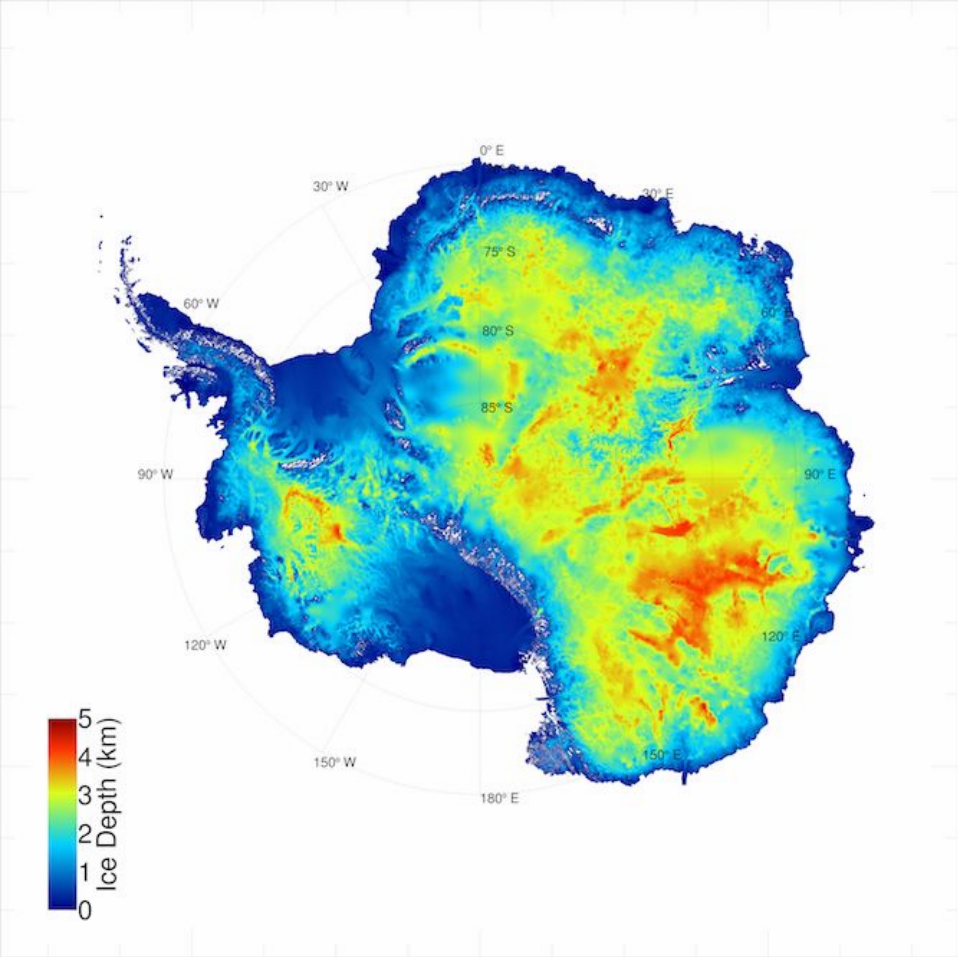
Solar powered

Flies at altitude of 37-40km

Over 1 million km^3 ice visible

credit: S. Prohira

Why Antarctica?



Radio quiet

Lots of thick ice

Ice is radio transparent (~1km attenuation length)

Conveniently, location of NASA's long duration balloon program

Neutrino detection mechanism: the Askaryan effect

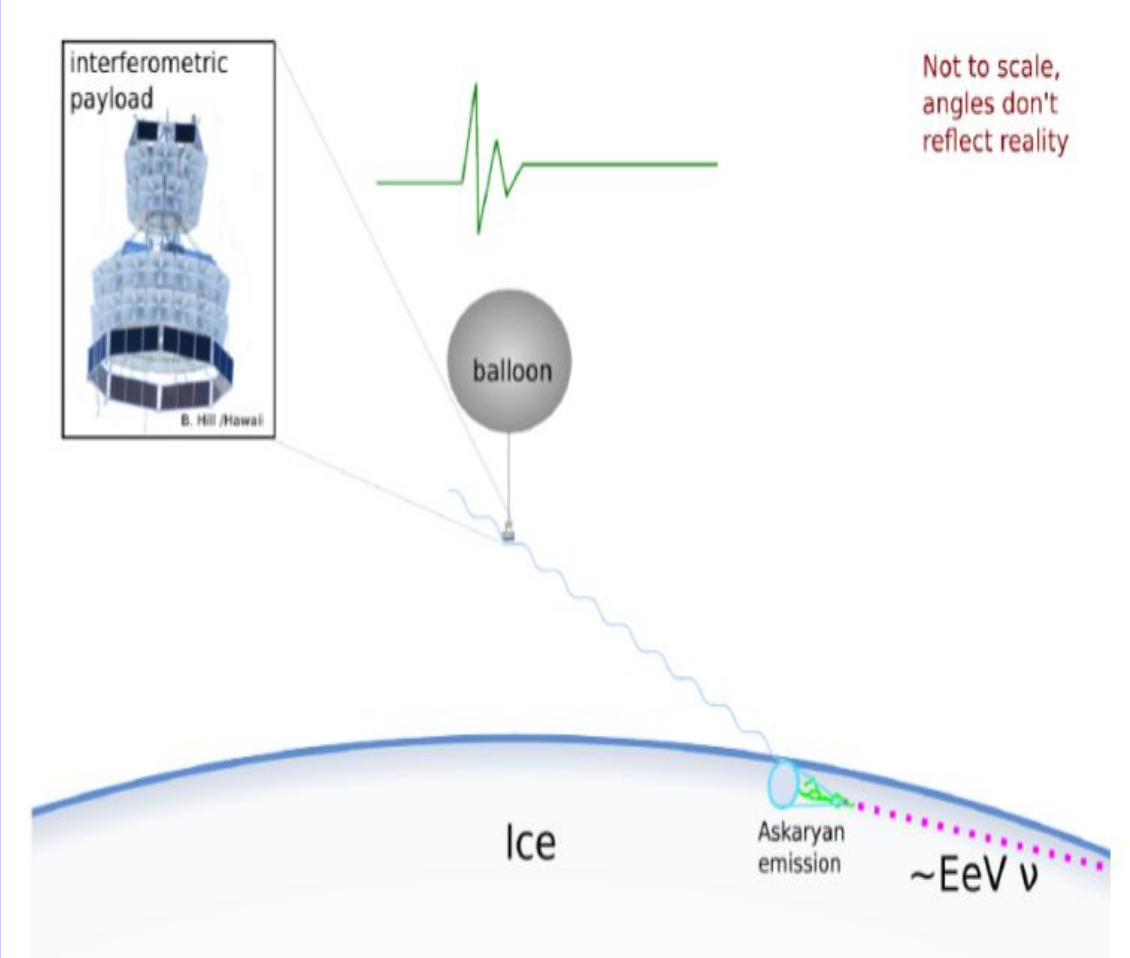
First observed in 2001

Coherent radio emission from negative charge excess in EM shower

Shower is actually a thin disk of particles

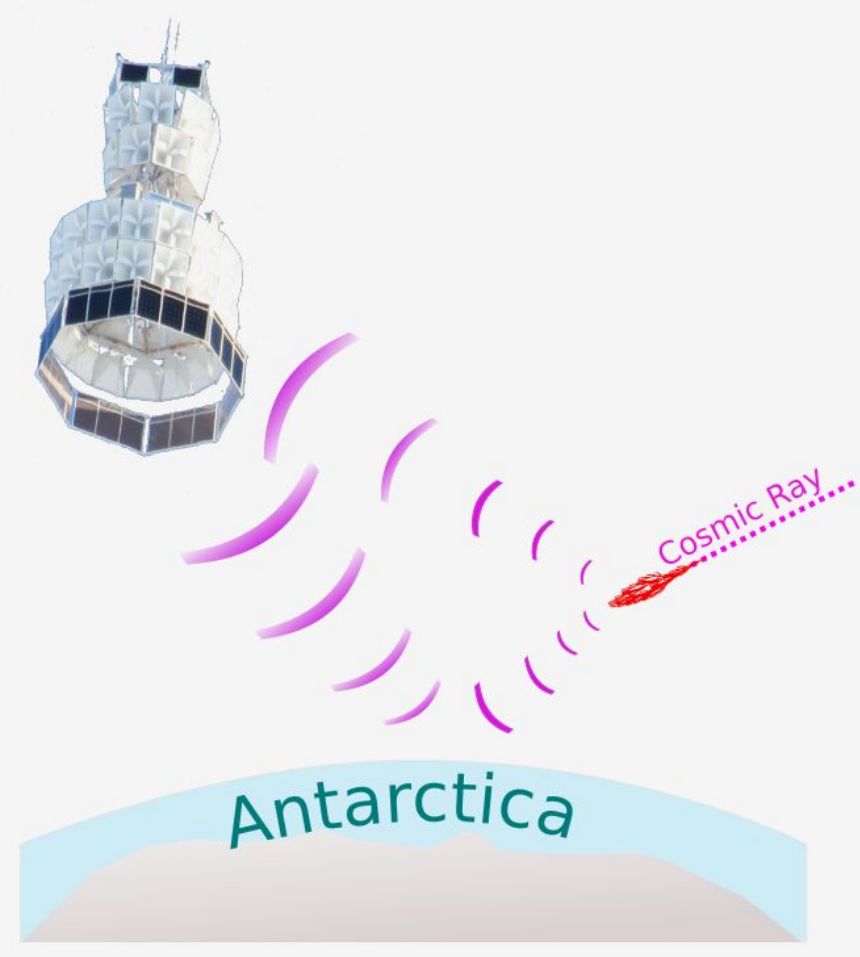
Coherent at wavelengths longer than the radius of disk

Polarized radially



credit: C. Deaconu

Cosmic ray detection with geomagnetic radiation



credit: C. Deaconu

Cosmic rays cause an EM shower

Due to Lorentz force, shower is curved around the Earth's B-field lines

Polarized mostly horizontally

Forward beamed radiation is picked up directly or reflected off the ice

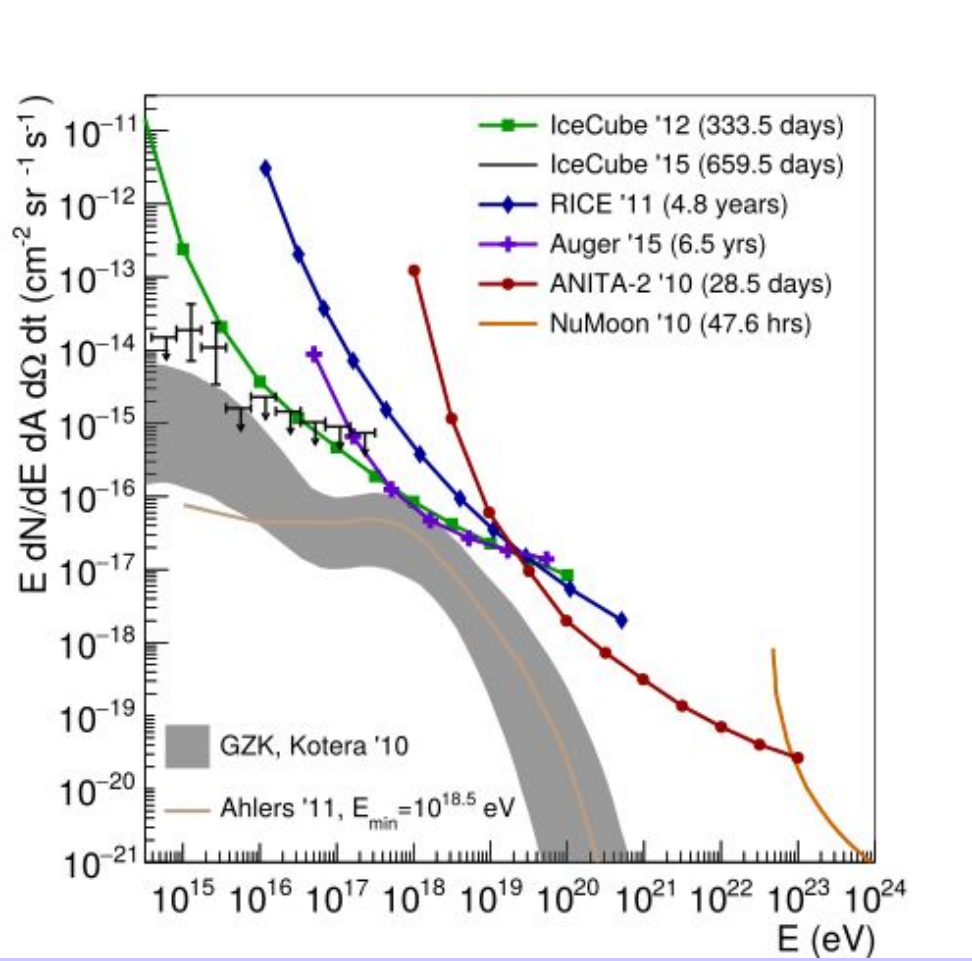
Results from previous flights

ANITA-1 unexpectedly found 16 cosmic rays

ANITA-2 still has the best limits on UHE neutrino flux above $10^{19.5}$ eV

ANITA-3 results are nearly complete

ANITA-4 results are in progress

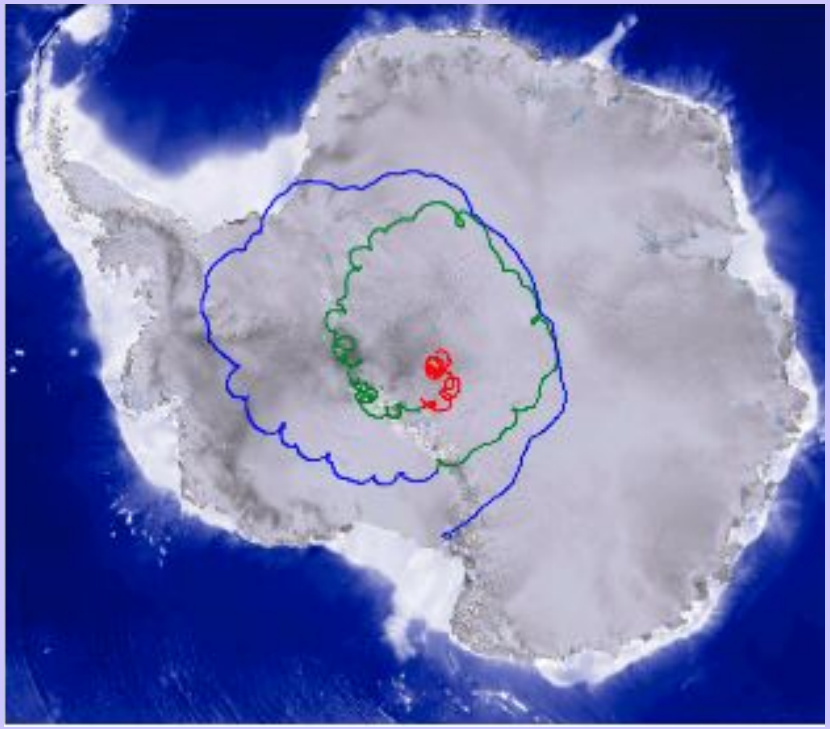


credit: A. Connolly

ANITA-3 problems

credit: NASA

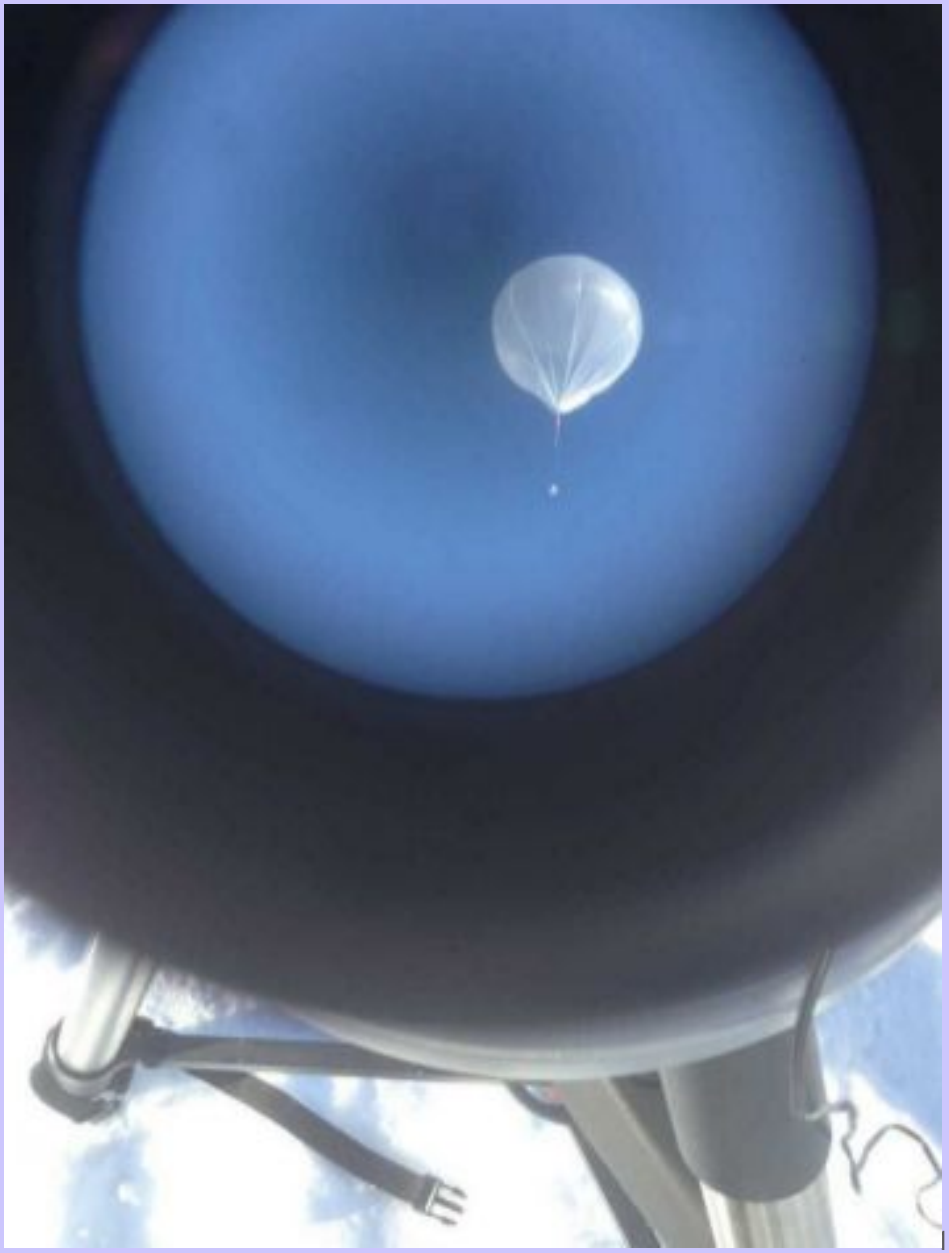
ANITA-4 flight



ANITA-4 Flight Path

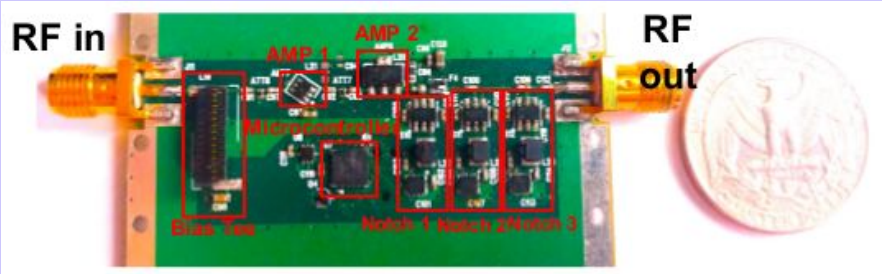
Flew for 28 days

Data was recovered in January



ANITA at float (40km up)

ANITA-4 improvements

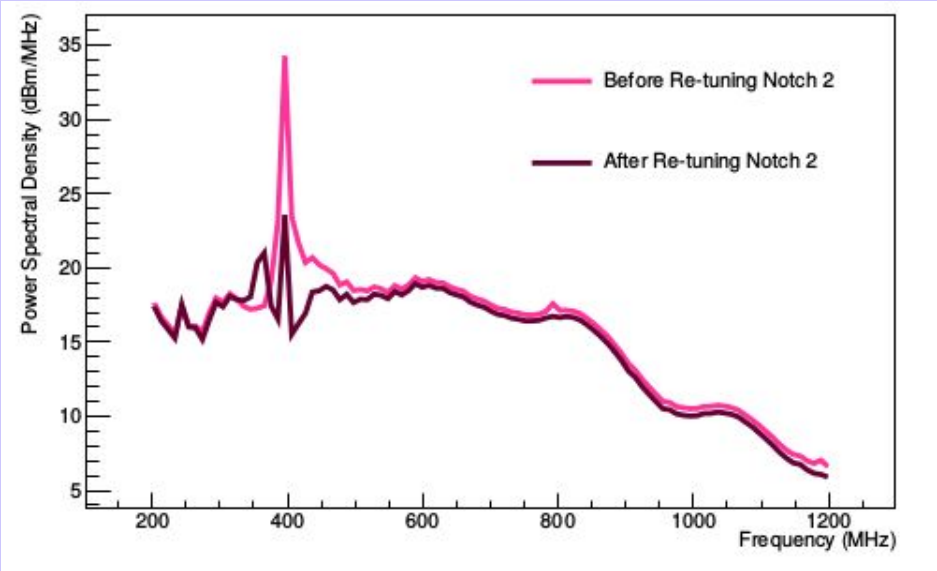


1 of 96 Tunable Universal Frontend Filters (TUFFs) (credit: O. Banerjee)

Triggering favors linearly polarized signals

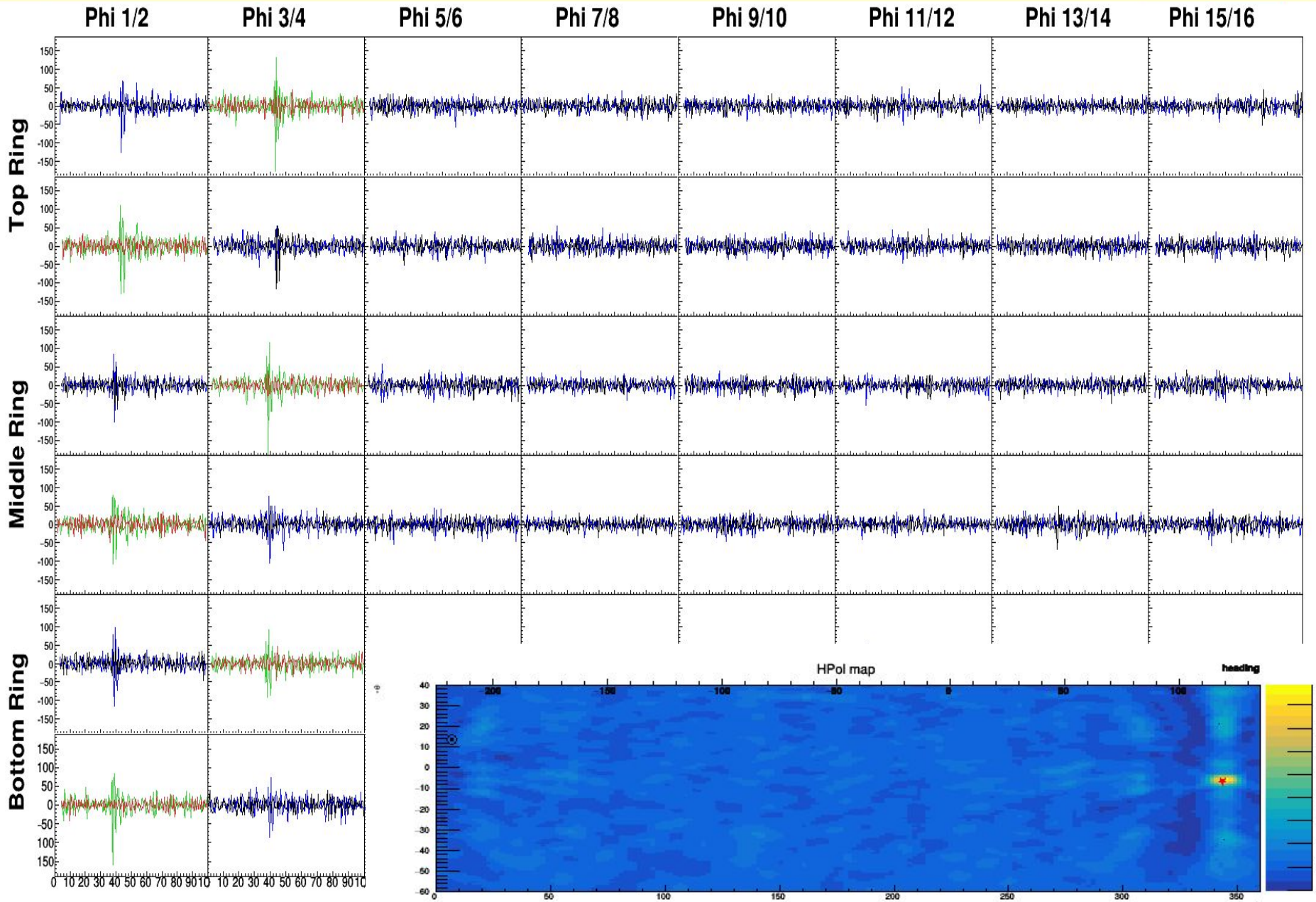
Notch filters that were tunable in flight

Cabling up the signal chain (credit: E. Oberla)

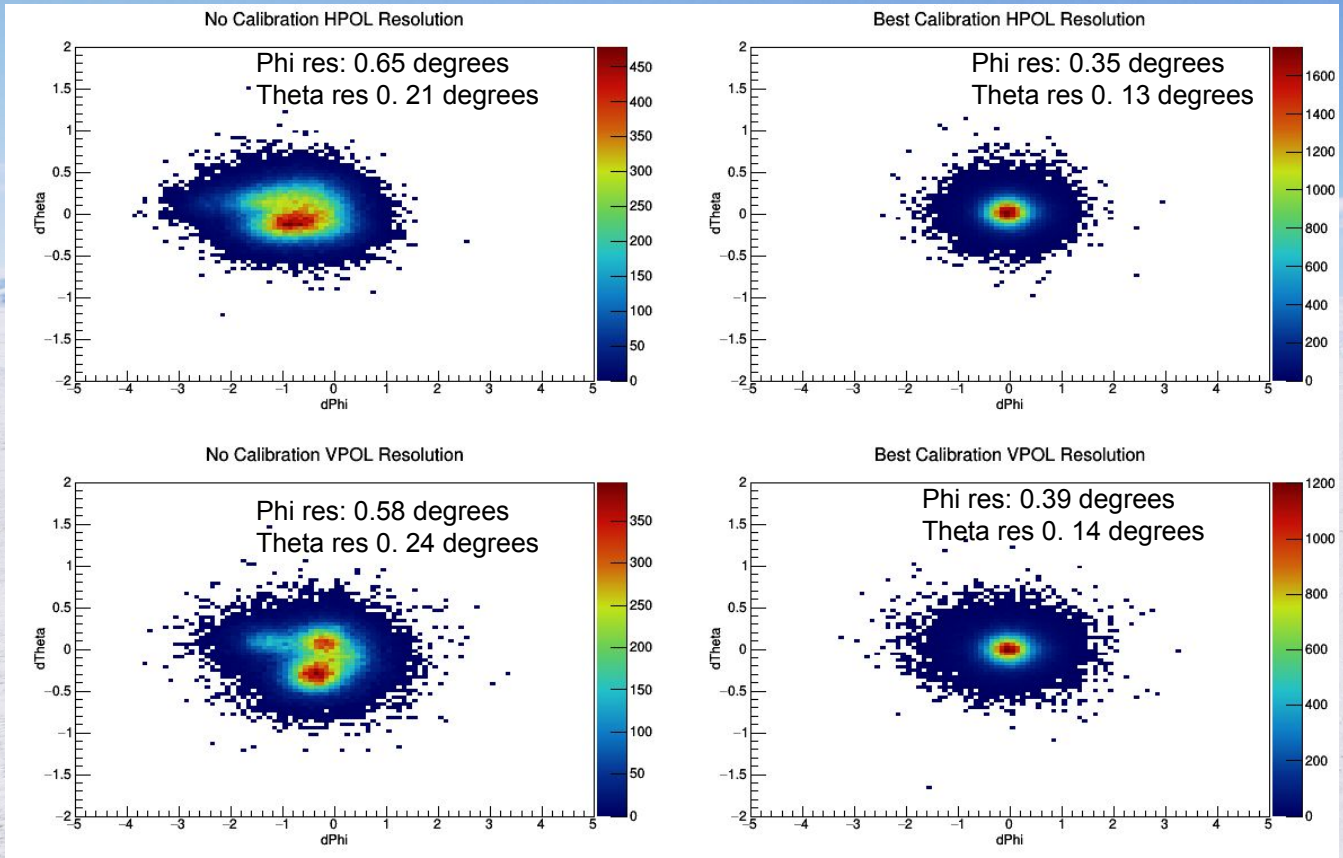


Example of notch being dynamically re-tuned in flight to block out continuous waveform noise (credit: O. Banerjee)

ANITA-4 data


Phi 1/2
Phi 3/4
Phi 5/6
Phi 7/8
Phi 9/10
Phi 11/12
Phi 13/14
Phi 15/16
Top Ring
Middle Ring
Bottom Ring
HPol map
heading

ANITA-4 calibration



Calibration pulser setup (credit: E. Oberla)

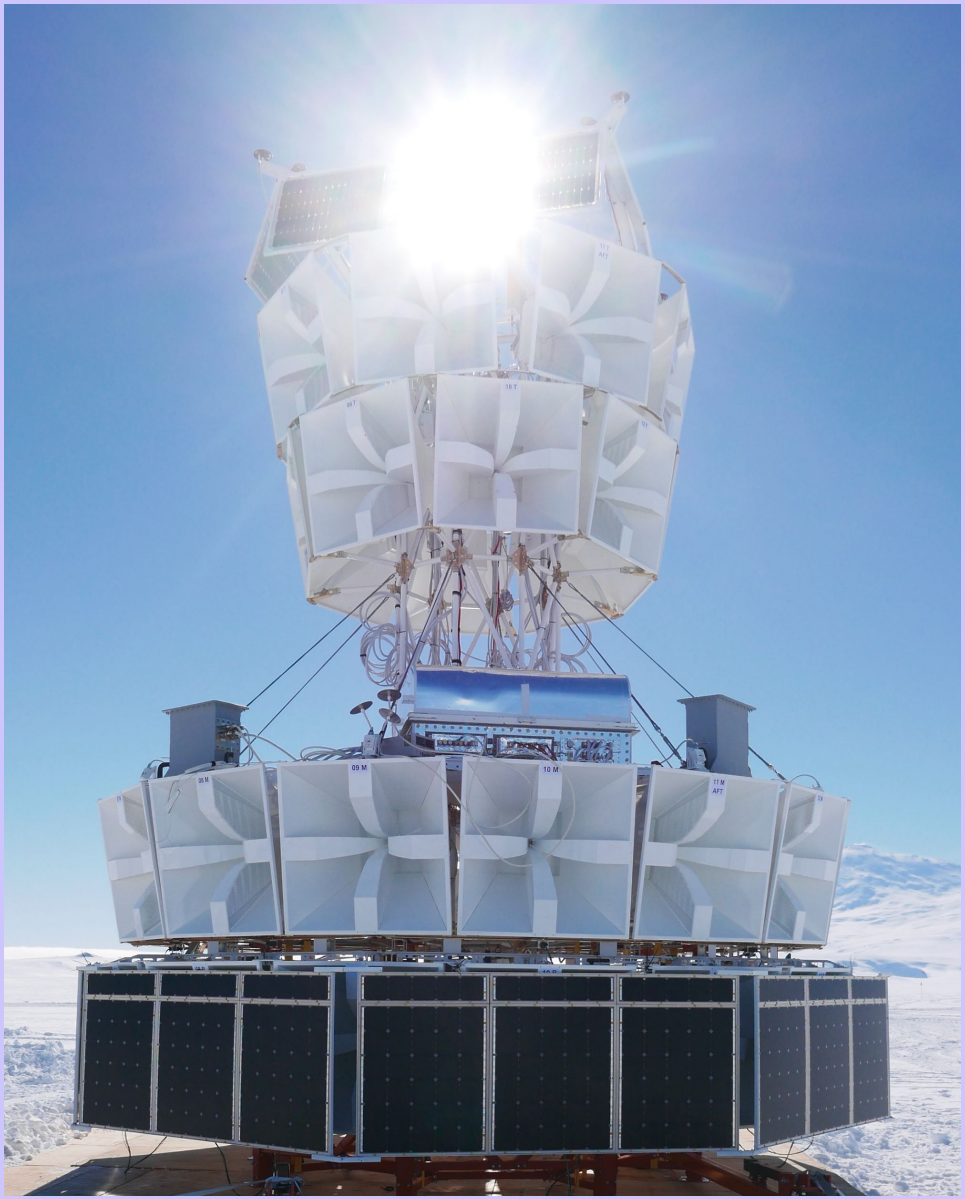
What's Next for ANITA

Results for ANITA-3 soon

Results for ANITA-4 out within the next year

ANITA has a pending proposal for a 5th flight with:

- Phased array type triggering
- New electronics for greater sensitivity, record length, buffer depth



My favorite ANITA picture
(credit: E. Oberla)

Thanks!

Thanks to A. Vieregg and C. Deaconu for their frequent help

Thanks to NASA's Scientific Ballooning Facility engineers and launch crew for excellent support.