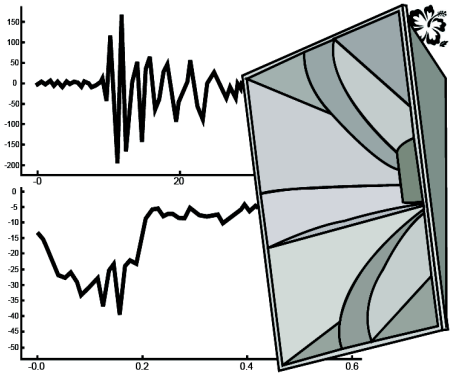
ANITA

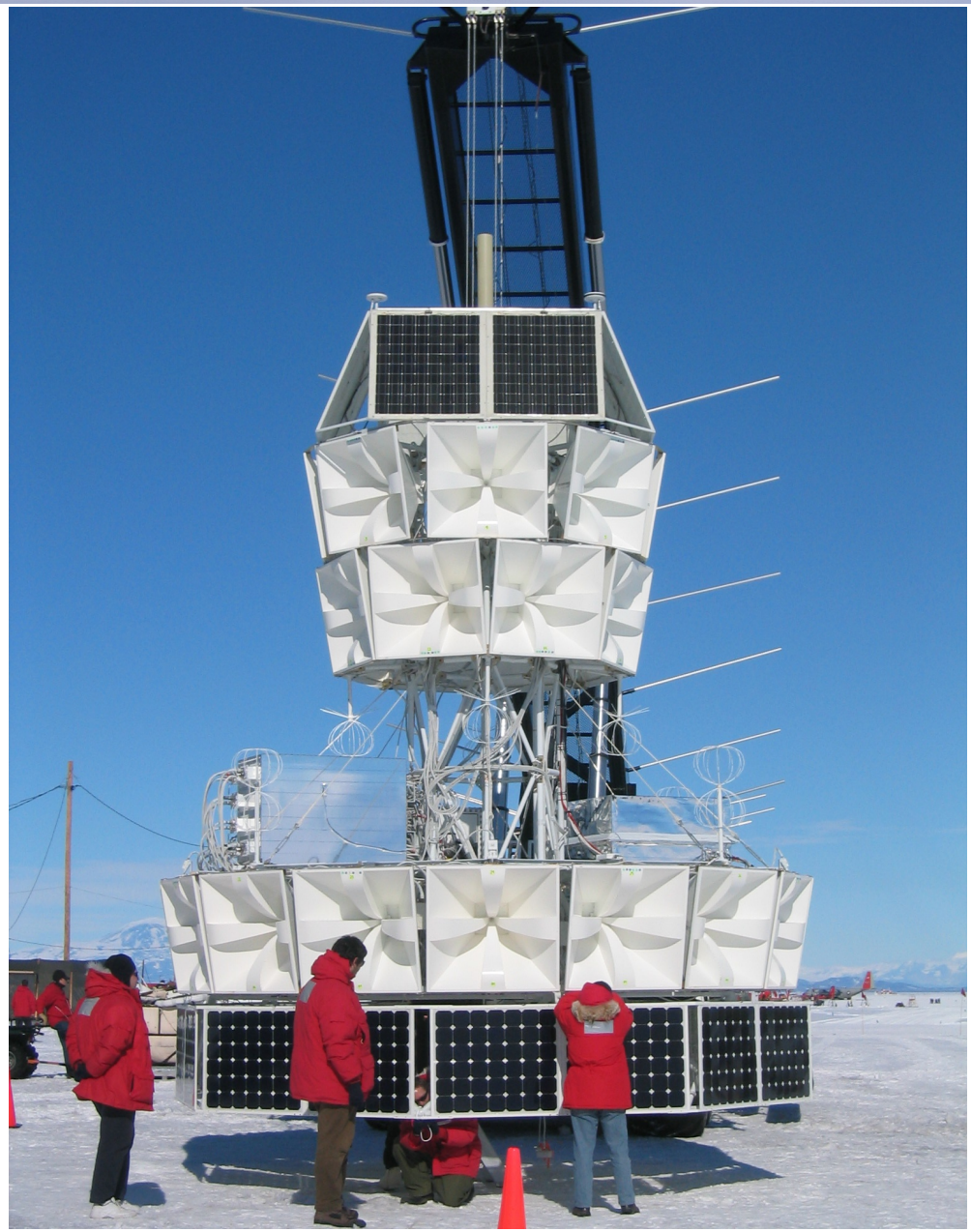


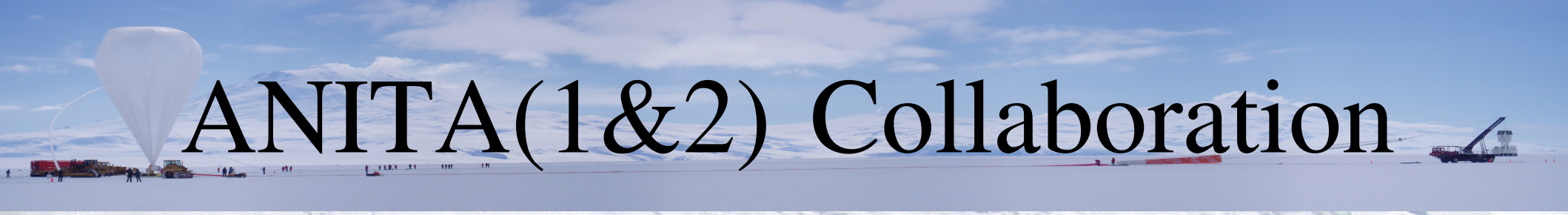
The Search for Astrophysical Ultra High Energy Neutrinos

Kimberly J. Palladino

THE OHIO STATE UNIVERSITY

for the ANITA Collaboration





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*are no longer at said institution

Talk Outline

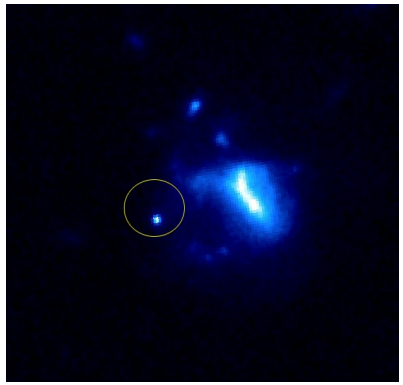
- Sources of UHE Neutrinos
- Radio Detection of Neutrino Induced Showers
- ANITA concept and design
- ANITA's '06-'07 Flight
  - Calibration and RF Performance
  - Event Reconstruction
  - Preliminary limits
- ANITA '08-'09 Outlook

Astrophysical Sources

The (Almost) Mundane:

AGN M87 with Jets from HST

- Neutrino sources may be the same as sources of UHECRs:
  - -AGNs
  - -GRBs
- Covered by the Waxman-Bahcall bound
- Generally assume $L_\gamma \sim L_p \sim L_\nu$

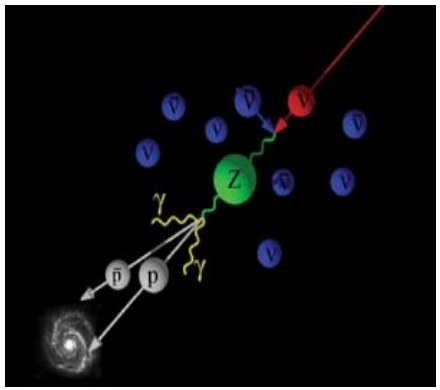


GRB 050709 from HST

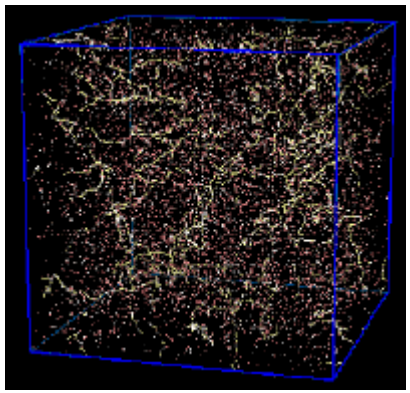
A Little more Exotic:

New mechanisms allow the WB bound to be exceeded

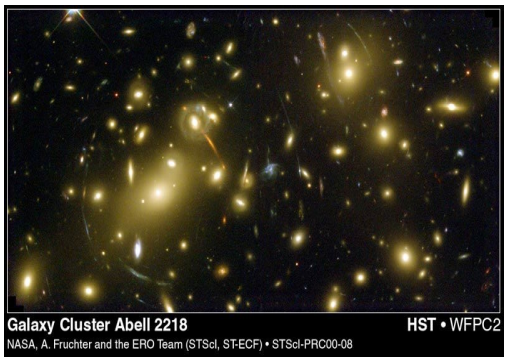
Z-bursts



Topological Defects

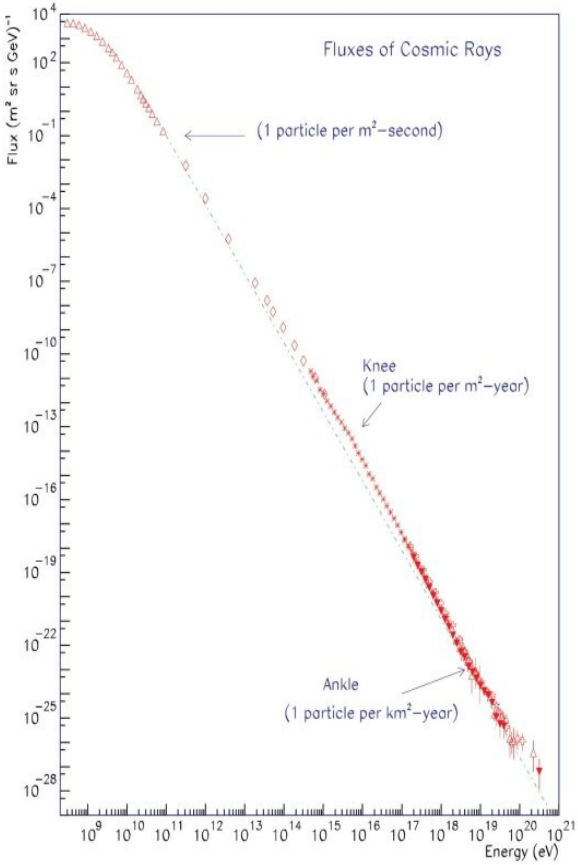


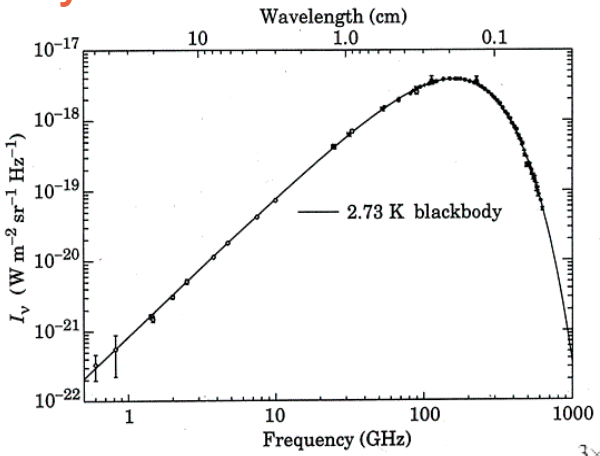
Massive Dark Matter Decays



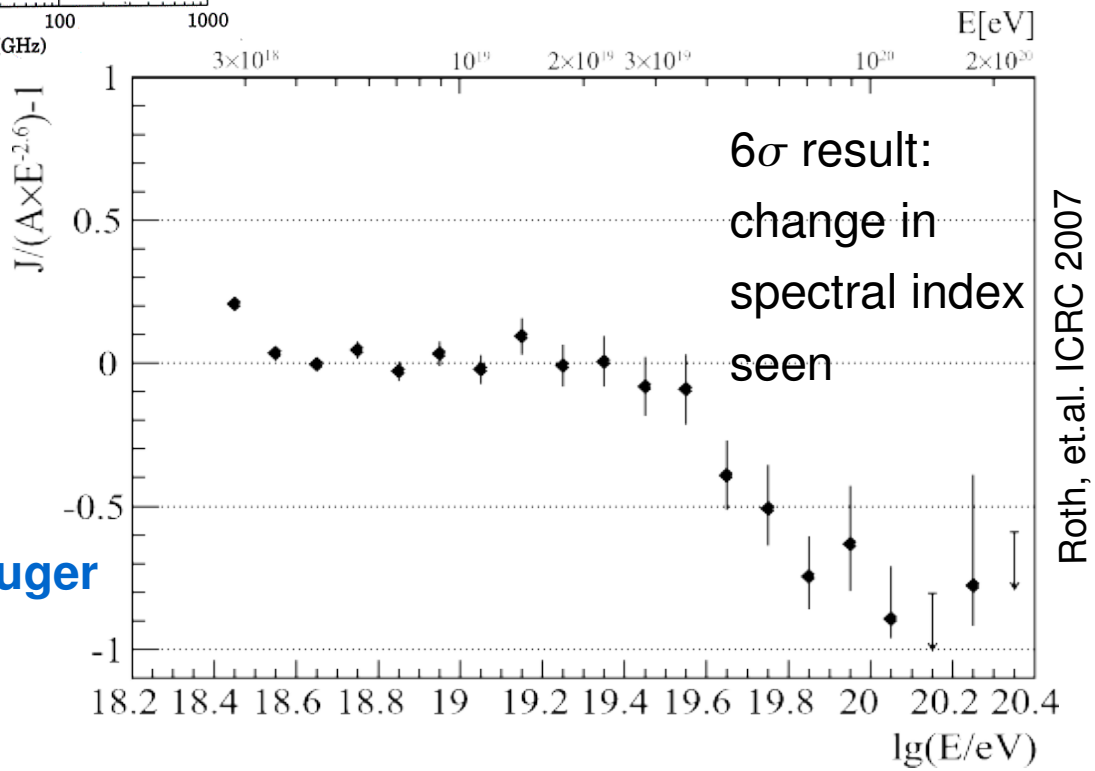
GZK Neutrinos: Guaranteed

High Energy Cosmic Rays will interact with the CMB- and produce neutrinos!





$$p + \gamma_{CMB} \rightarrow \Delta^+ \rightarrow \pi^0 + p$$
$$\rightarrow \pi^+ + n$$
$$\rightarrow \mu^+ + \nu_\mu$$
$$\rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

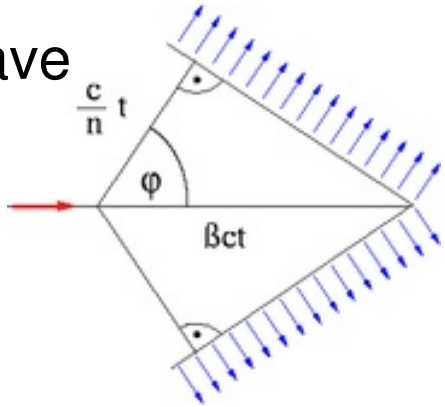


Confirmation of GZK cutoff by HiRes and Auger

Radio Cherenkov: Askaryan Effect

So how are we going to detect high energy neutrinos?

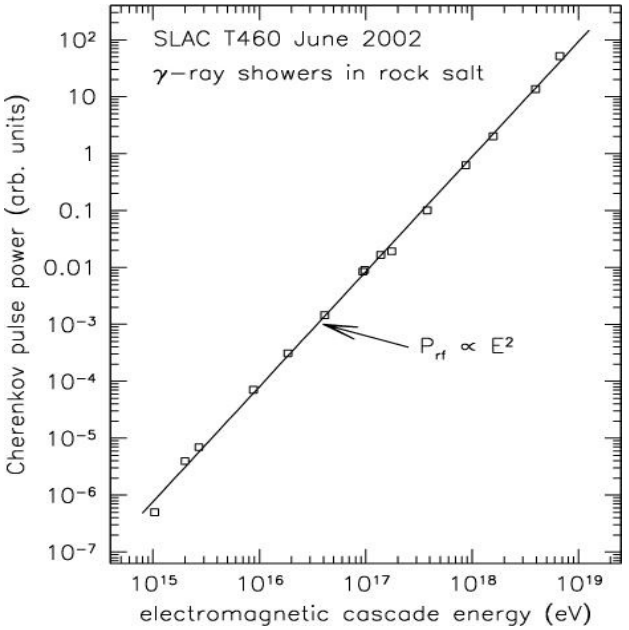
Neutrino interacts → particle shower →showers in matter have 20% excess negative charge



- Compton scattering: $\gamma + e^-(\text{at rest}) \rightarrow \gamma + e^-$
- Positron annihilation: $e^+ + e^-(\text{at rest}) \rightarrow \gamma + \gamma$

Excess Charge with v>c/n → Cherenkov radiation!

Seen experimentally at SLAC!

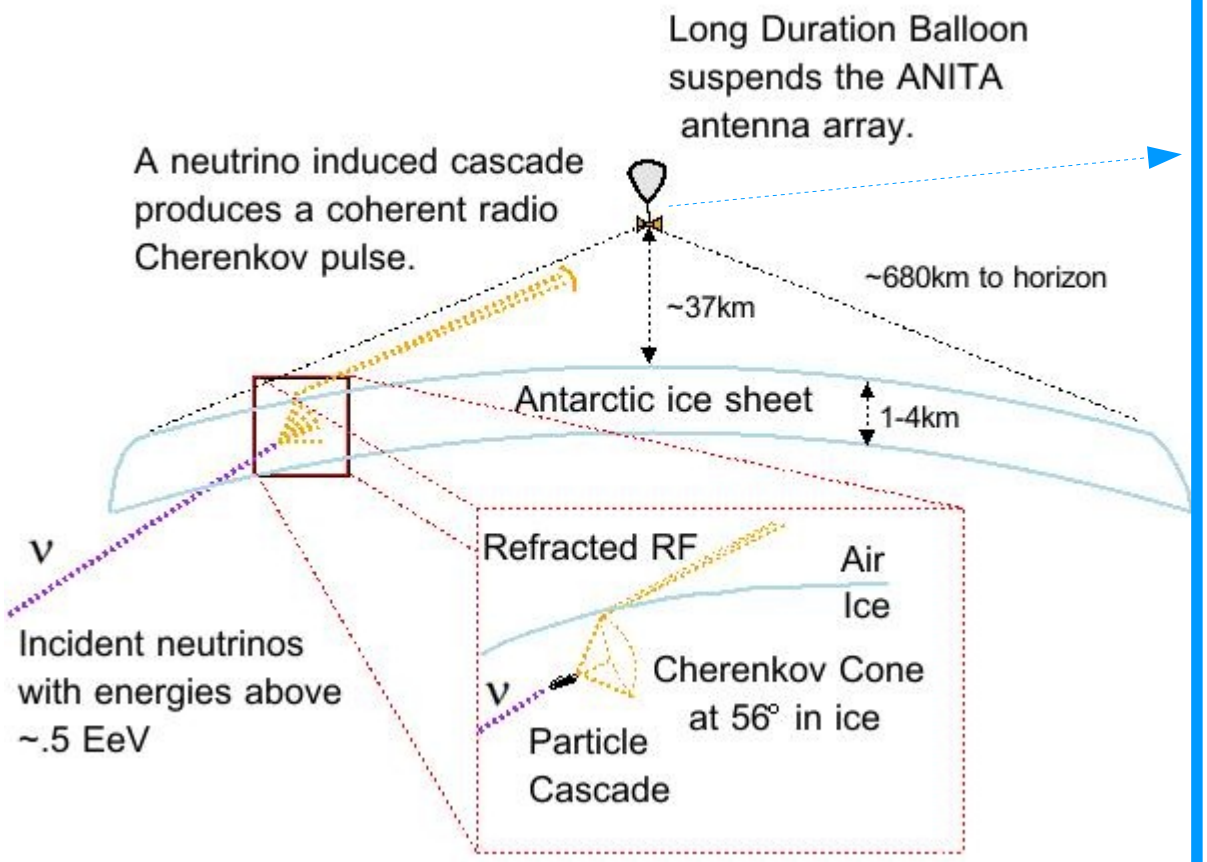


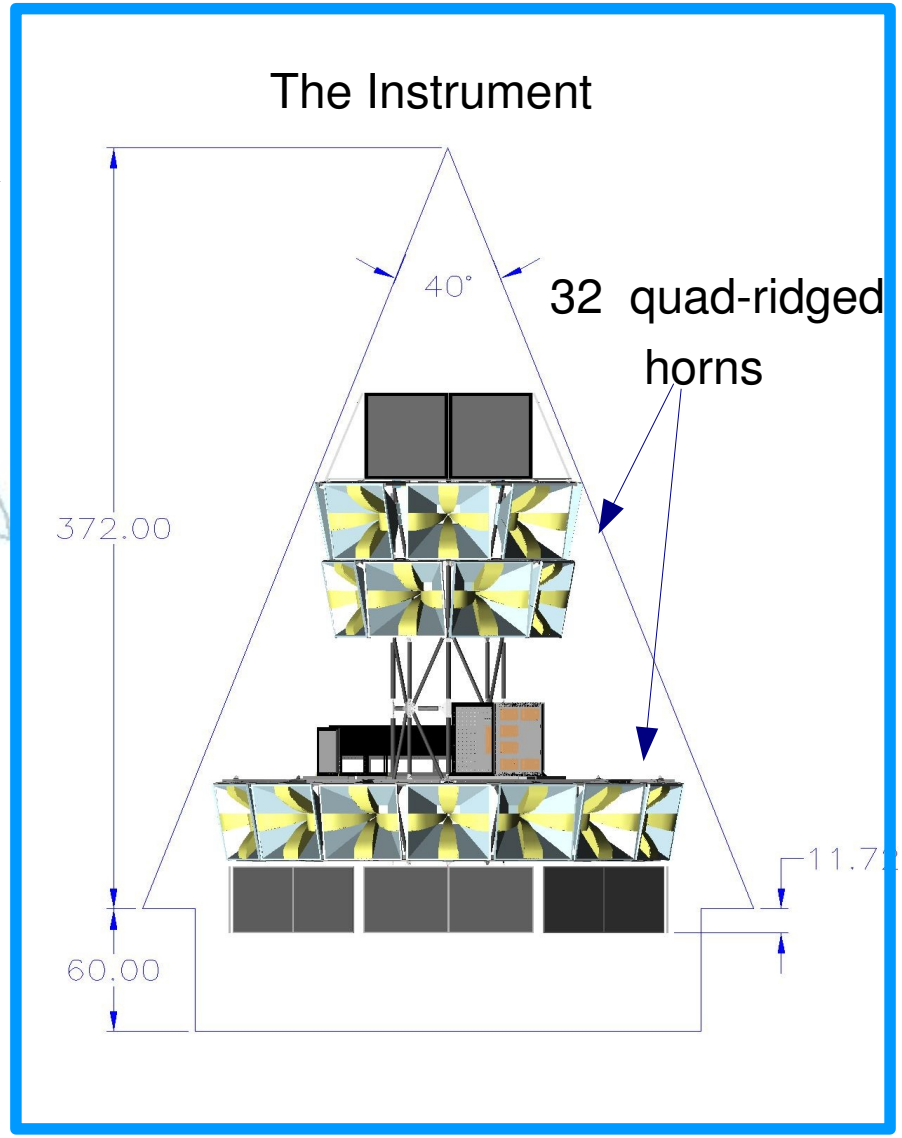
Saltzberg, *et al.* **PRL 86,** (2001)2802

Askaryan Signal Characteristics

- Coherent in Radio Frequencies
- Power goes as E^2
- Peak Field Strength at Cherenkov angle
- Field strength increases with frequency
- Linearly polarized signal

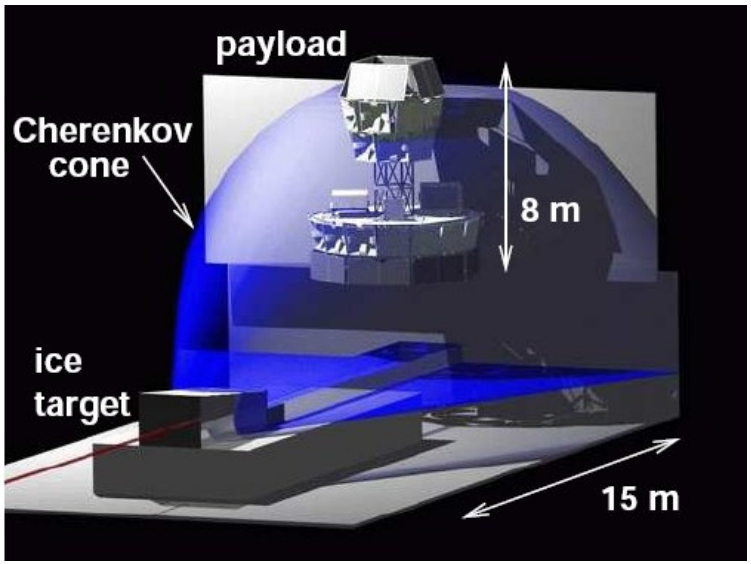
ANITA Concept and Design





- .2-1.2 GHz bandwidth
- 3 GHz digitization
- Impulses resolved to 1 ns
- 1.5 M km^2 viewing area

ANITA & Askaryan in the Lab



Full payload

7.5 ton ice target

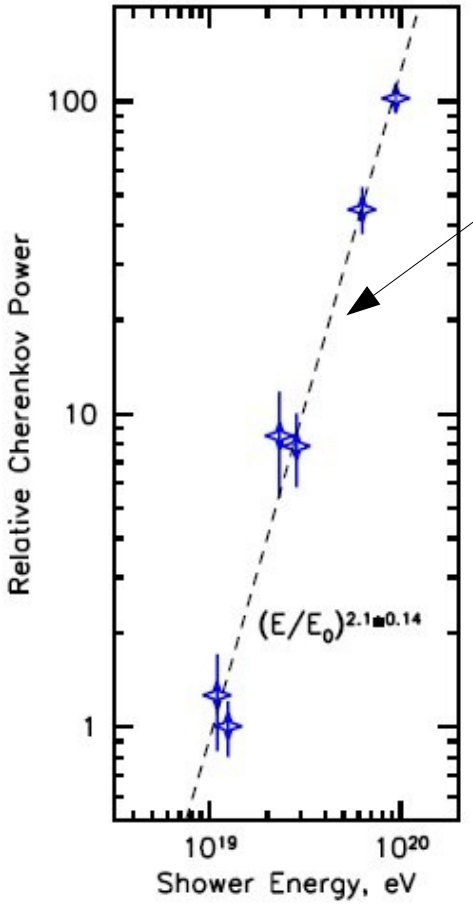
Showers of $10^{8\text{-}9}$ e^- of 28 GeV

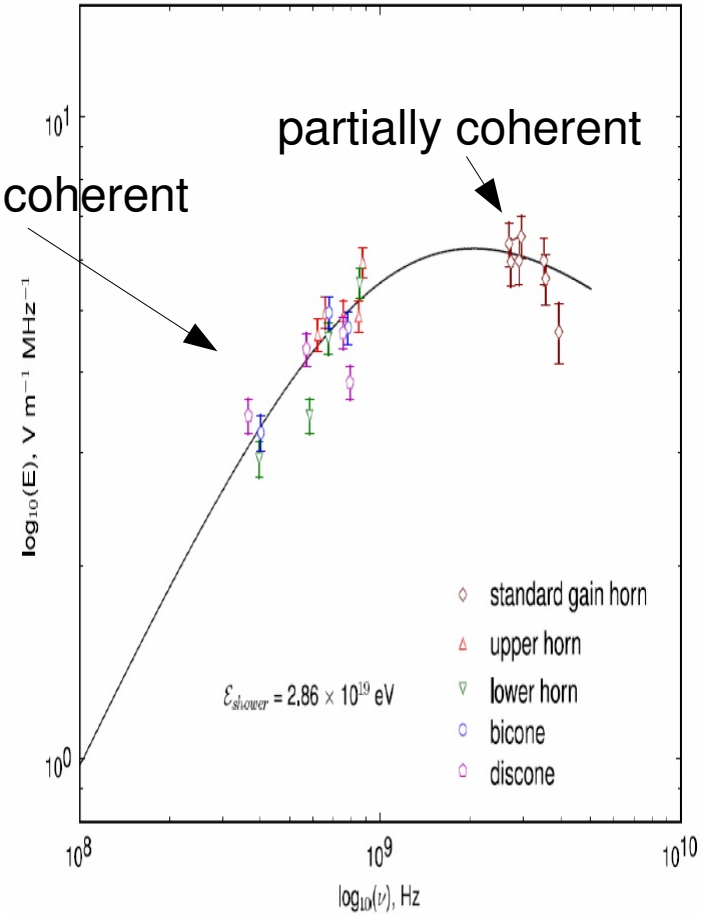
total ~3x10^19 eV

1st direct observation of radio cherenkov cone verified:

- frequency dependence
- angular dependence
- shower energy dependence

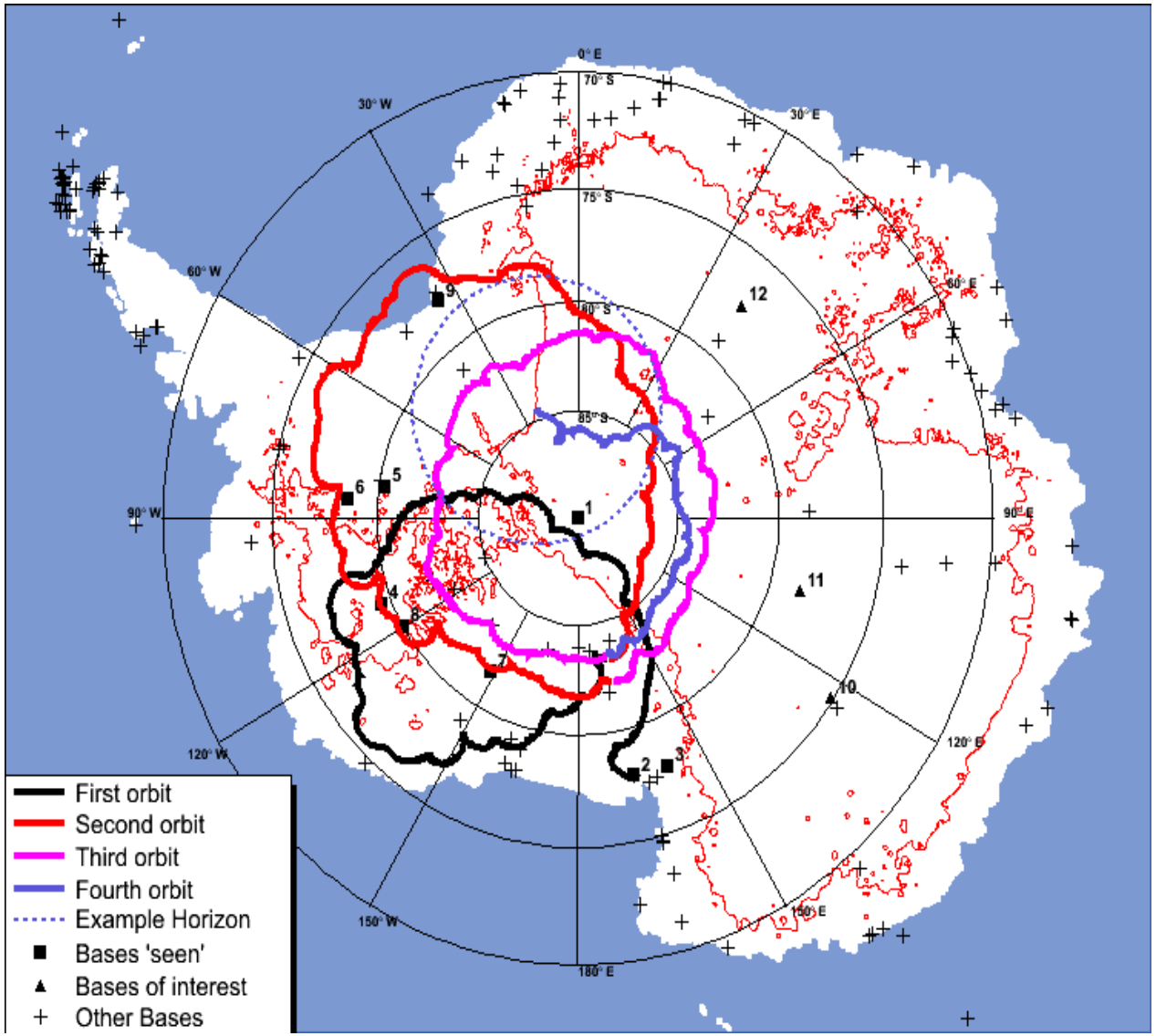
June 2006: Beam test at SLAC, T486





Gorham, et.al. PRL.99:171101,2007.

ANITA's '06-'07 Flight



Launched Dec. 15 2006

Terminated Jan. 19 2007

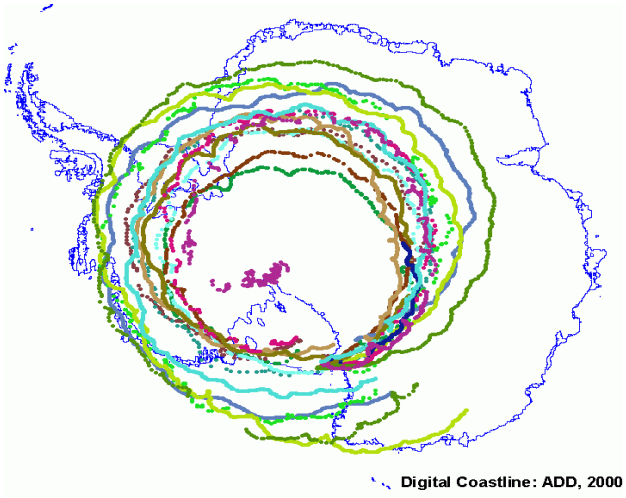
3.5 orbits

Live time of ~18 days

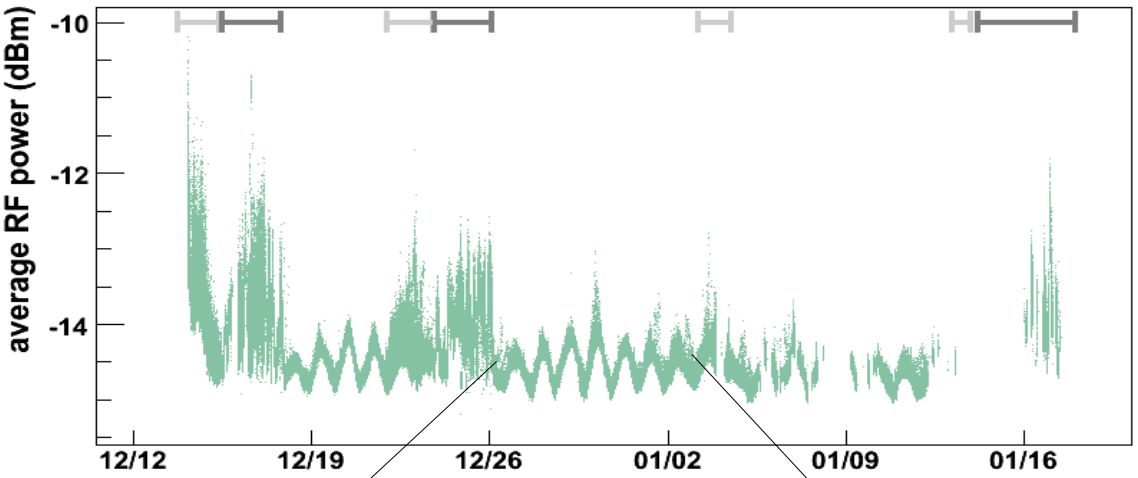
Out of view of bases ~8 days

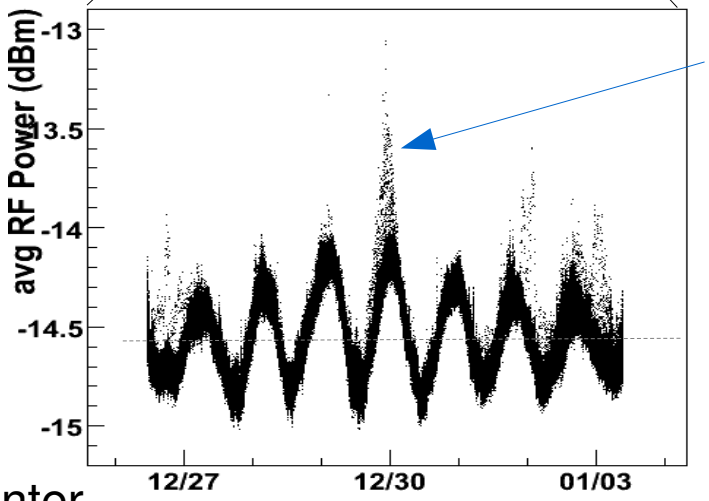
Avg ice depth in view 1.7 km

One of these flight paths doesn't look like the others....



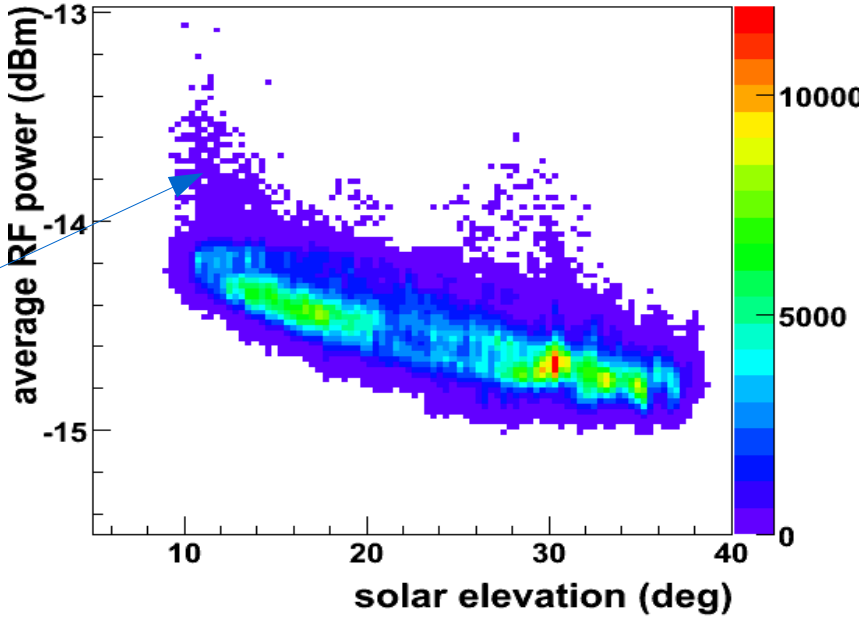
RF Performance





Bases clearly seen in average RF Power

Diurnal modulation due to solar angle



ANITA was over water

$\Delta T \sim 50K$ due to sun + galactic center

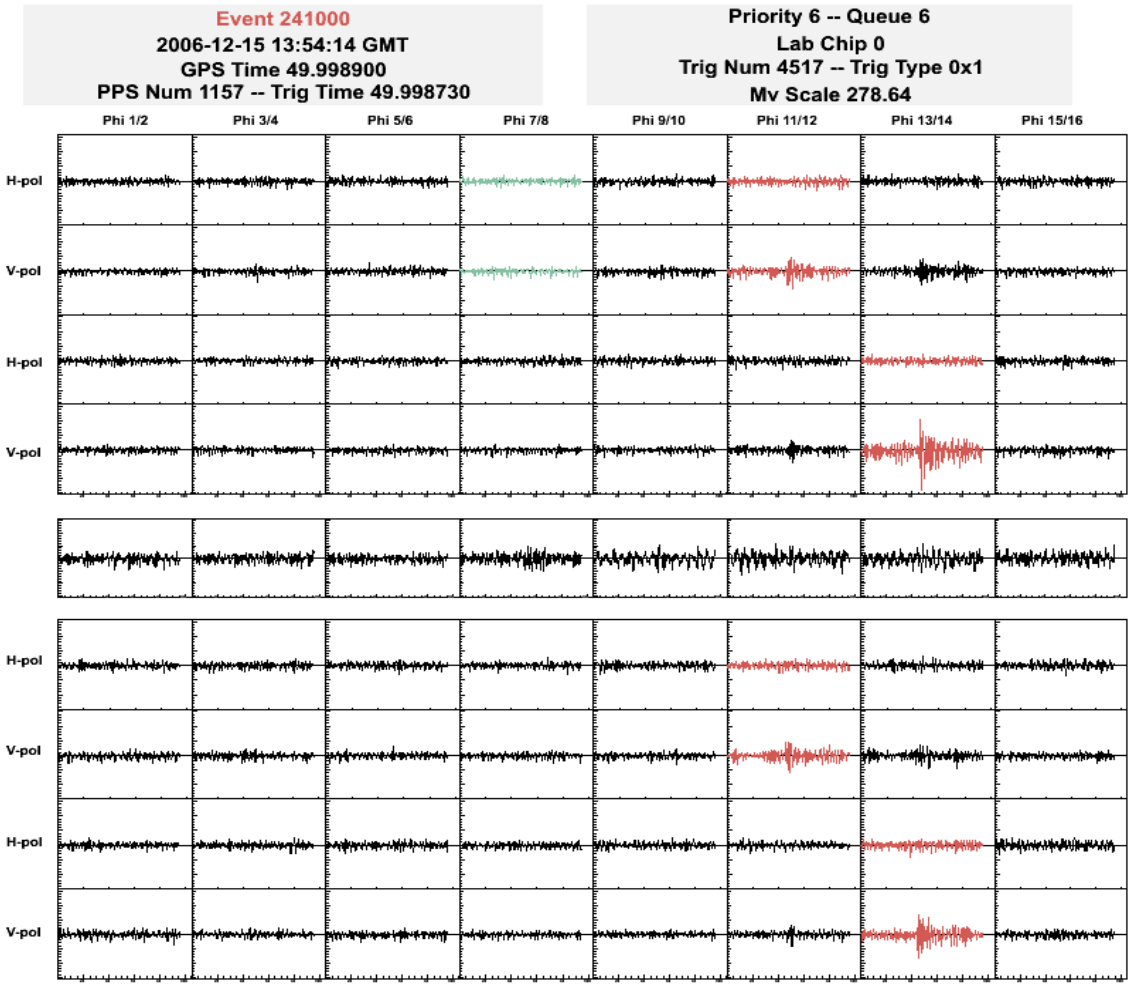
Thermal noise floor: $T_{sys} + T_{ice} + T_{sky}$

~140K + ~230K + 20-80K → <T> ~180K

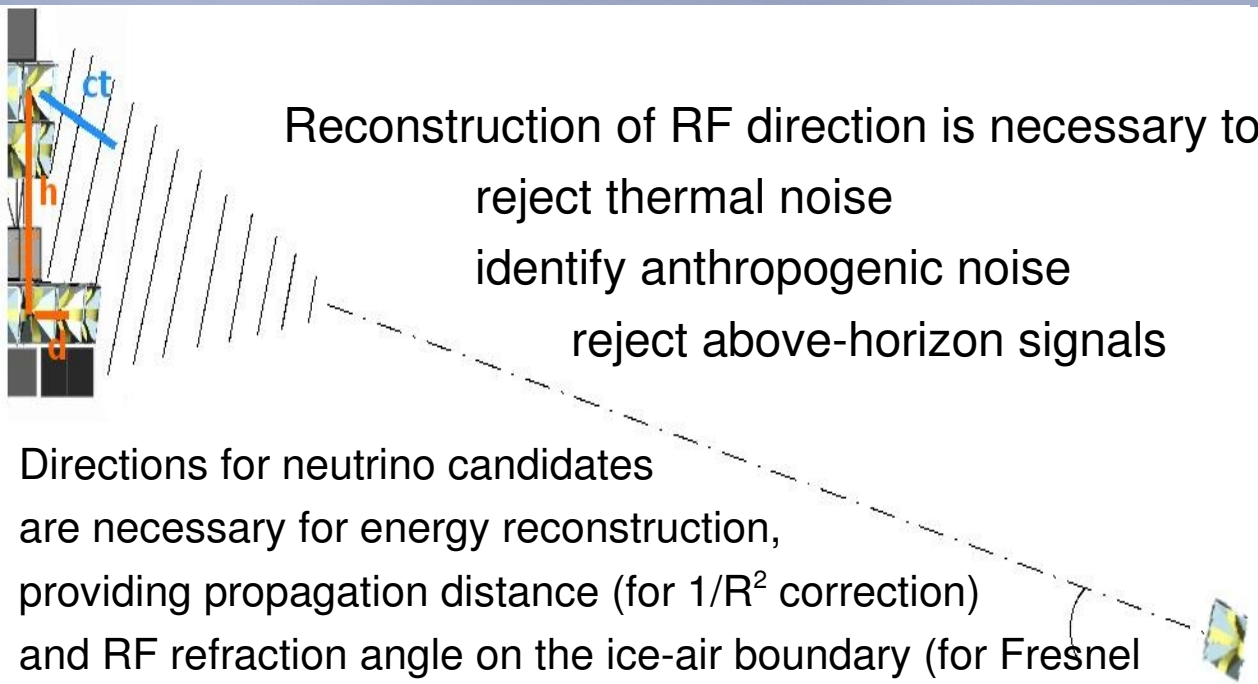
Ground Calibration Pulses

Above ground and in ice transmitting antennas at both McMurdo and the Taylor Dome field camp

Willy Field (McMurdo) borehole pulser events from 25m depth - primary test of reconstruction



Pulse-Phase Interferometry



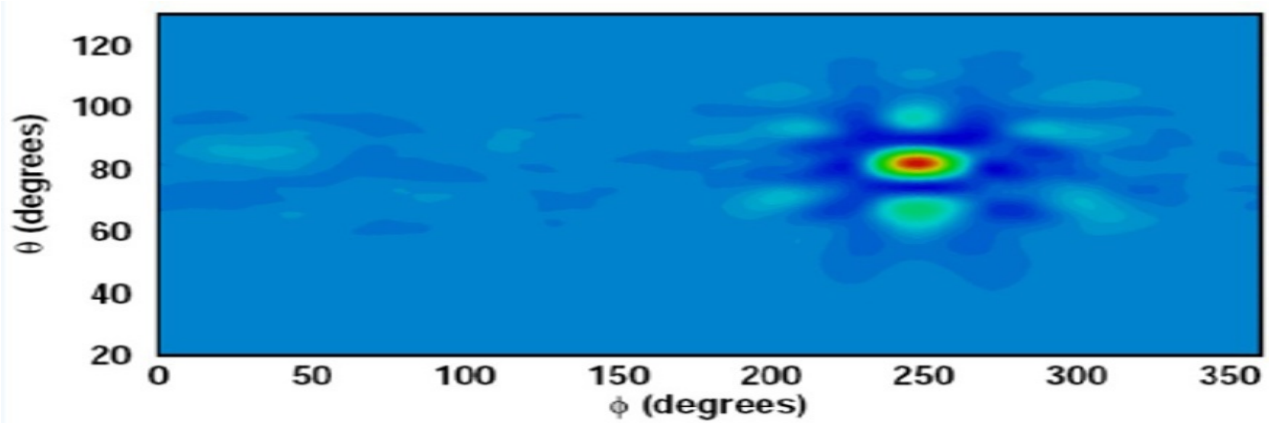
Reconstruction of RF direction is necessary to:

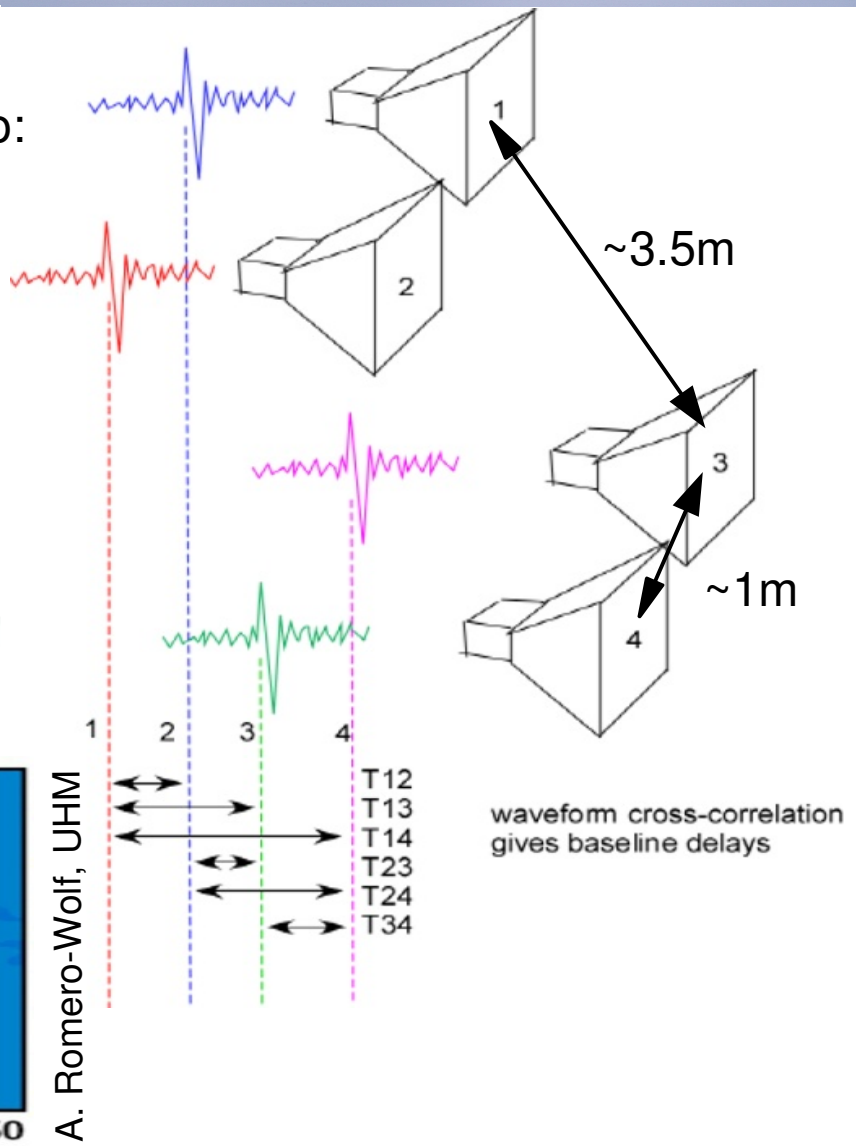
reject thermal noise

identify anthropogenic noise

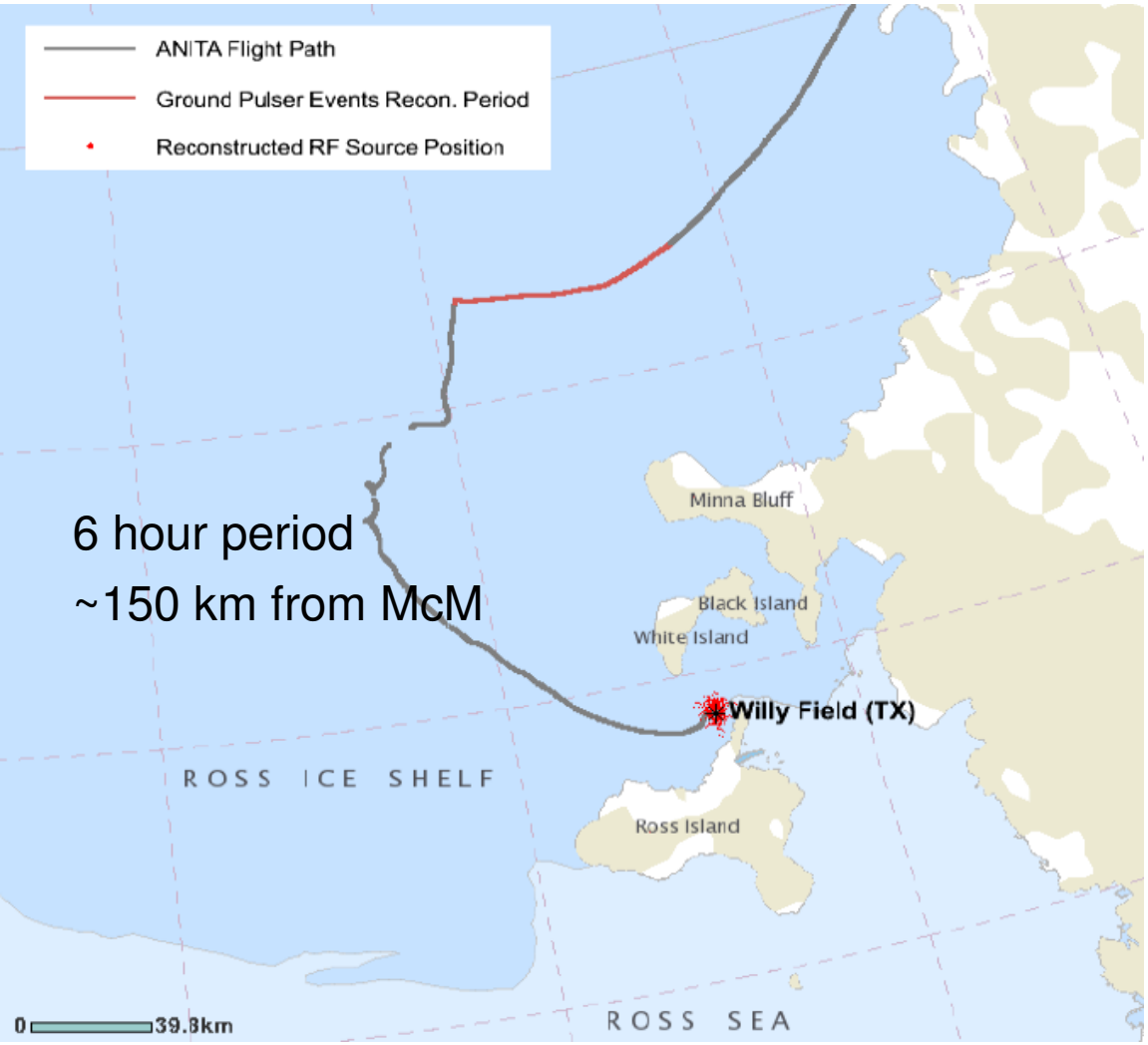
reject above-horizon signals

Directions for neutrino candidates are necessary for energy reconstruction, providing propagation distance (for $1/R^2$ correction) and RF refraction angle on the ice-air boundary (for Fresnel correction).





Borehole Event Reconstruction



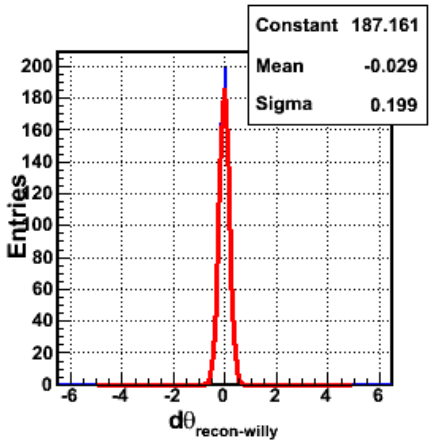
6 hour period
~150 km from McM

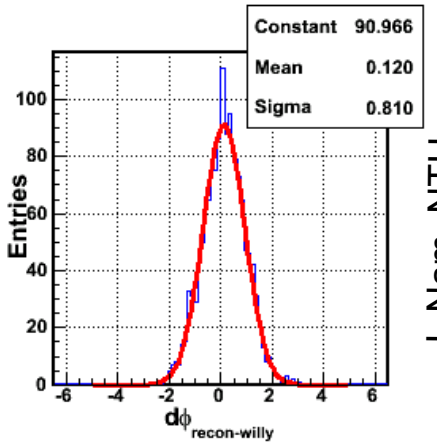
J. Nam, NTU

Timing resolution:
- 40 ps (vertical, recorded on same board)
- 60 ps (horiz., between boards)

Angular resolution:
- 0.2° elevation
- 0.8° azimuth

Reconstruction efficiency:
- 98% for SNR >4.5
- .02% mis-reconstruction rate





J. Nam, NTU

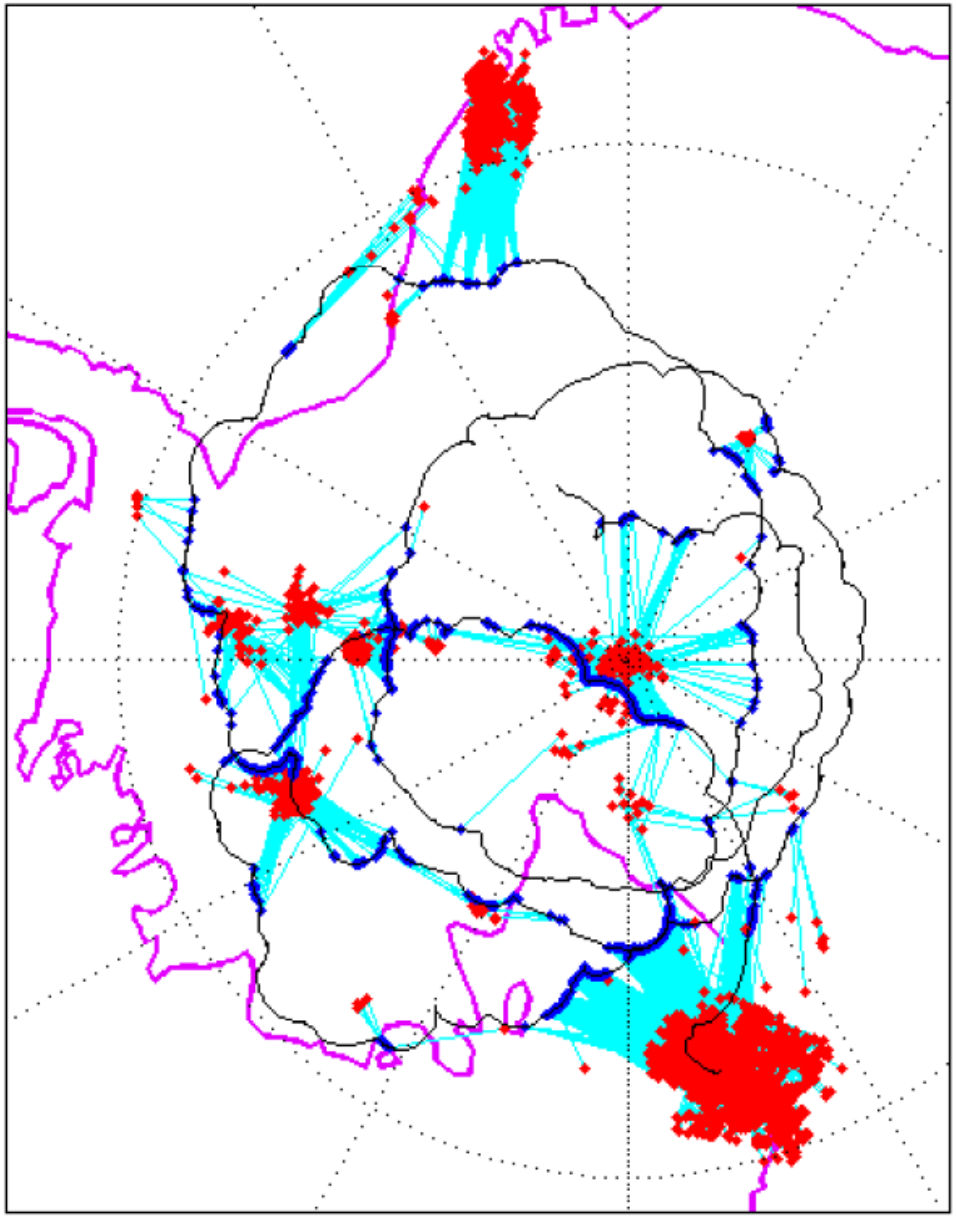
Prelim Analysis 1

44,914 events reconstruct to Antarctic surface

14 events pass 3σ cut in overlap of projected error ellipses

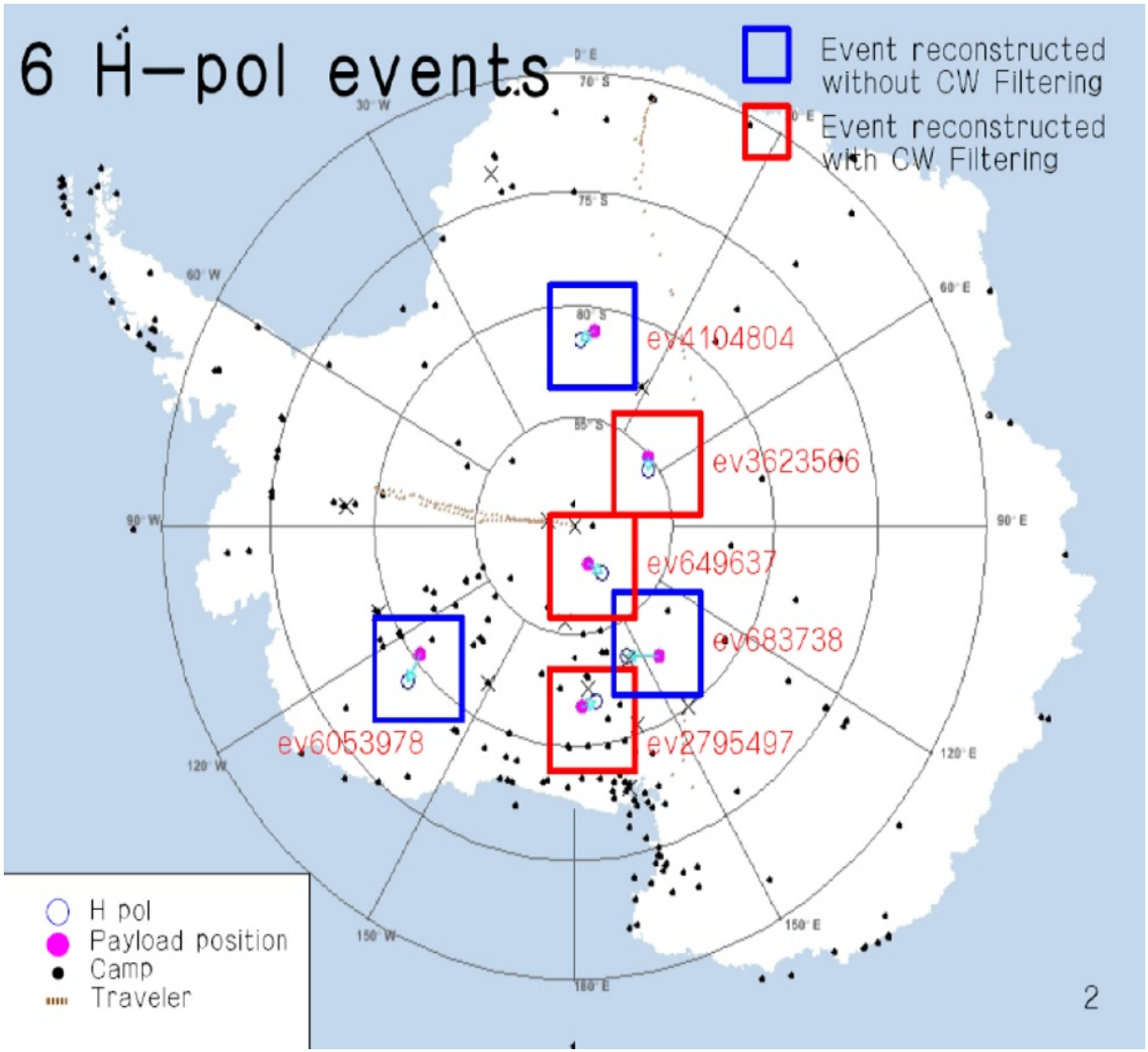
5 events pass CW filtering and reconstruction consistency

Full RF analysis of these events, including horizontal polarization as well as another look at nearby anthropogenic sources still remains to be done.



A. Romero-Wolf, UHM

Prelim Analysis 2



J. Nam, NTU

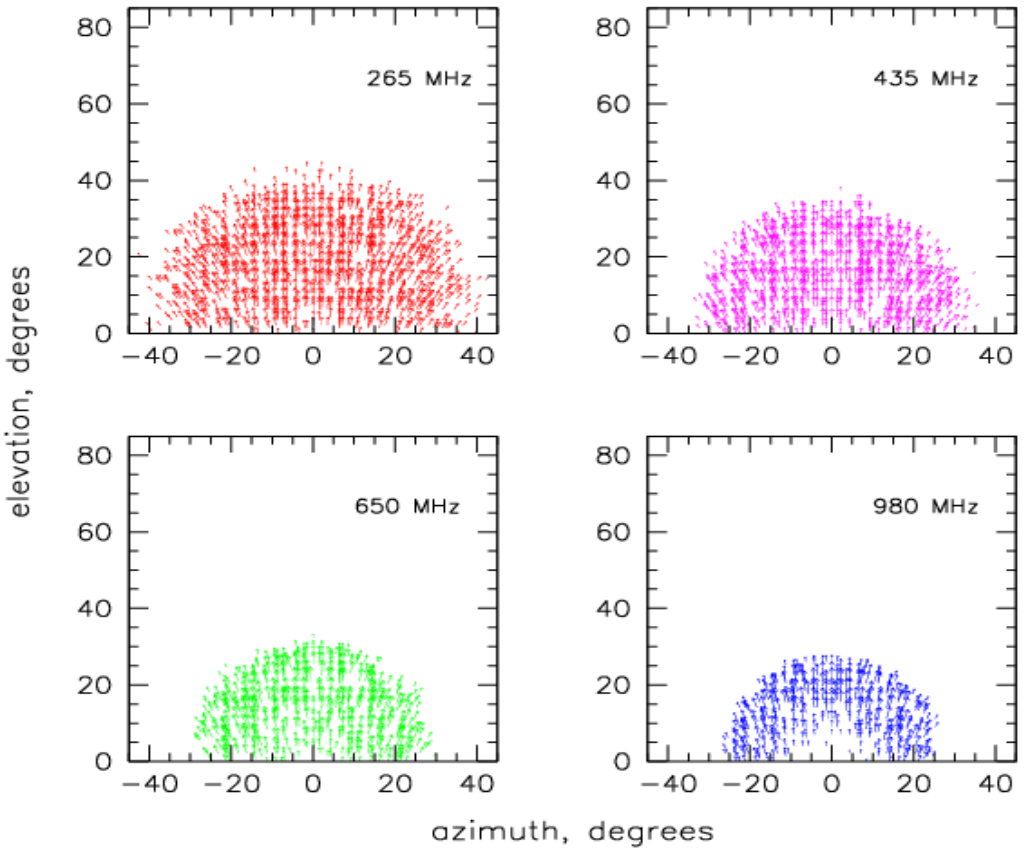
- 19695 events reconstruct as impulsive vents from Ant. surface (9600 V-pol, 10095 H-pol)
- 0 V-pol events pass cuts of repeating location (H, V, H+V) or within 50 km of known camp*
- 6 H-pol events pass location cuts
- 5 H-pol events pass CW filtering

*known camps: any man-made installation, most inactive, but static discharge from exposed metals are possible

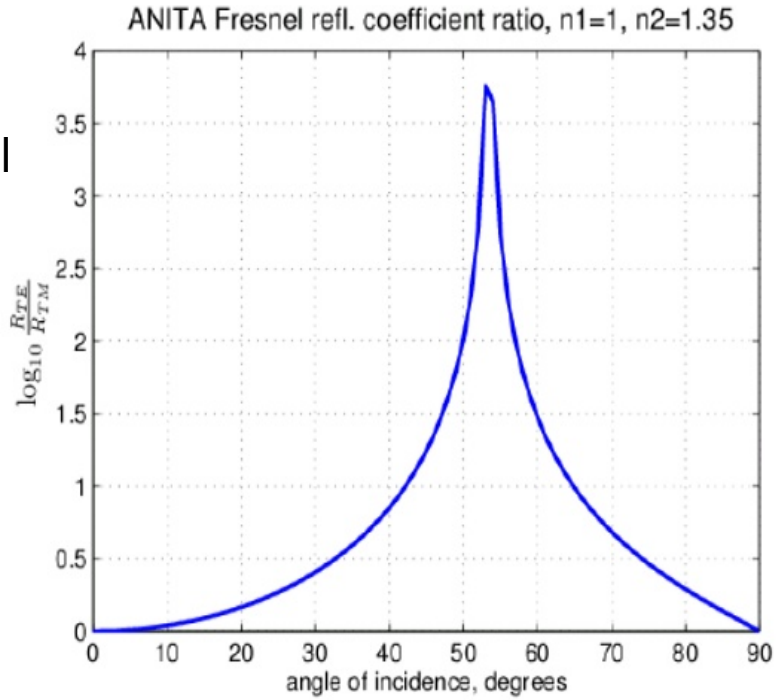
Horizontal Backgrounds

Askaryan pulses will primarily be V-pol

- only top quadrant of Cherenkov cones escapes TIR
- Fresnel coefficient has greater transmission of V-pol (TM) than H-pol (TE)



P. Gorham, UHM



P. Gorham, UHM

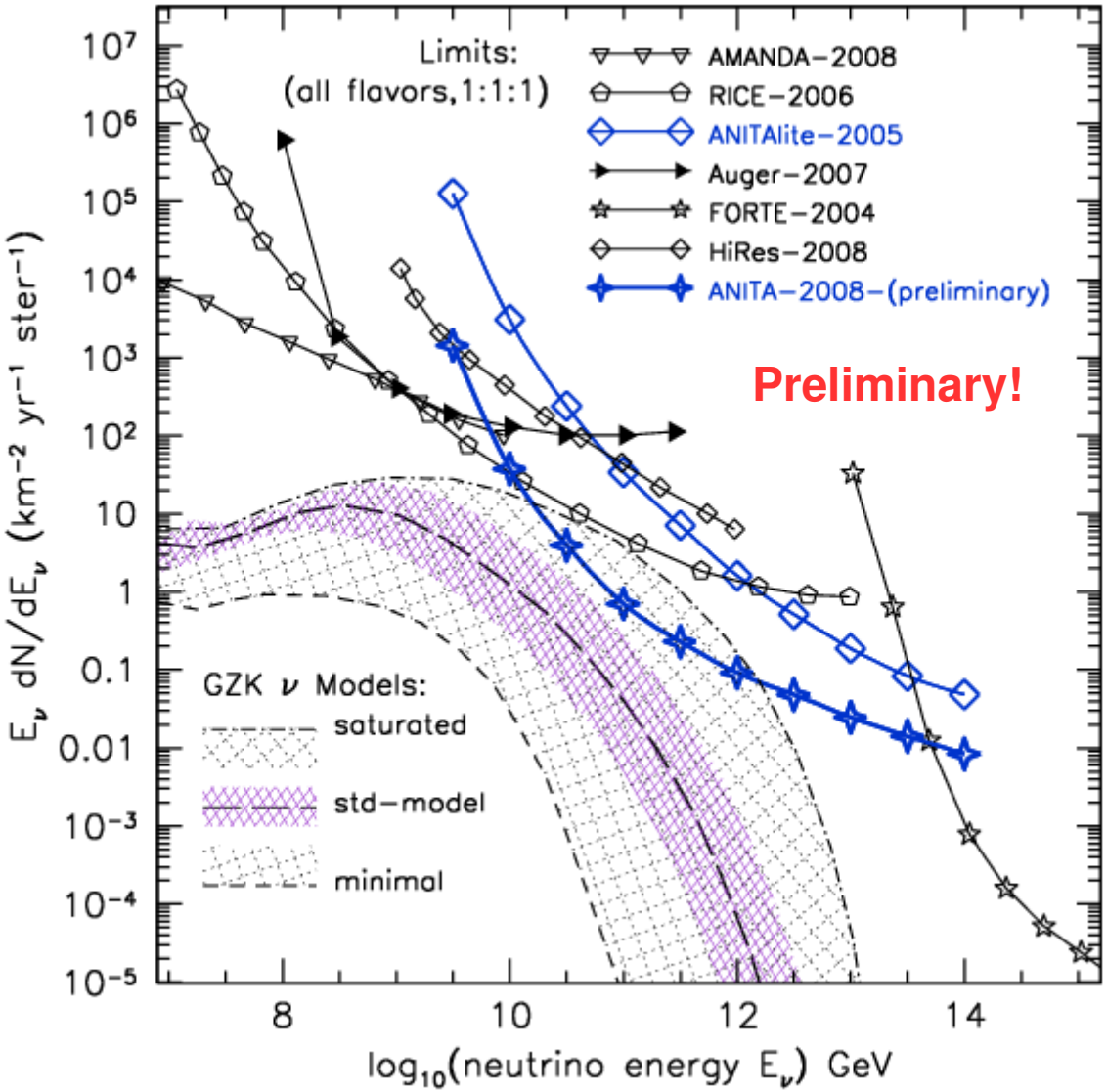
Fresnel Coefficients have greater reflection of H-pol (TE) from above ice

New EAS MC indicates 4.5±.5 horizontal background events

H-pol events could be anthro. reflections

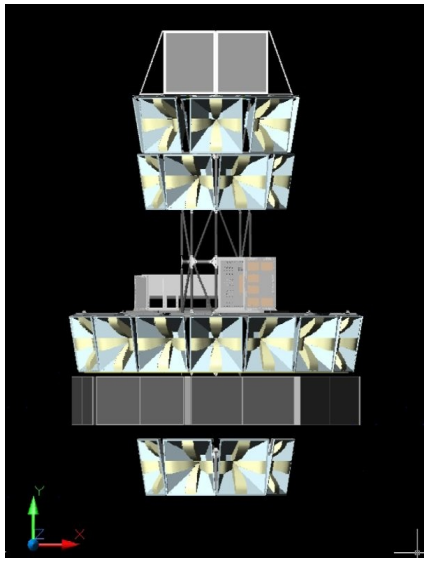
Preliminary Flux Limit

GZK models:
std: ESS flux
max: Berezinsky
mirror matter
min: iron primaries



P. Gorham, UHM

ANITA-II Improvements



Hardware additions

New tier of 8 antennas:

gain in sensitivity, and timing baseline for reconstruction

New RF front end:

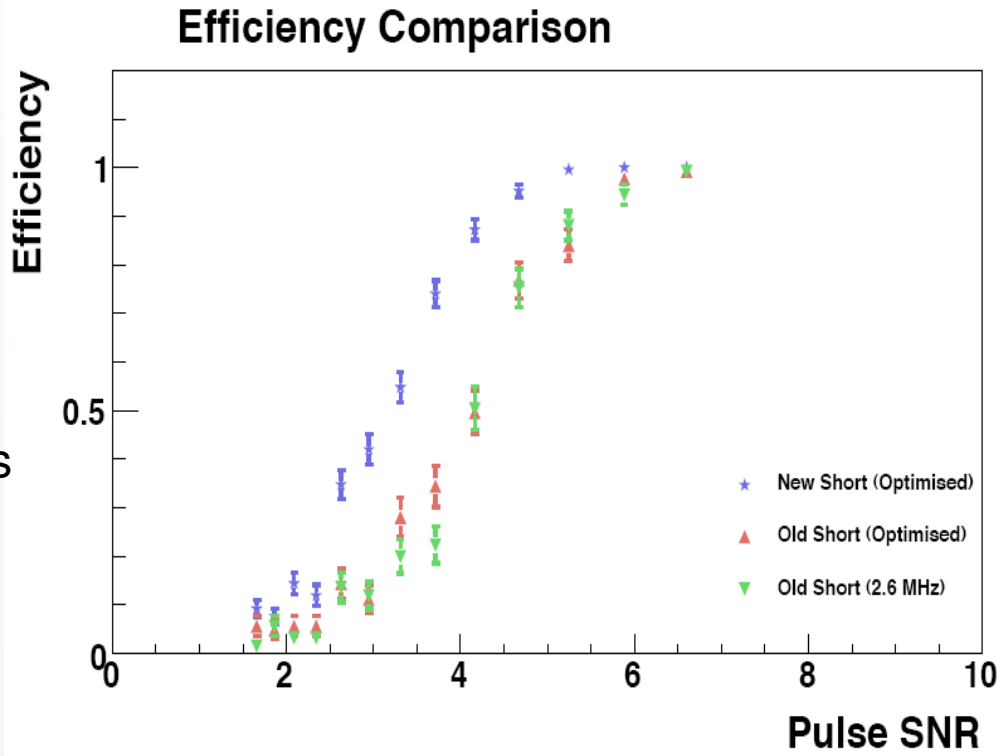
Improvement of 40K in system temperature

Trigger Scheme

Vertical polarization trigger

New trigger bands including fullband

Active direction masking for handling bases



R. Nichol, UCL

ANITA-II Outlook

Scheduled Flight for this coming Antarctic Season '08-'09

Gain a factor of 1.7 in energy threshold

(drop-downs + trigger + T_{sys})

Event rate $\propto E_{thr}^{-2} \rightarrow 1.7^2 \approx$ factor of 3

Improvement of 30% possible with a better trajectory and low thresholds maintained with direction masking

Improvement of 40% possible in live time

Total possible gain in event rate: 3 x 1.3 x 1.4 ≈ 5

Summary

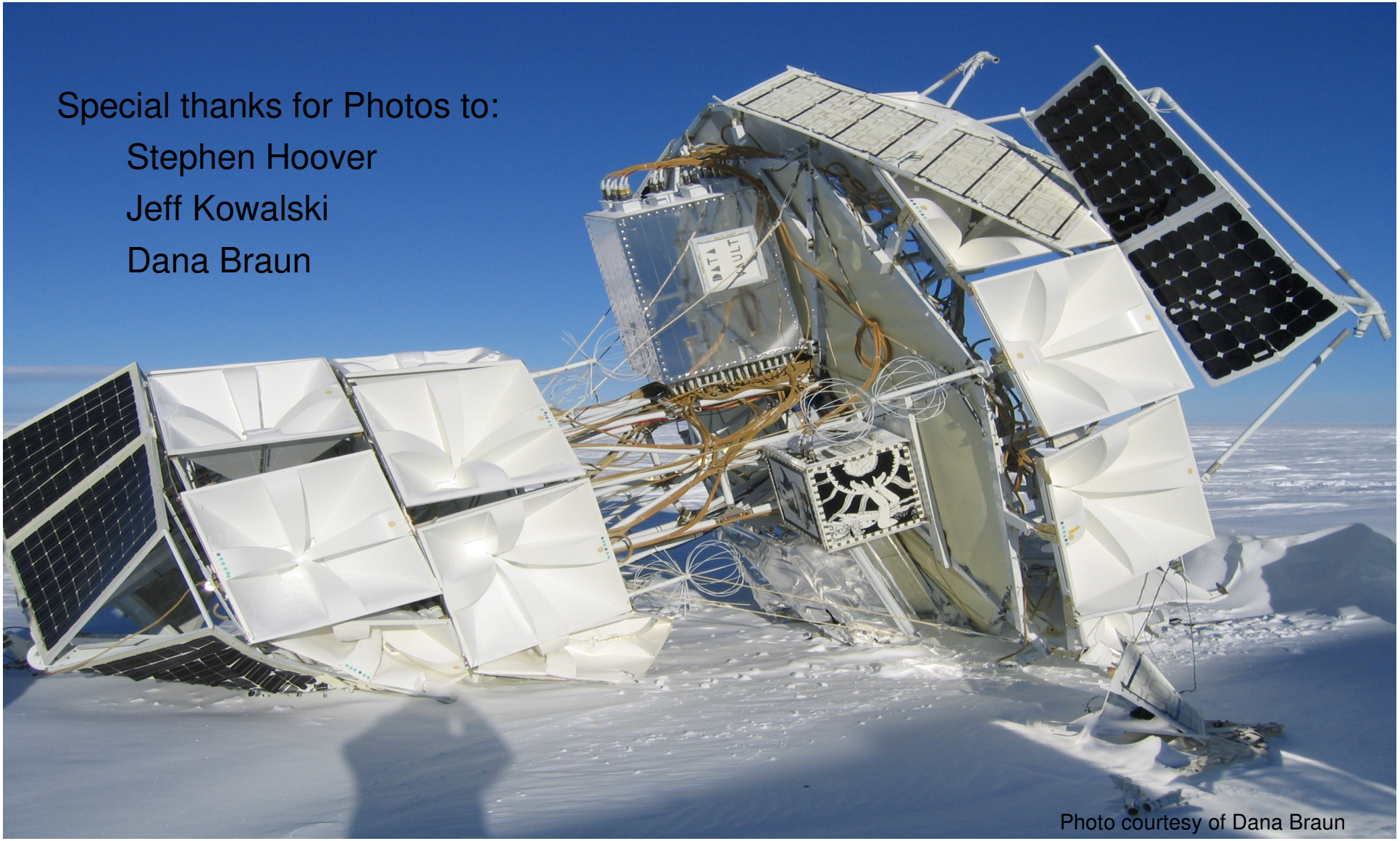
Analysis ongoing for ANITA '06-'07 flight

- **No neutrinos identified, but still refining analysis and Monte Carlo**
- **Further analyses for neutrino cross-section, flavor identification, monopole, and GRBνs coming**
- **Source evolution models will be constrained**

ANITA '08-'09 flight will be able to dig deep into GZK flux model space

- **Improved hardware and Trigger logic and settings can nearly double the sensitivity**
- **Luck with flight path and length (meeting historical means) can bring similar gains**

The End


Special thanks for Photos to:
Stephen Hoover
Jeff Kowalski
Dana Braun
Photo courtesy of Dana Braun