Probing Physics at Energy Frontier

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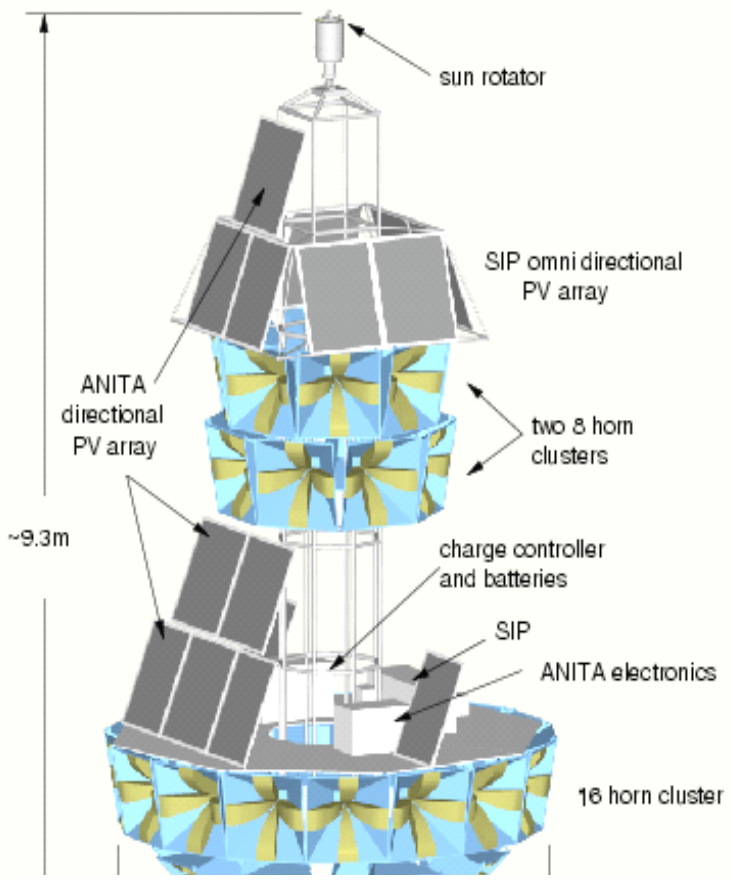
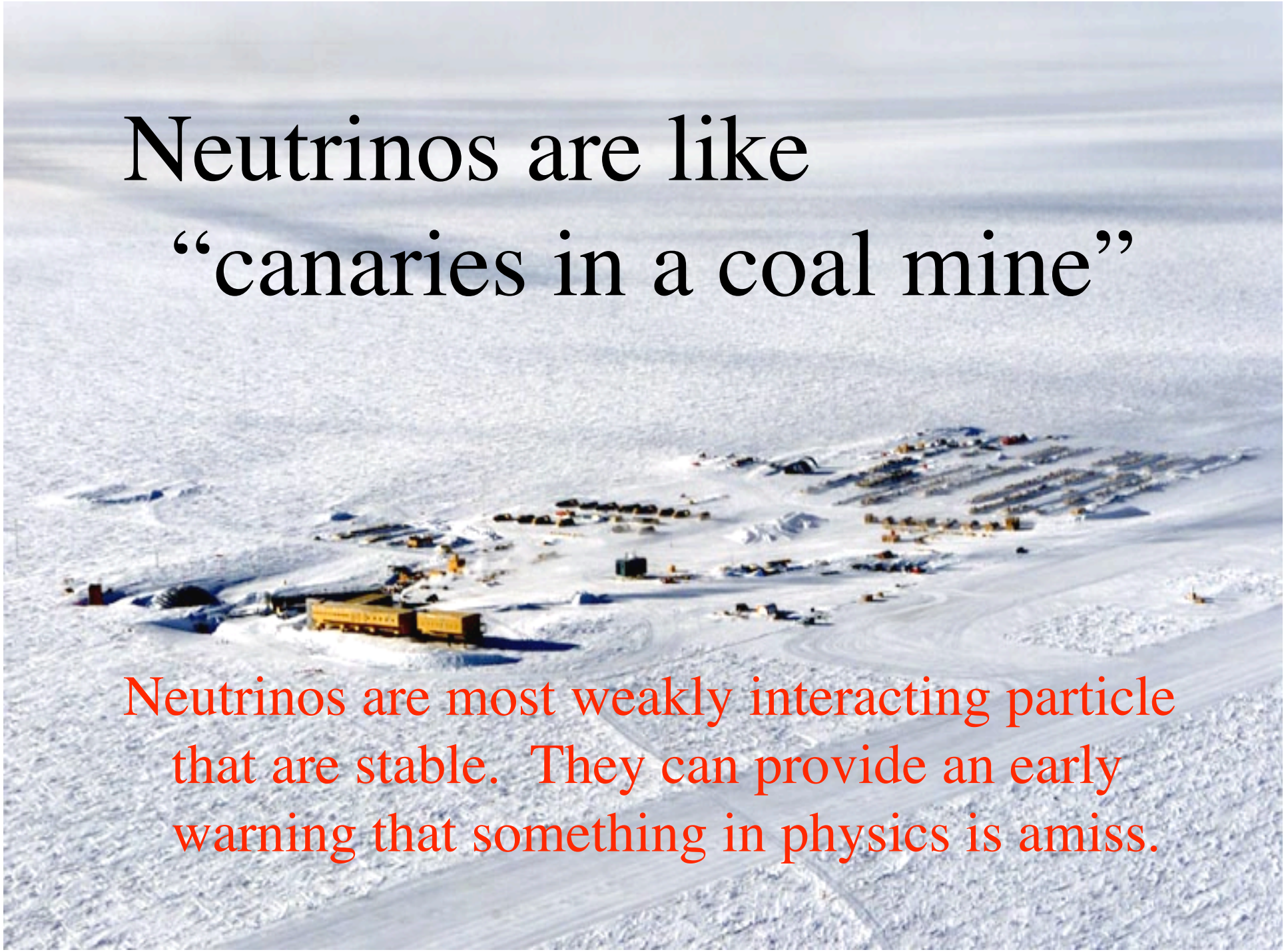
ANITA Collaboration

U. Hawaii, UCI, UCLA,
JPL, Wash. U., Ohio State,
Penn State, U. Delaware
(Bartol), U. Minnesota



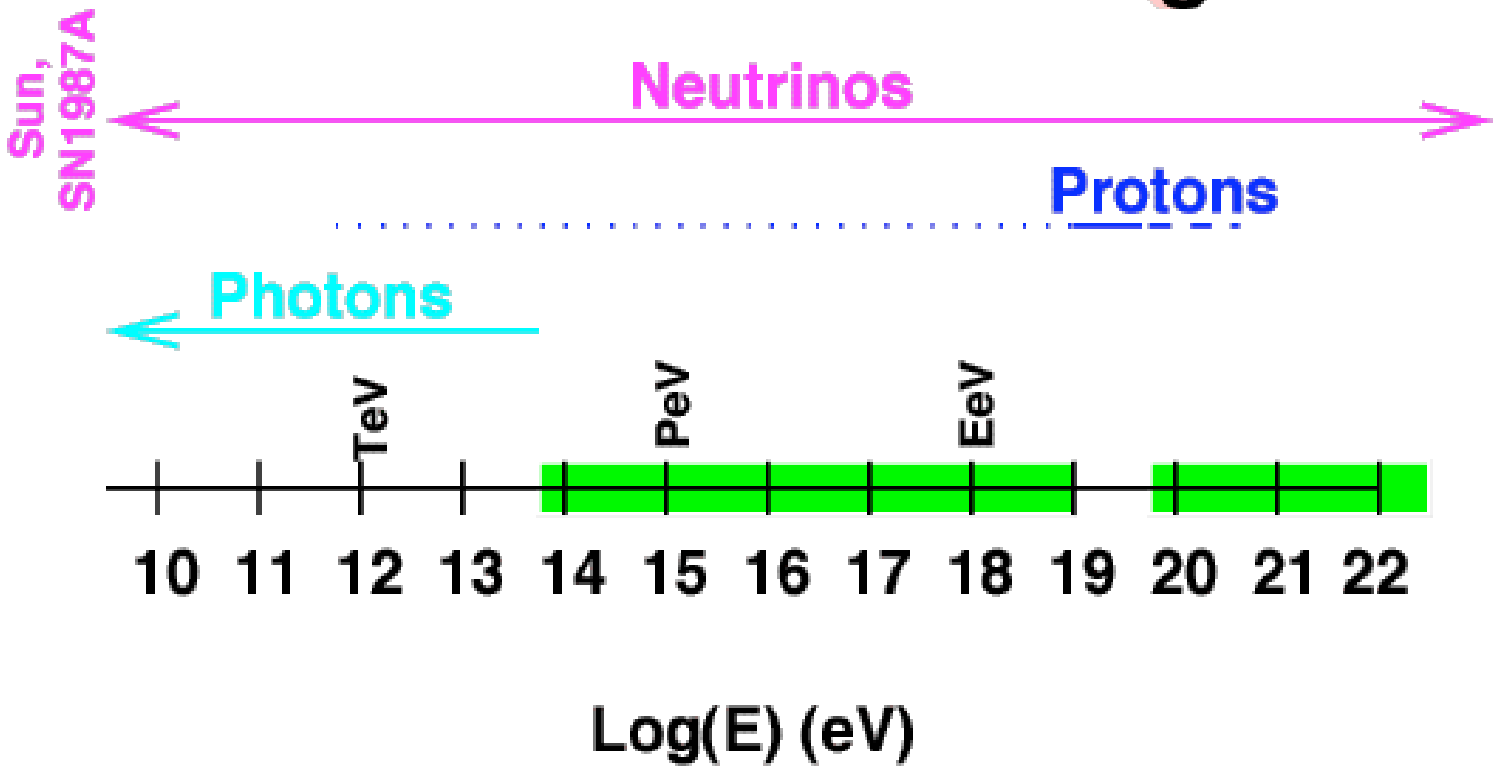
http://www.ps.uci.edu/~anita

Neutrinos are like "canaries in a coal mine"



Neutrinos are most weakly interacting particle that are stable. They can provide an early warning that something in physics is amiss.

Astronomical Messengers

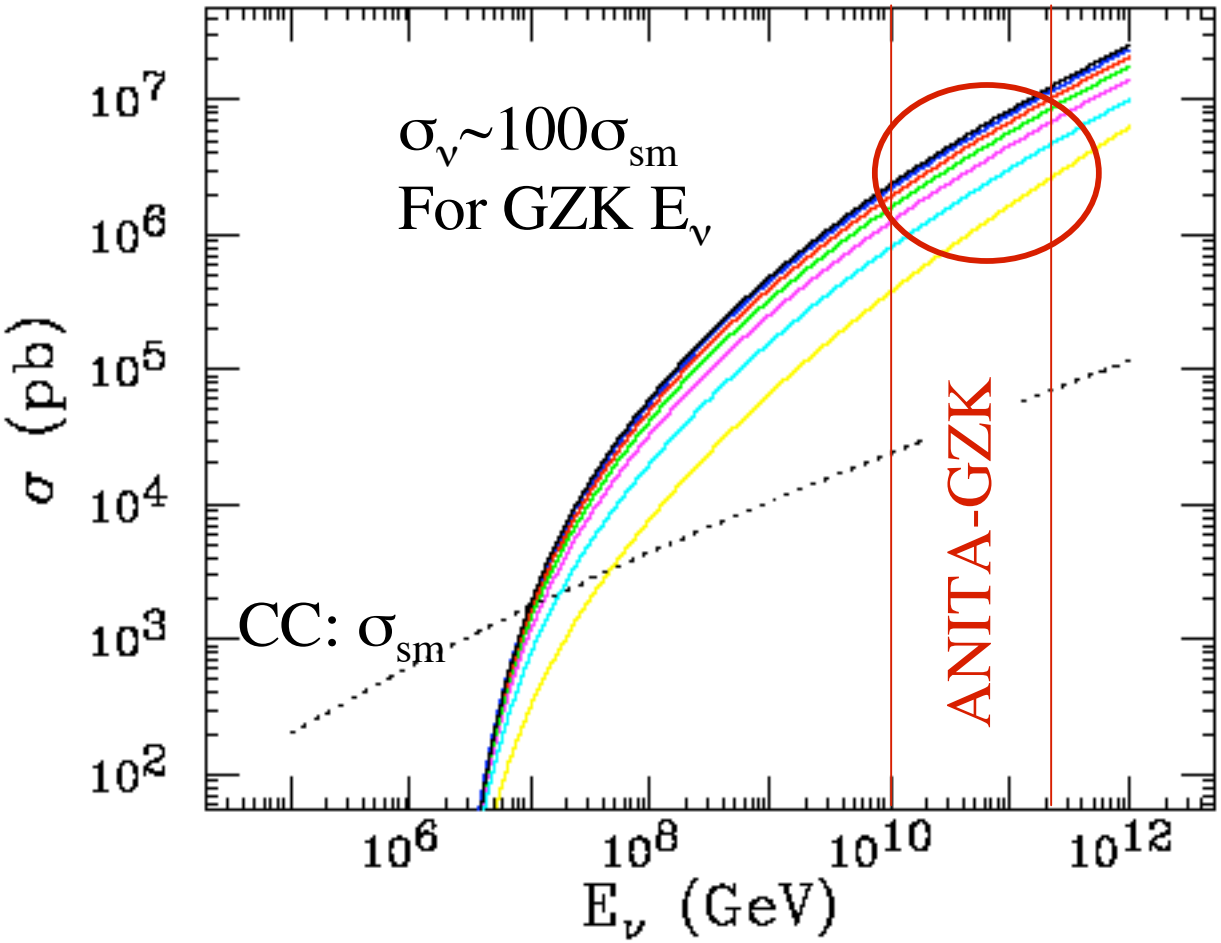


PHOTONS: not deflected, but: reprocessed in sources, absorbed in IR (100 TeV), and CBR

PROTONS: deflection in magnetic fields, GZK cutoff

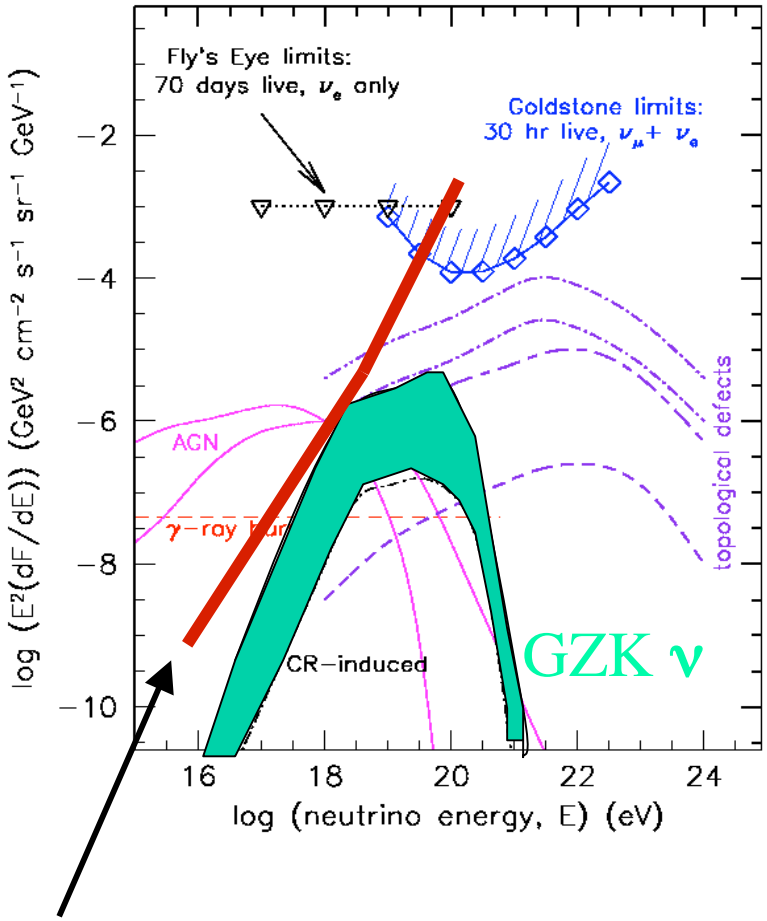
NEUTRINOS: not absorbed or deflected, hard to see

EHE Neutrinos Explore Higher Dimensions



(Anchordoqui, et al, hep-ph/0307228)

Models of diffuse EHE Neutrinos



10^5

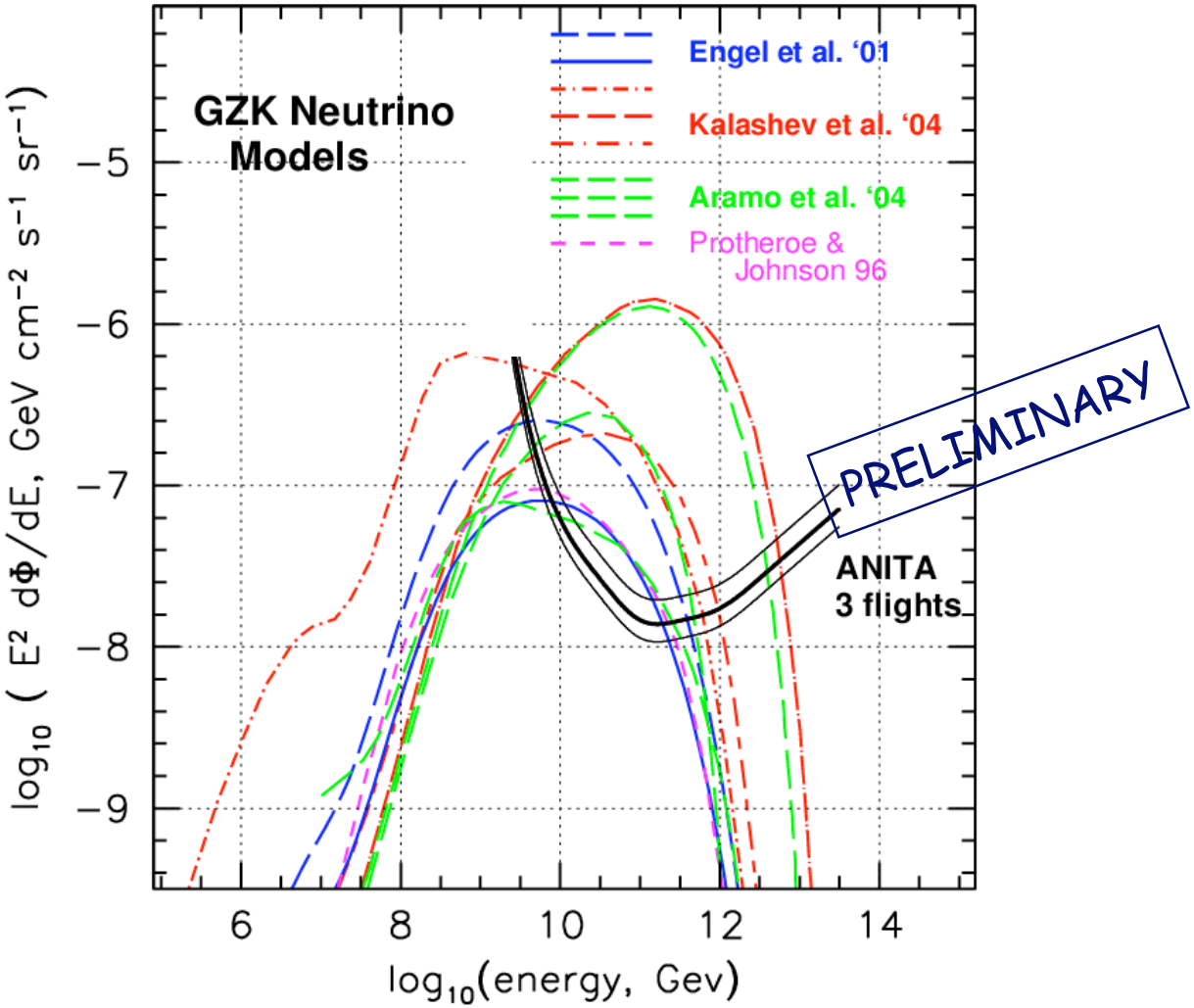
10^3

10

Exposure (km^{3}yr sr)

Required exposure to measure 10 events/decade at $E^2(dF/dE) = 10^{-7}$

GZK models - representative



ANtarctic Impulsive Transient Antenna

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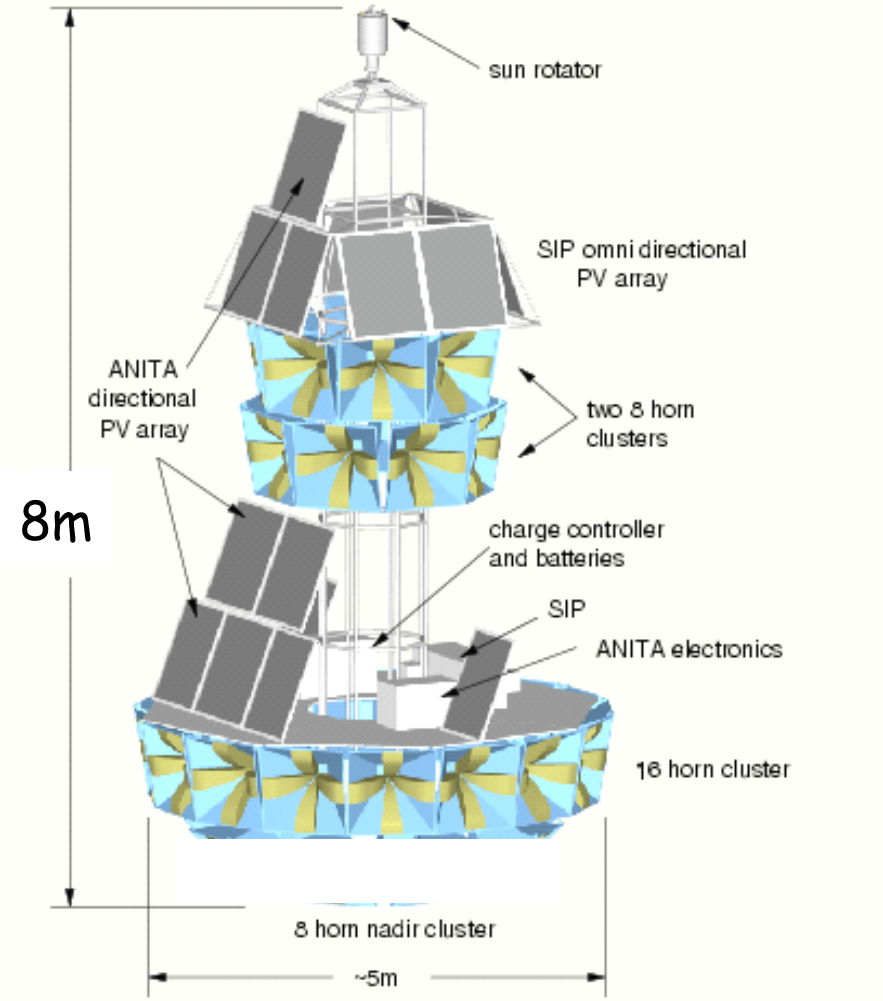
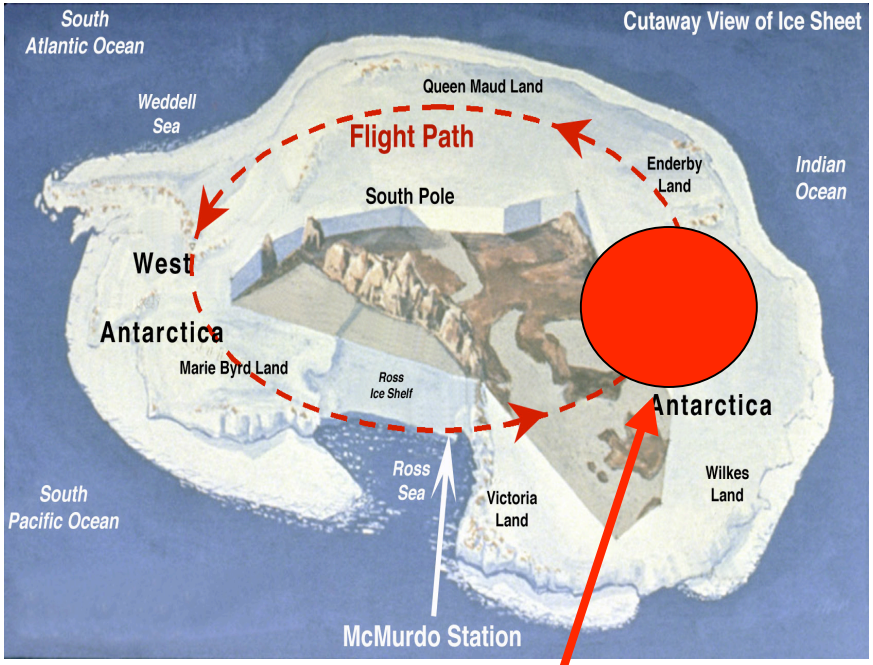
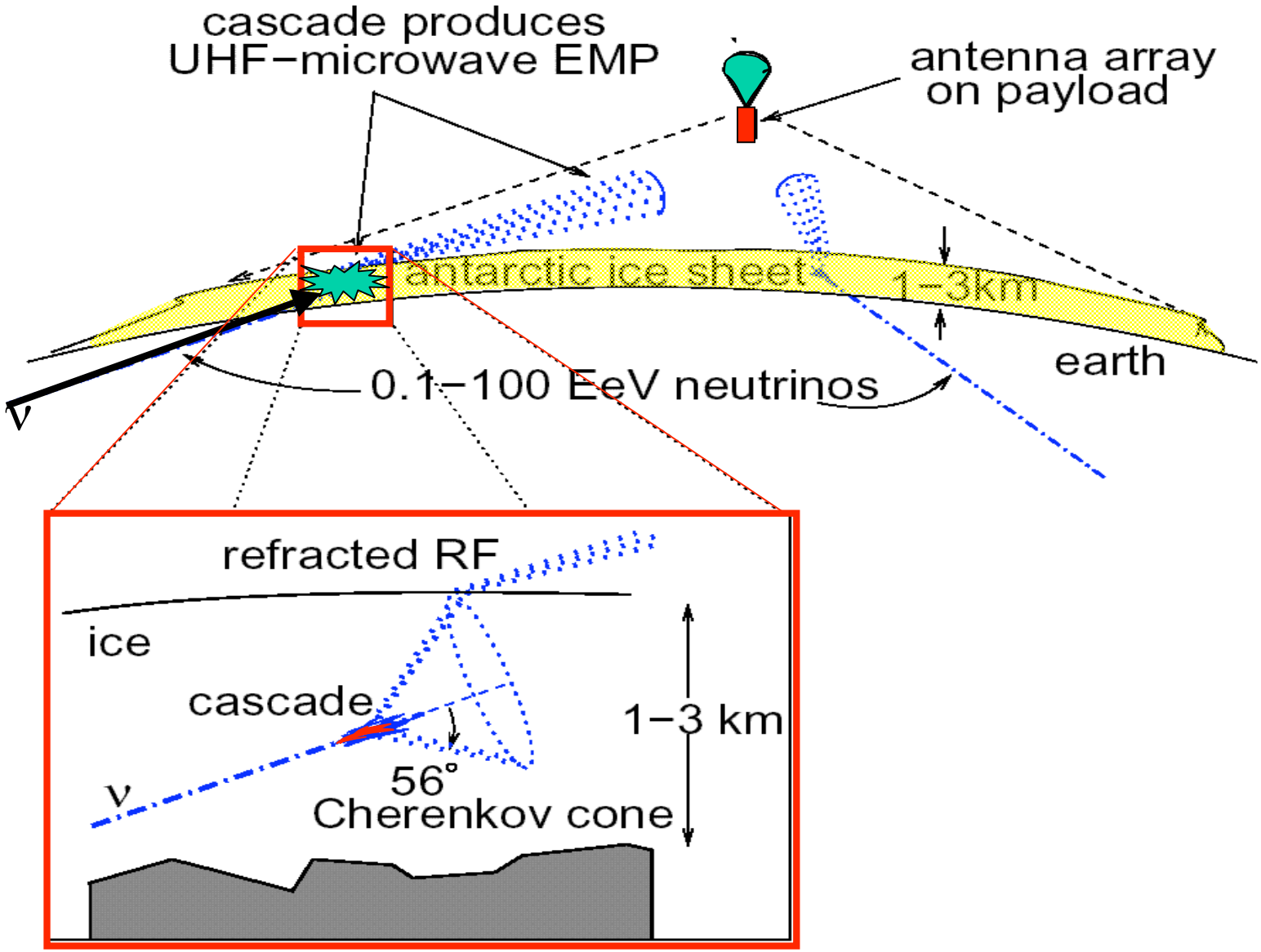




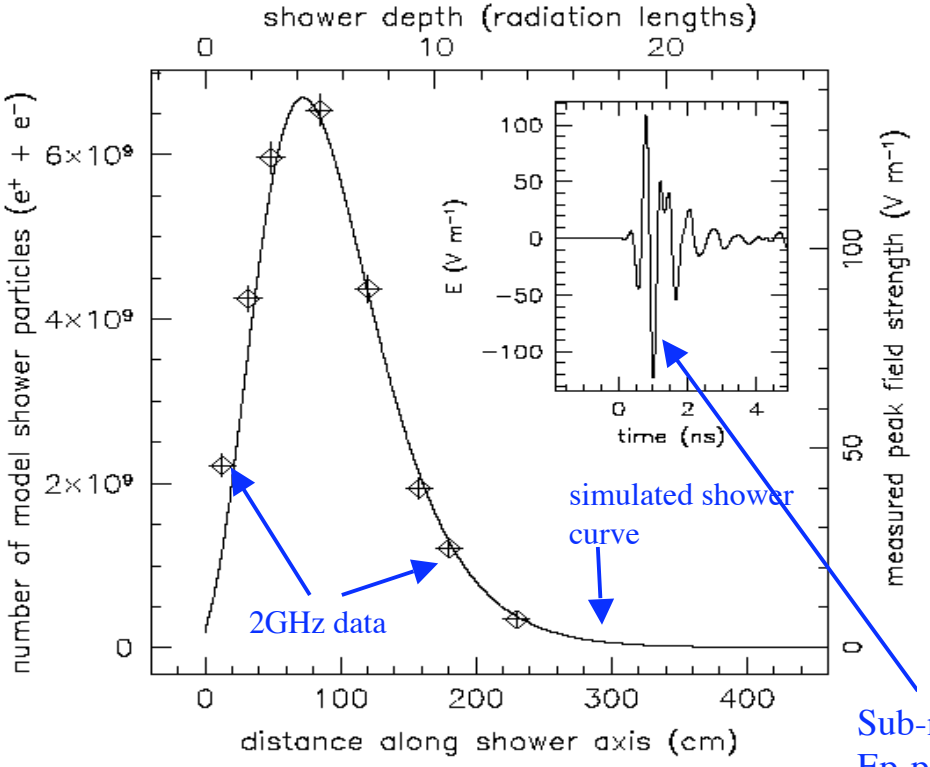
600 km radius,
1.1 million km^2

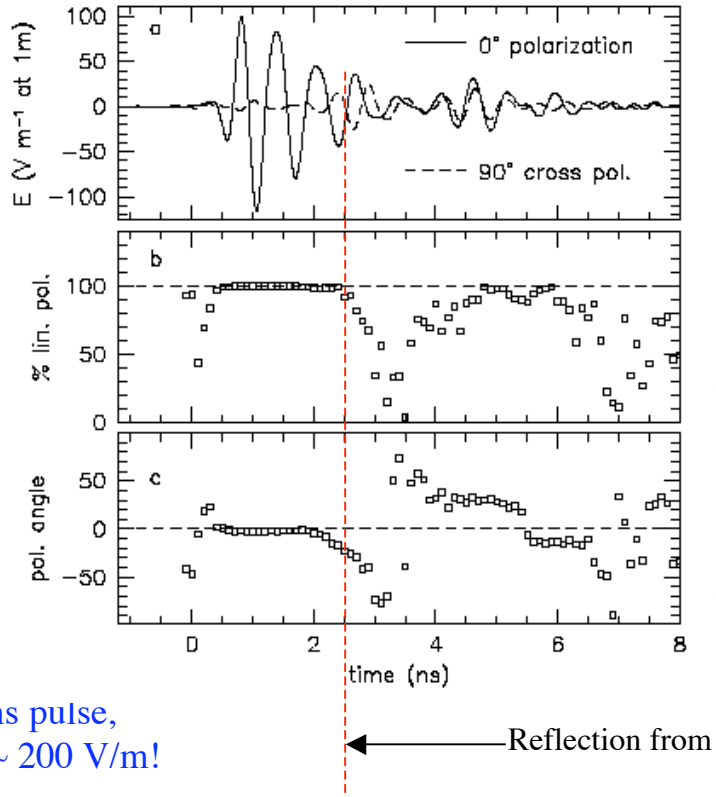
- NASA funding started ’03 for first launch in Dec ‘06

ANITA concept



Shower profile observed by radio (~2GHz)

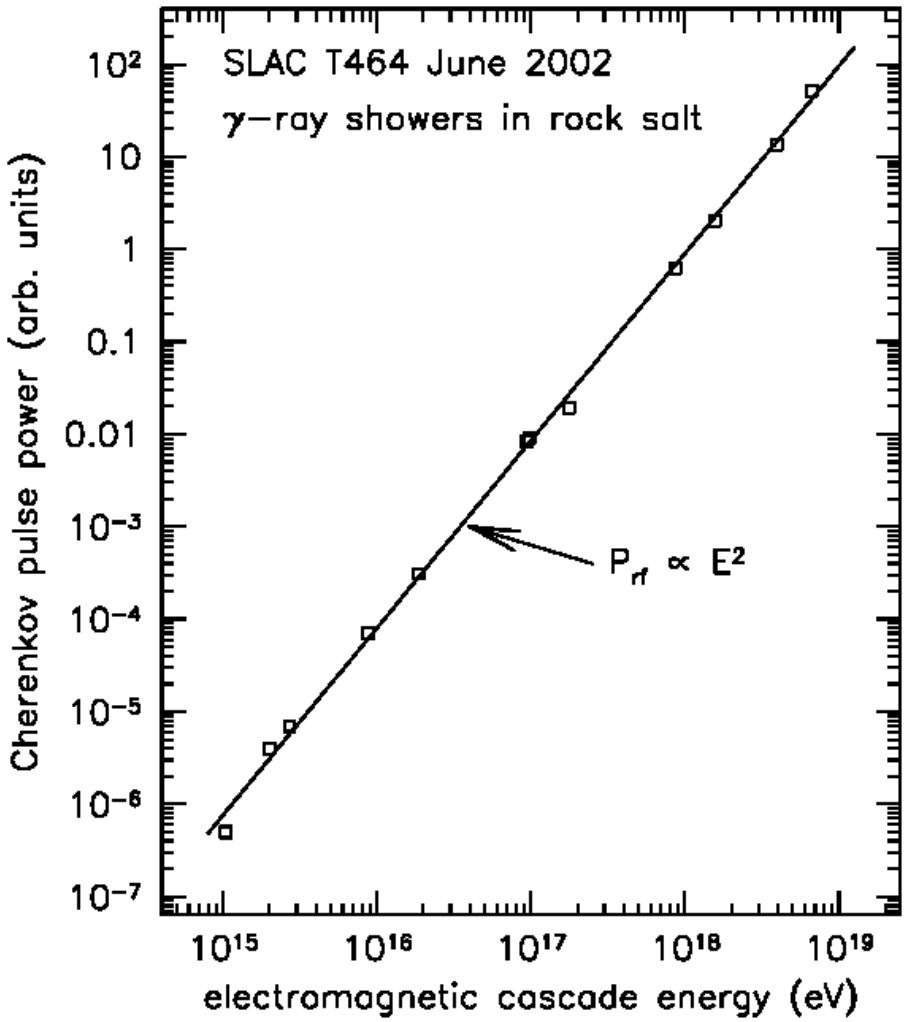




- Measured pulse field strengths follow shower profile very closely
- Charge excess also closely correlated to shower profile (EGS simulation)
- Polarization completely consistent with Cherenkov

New results—SLAC T460 June 2002

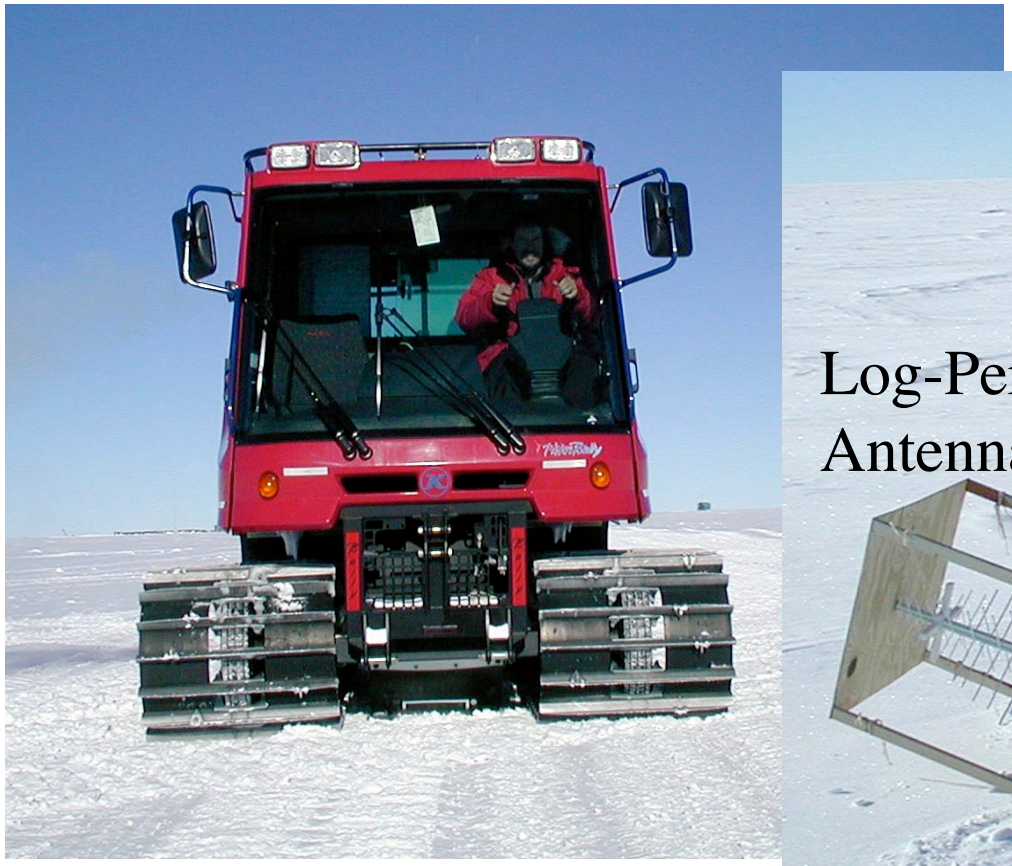
Follow up experiment to SLAC T444, with rock-salt target

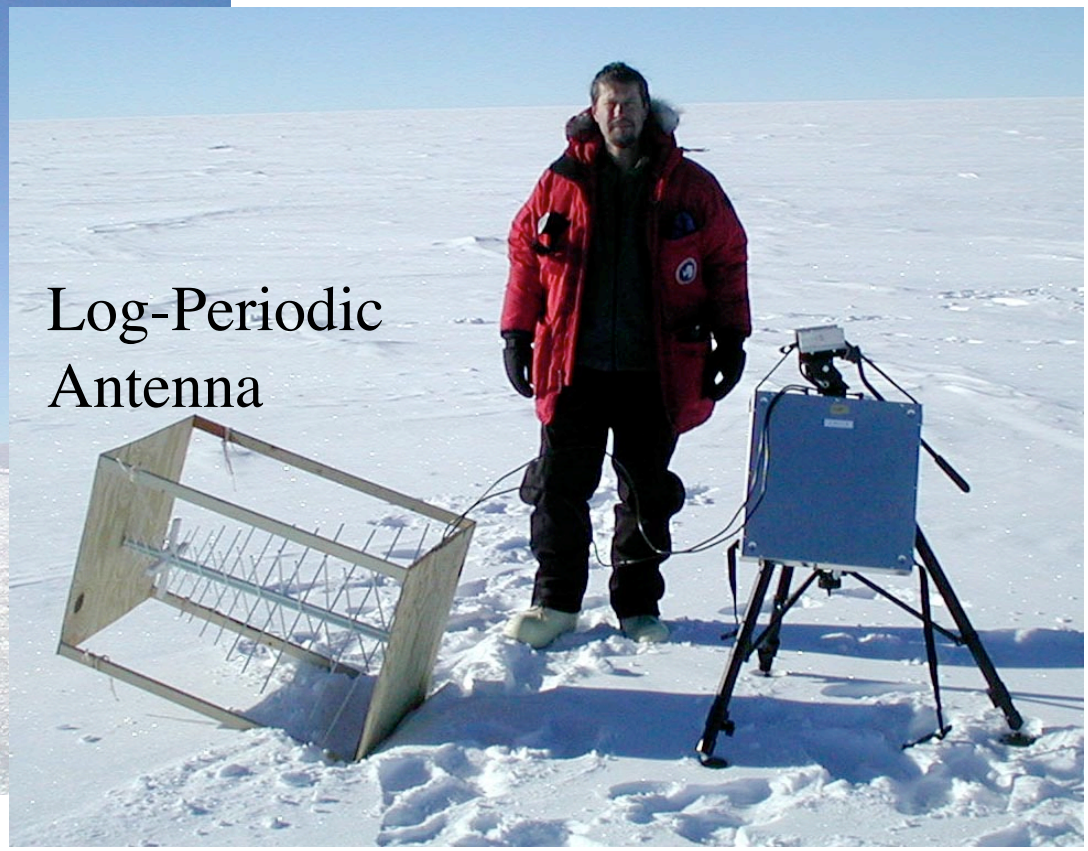


- Much wider energy range covered:
  - <1PeV up to 10 EeV
- Radio Cherenkov observed over 8 orders of magnitude in radio pulse power

Noise Tests at South Pole

- Ambient noise on the high plateau

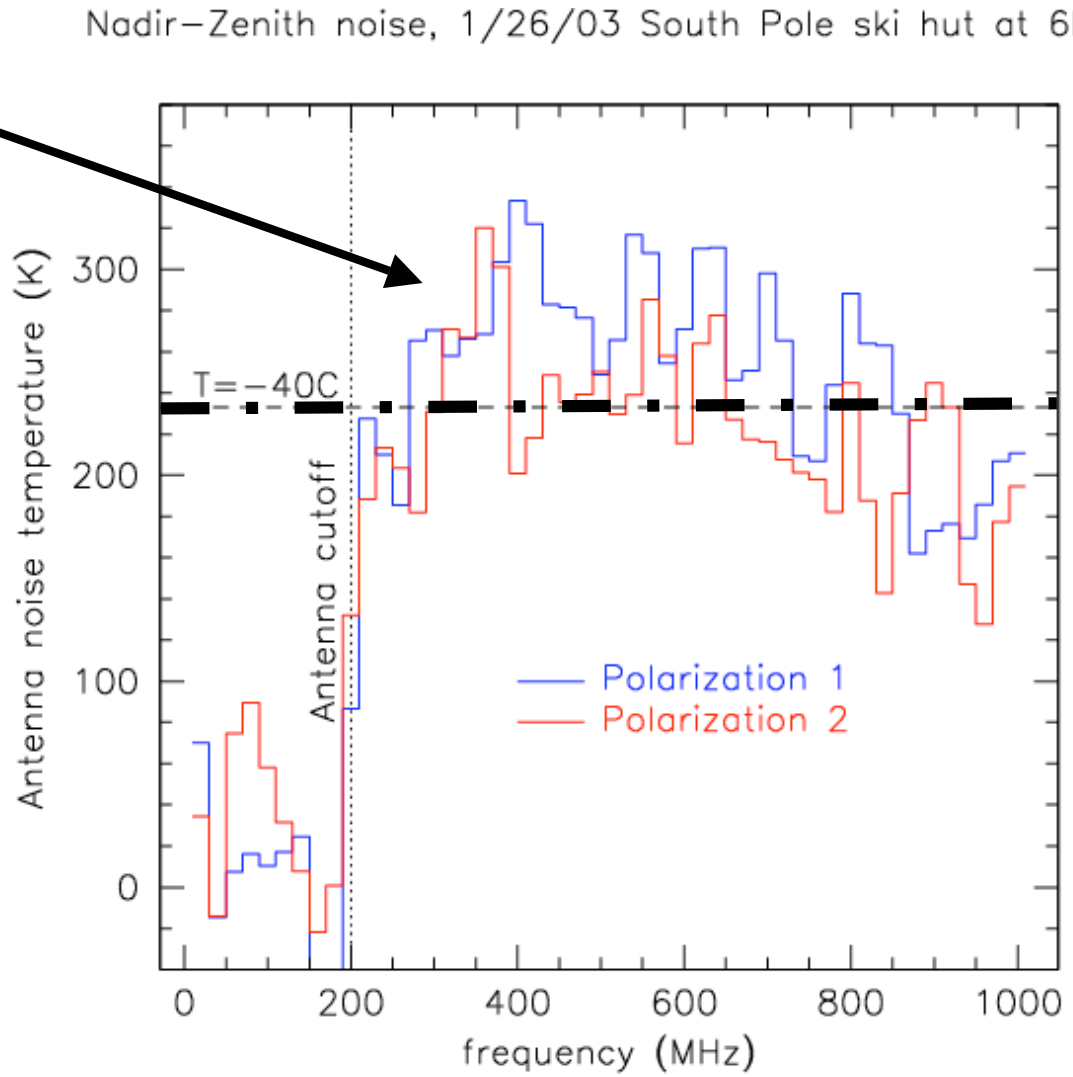




Initial Results from Polar Studies

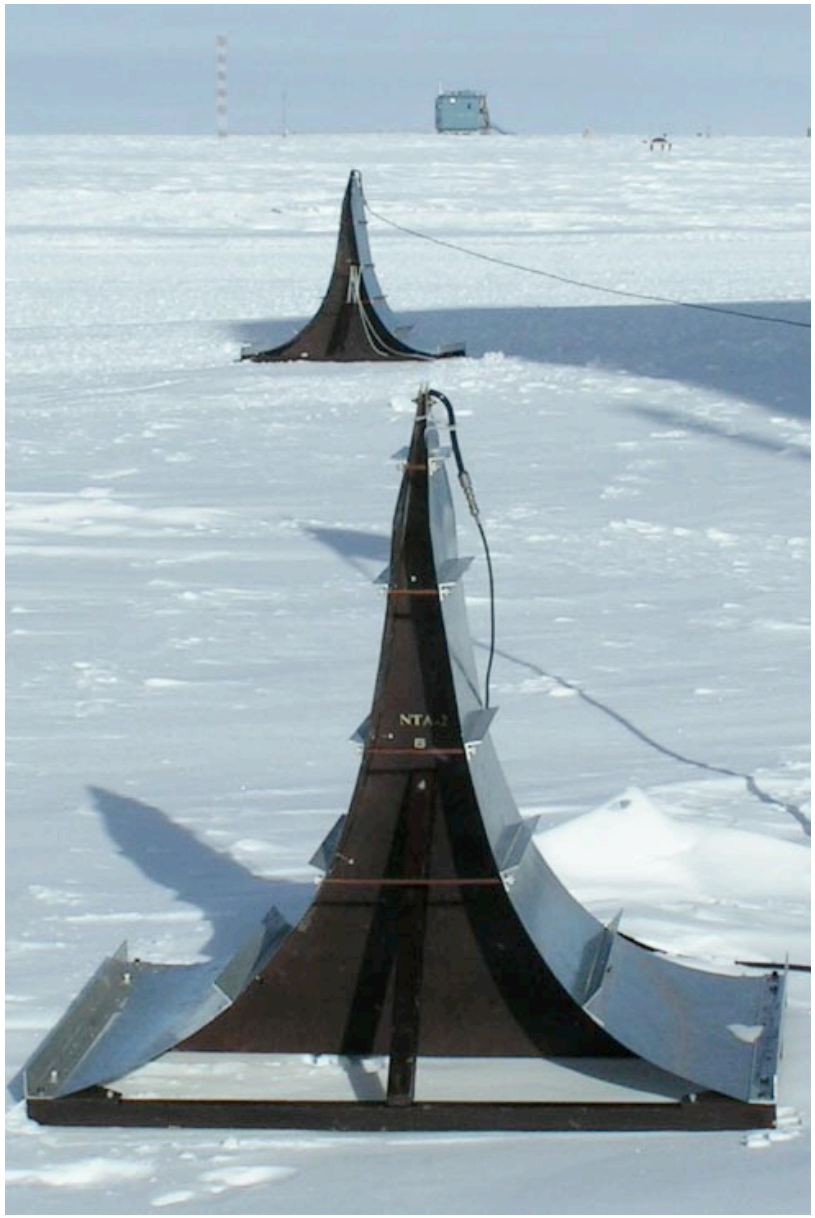
-It looks good, and confirmed by sun/galaxy measurements of ANITA-lite

RF emission from ice



Ice Attenuation at South Pole

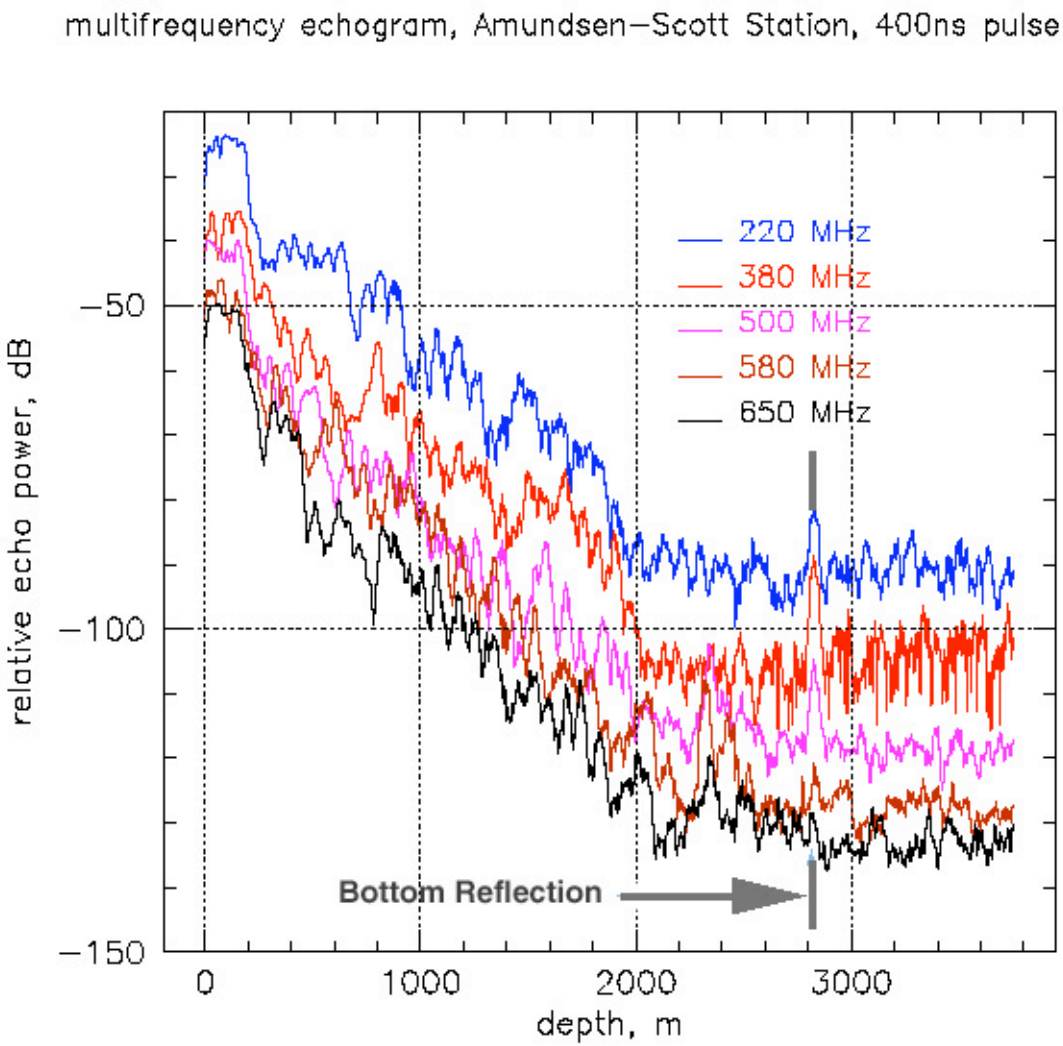
- from 200MHz to 700MHz



Jan. 2004

Ice Attenuation at South Pole

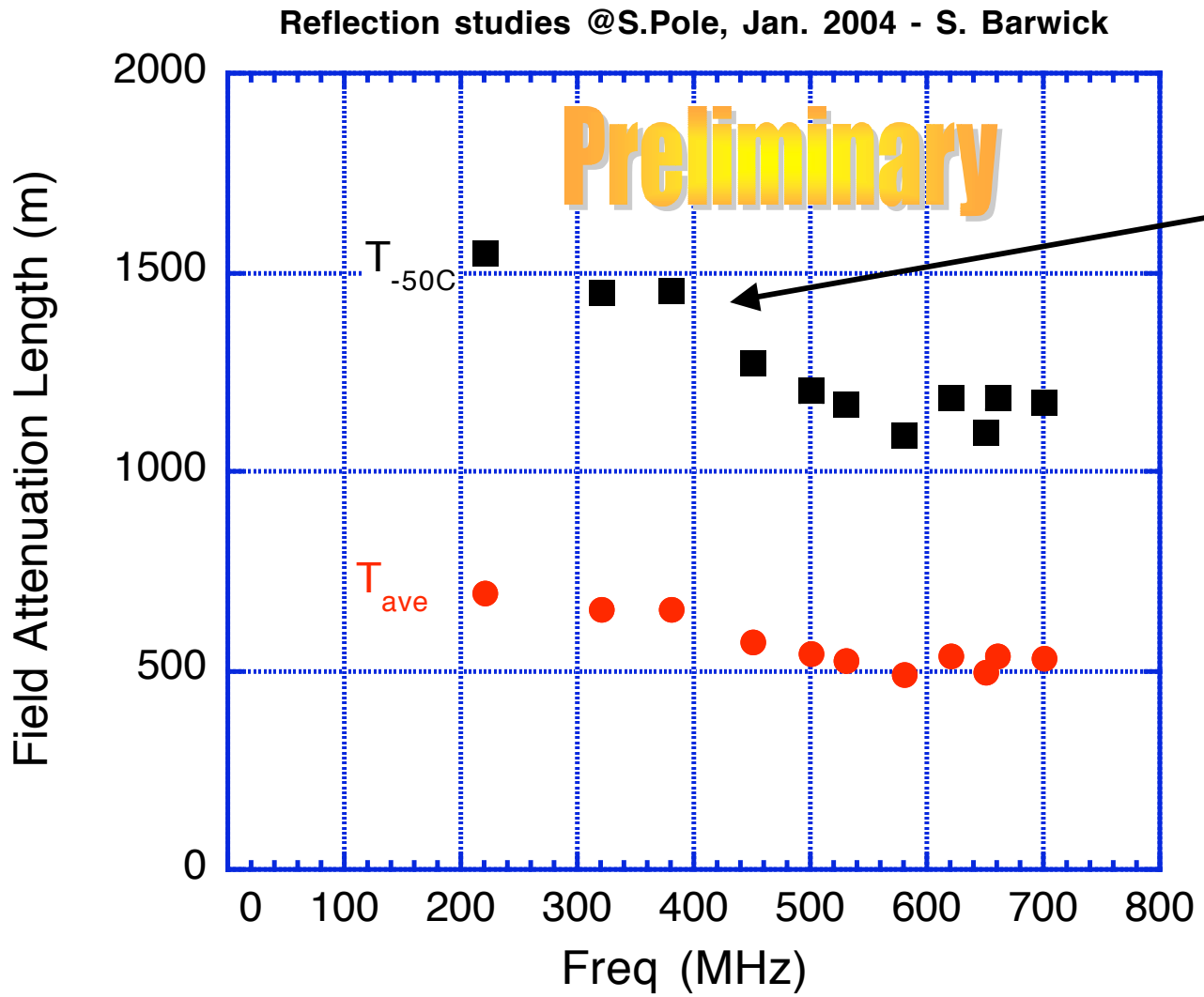
- from 200MHz to 700MHz



A clean reflection from the bottom implies that the attenuation lengths are very long!

Ice Attenuation at South Pole

- from 200MHz to 700MHz



Most of Antarctic ice is -50C!

Excellent transparency, compare to ~100 meter for light, it is 10x larger

ANITA-lite

2 Receiver Horns

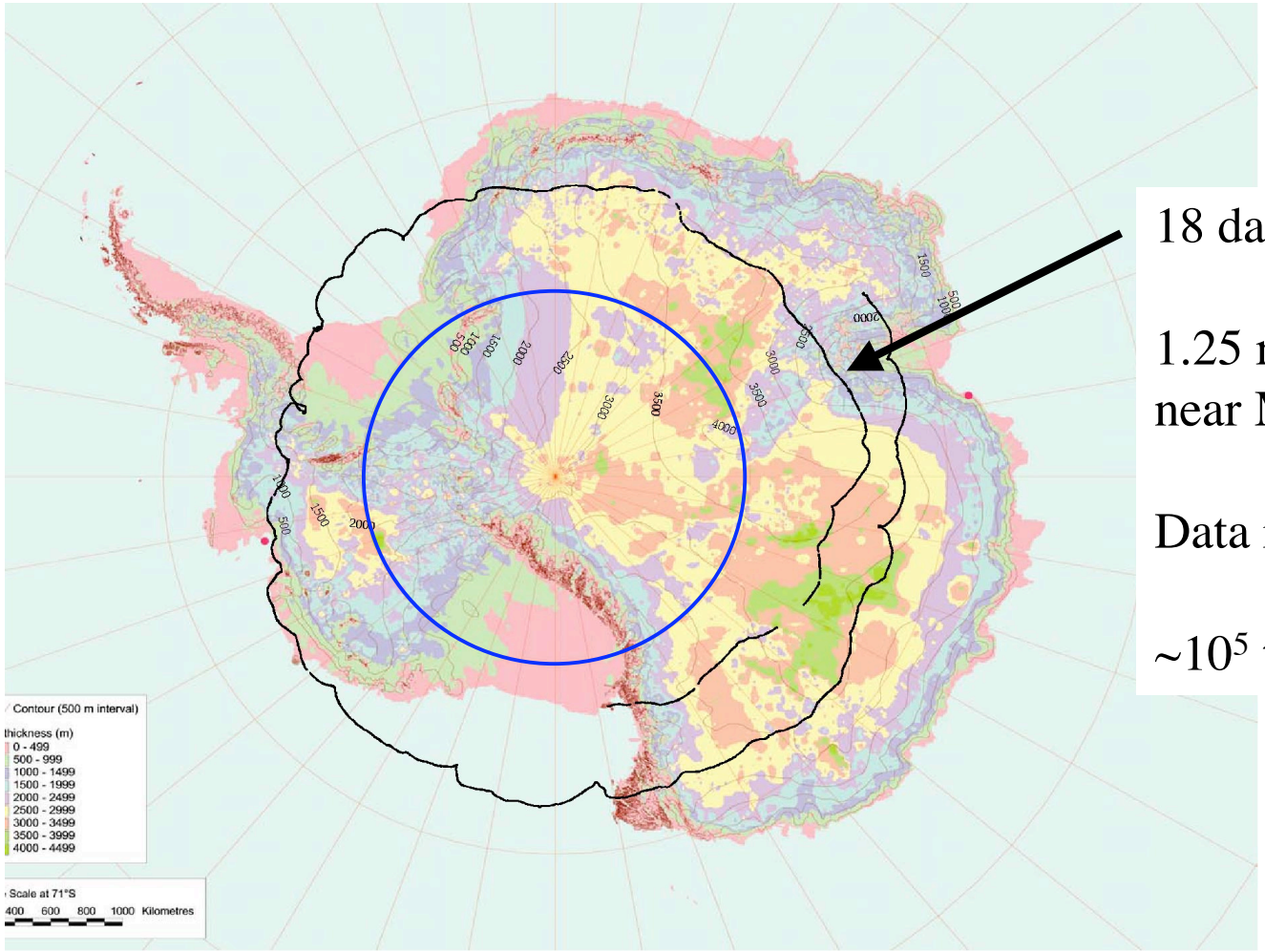
Electronics

Piggyback on TIGER Launch Dec '03

RF Survey of Antarctica

ANITA-lite prior to launch

ANITA-lite flight path 03/04



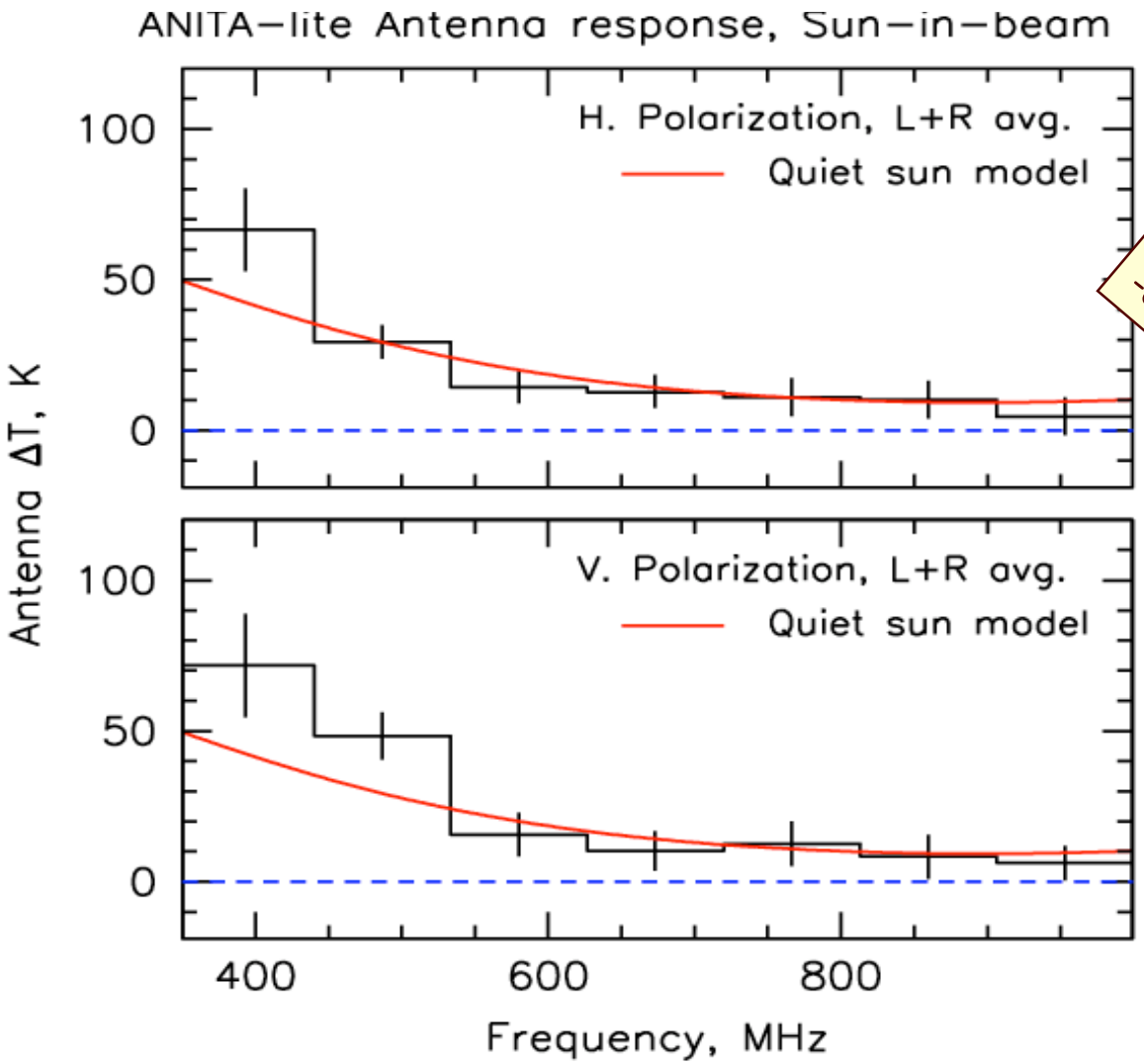
18 days at float altitude

1.25 revolutions, landing near Mawson Station

Data recovered in Feb 04

~10^5 triggered events

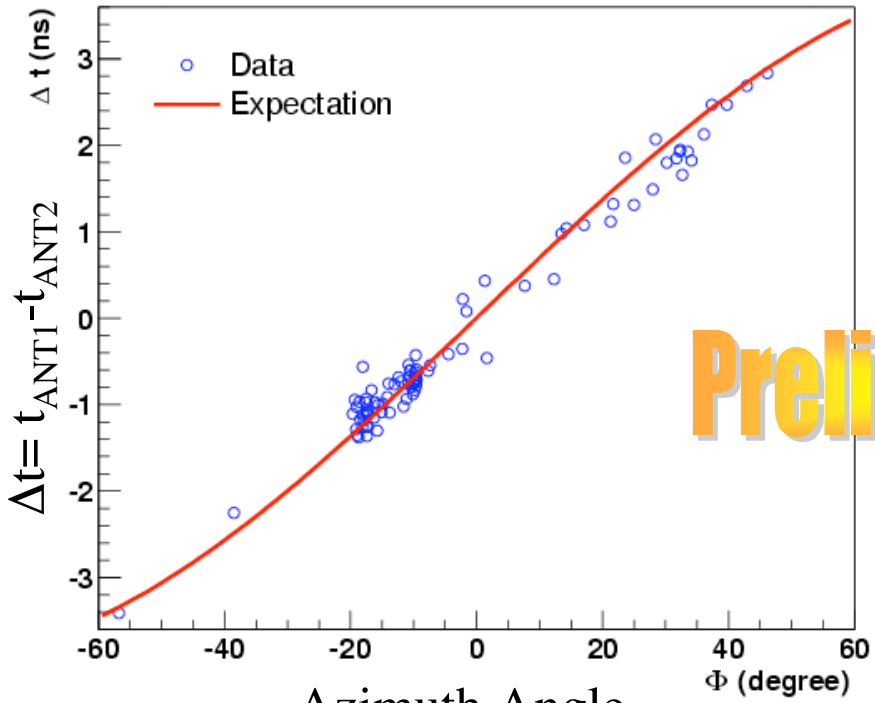
ANITA-lite detected Sun & GC



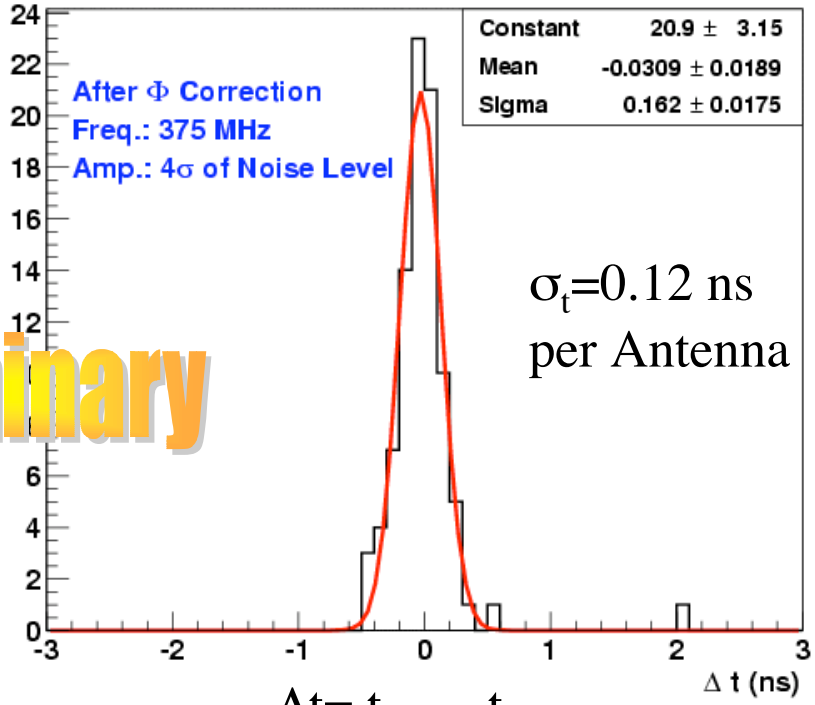
And thermal noise measurements
-consistent with galactic+solar+kT_{ic}

ANITA-lite timing resolution

Ground antenna transmits calib. pulse to Anita-lite @40km



Azimuth Angle



σ_t=0.12 ns per Antenna

$\Delta t = t_{ANT1} - t_{ANT2}$

Preliminary

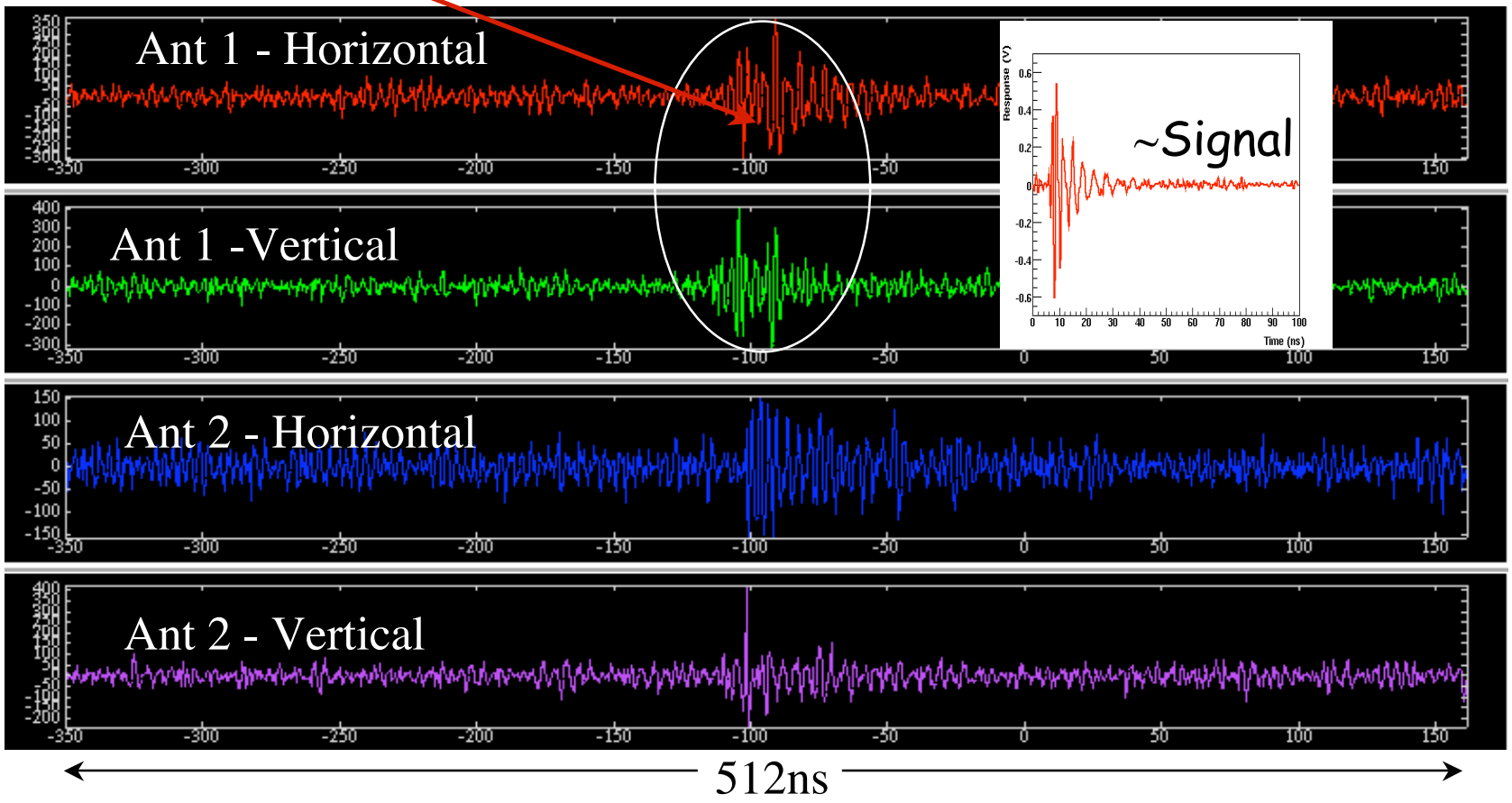
Expected Angular Resolution for ANITA

$\delta\theta \sim 0.5$ deg $\quad\quad$ $\delta\phi \sim 2$ deg

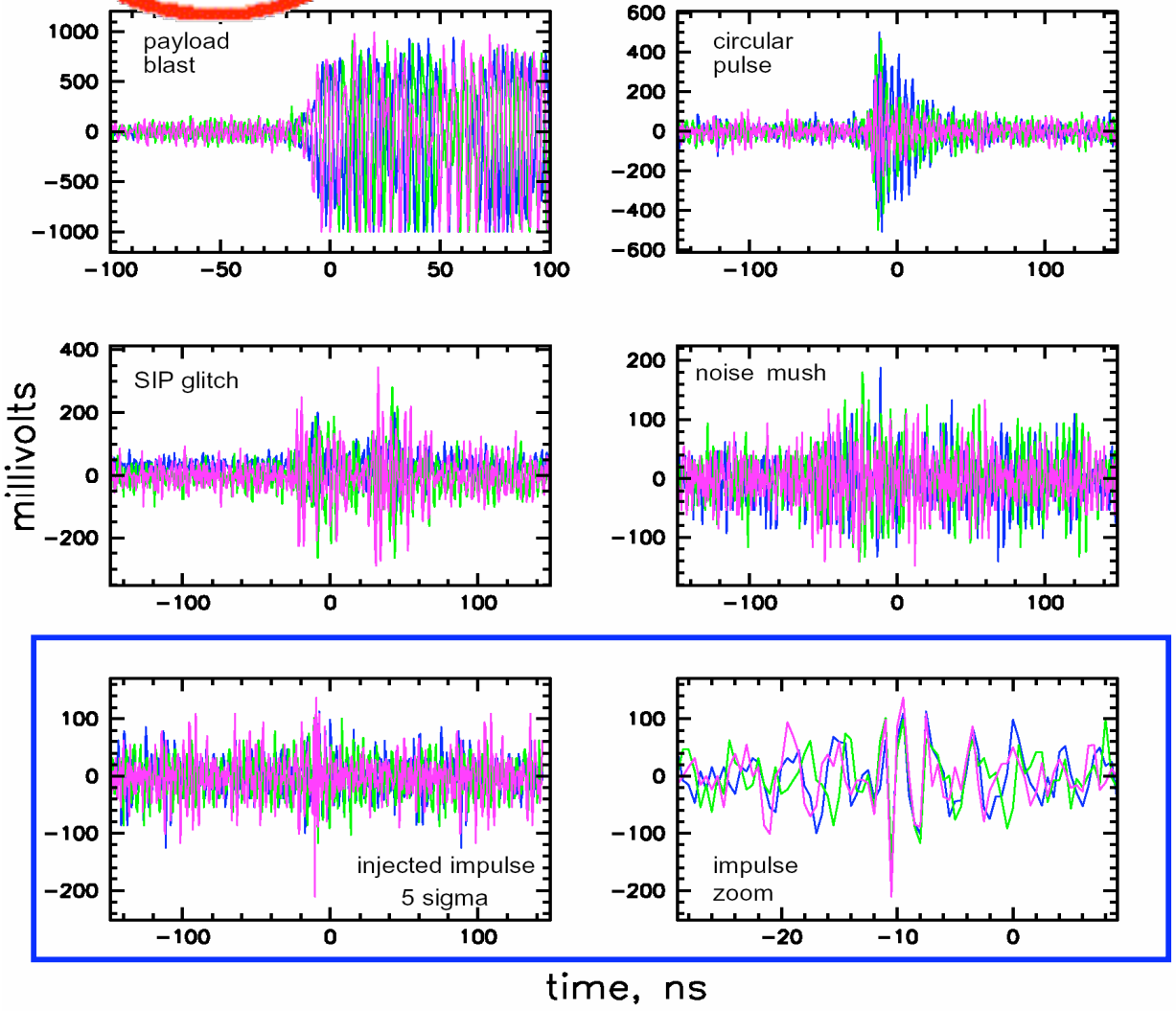
ANITA-lite BG event

Duration is too large for ν - associated with local TRX

data reveals no obvious ν signal



ANITA-lite impulse analysis



BACKGROUND

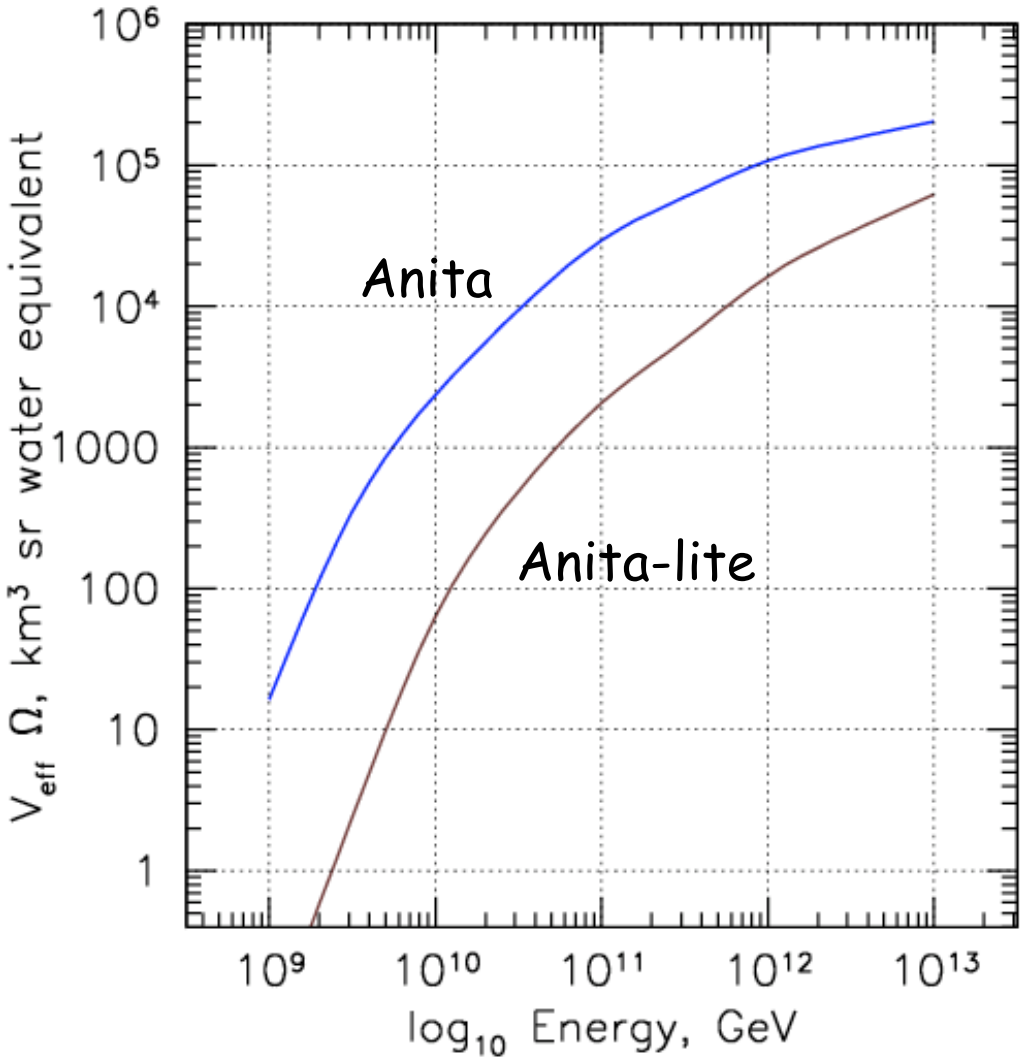
Dominated by payload local noise

Every event fell into distinct categories (4 shown here)

Expected SIGNAL

(superimposed on actual thermal noise)

ANITA-lite analysis summary



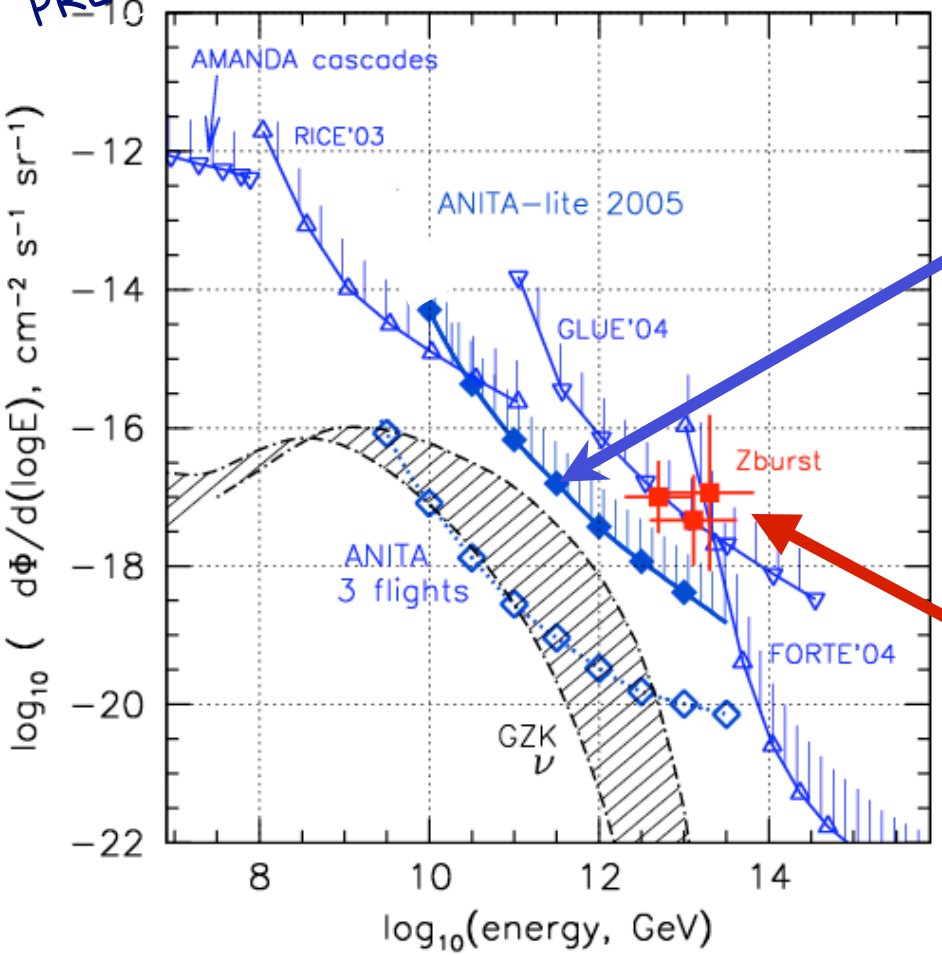
Signal Characteristics

1. Pulse shape and duration
2. Frequency content
3. 100% linearly polarized
4. Direction must come from ice

Anita-lite analysis only used rough pulse shape and duration to eliminate background

ν-Limits and Projected Sensitivity

PRELIMINARY

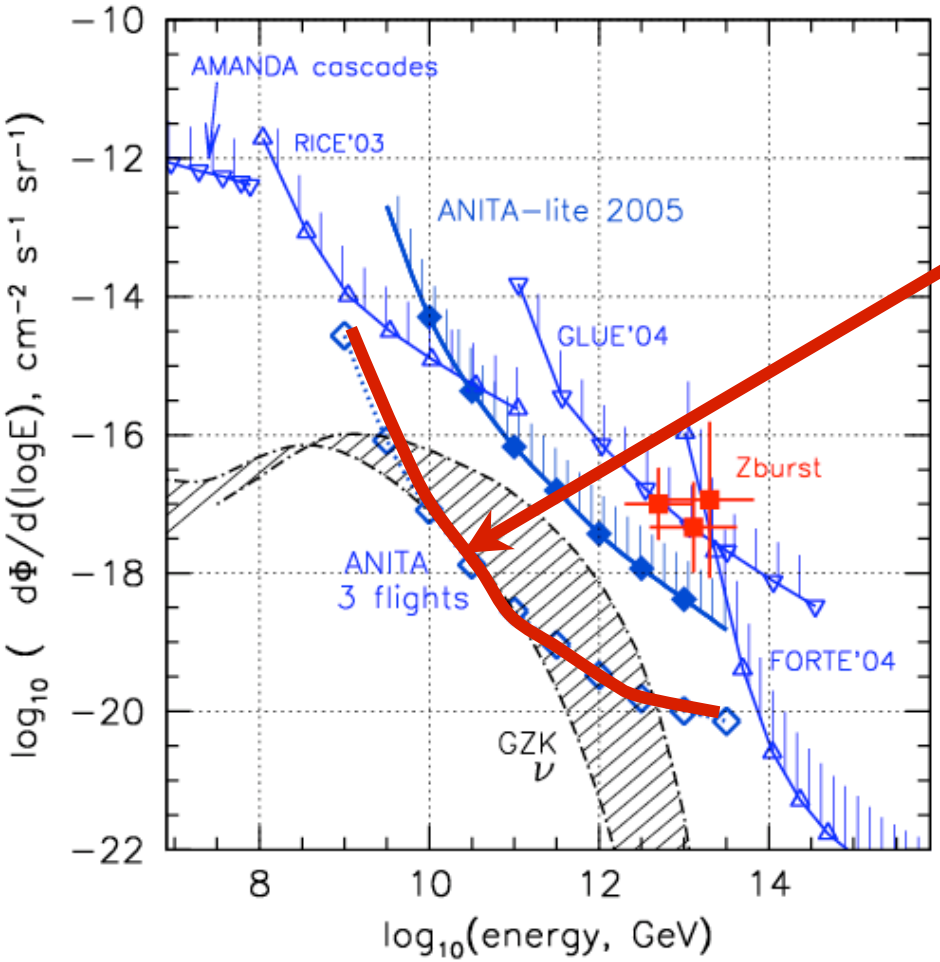


$$\Phi(E) = \frac{2.3 \cdot l_{\text{int}}(E)}{[V\Omega]_{\text{eff}}(E) \cdot t_{\text{live}} \cdot \epsilon}$$

- **Anita-Lite Flux Limit (7 days)**
- Sorry ….but no Z-burst neutrinos

ν-Limits and Projected Sensitivity

PRELIMINARY

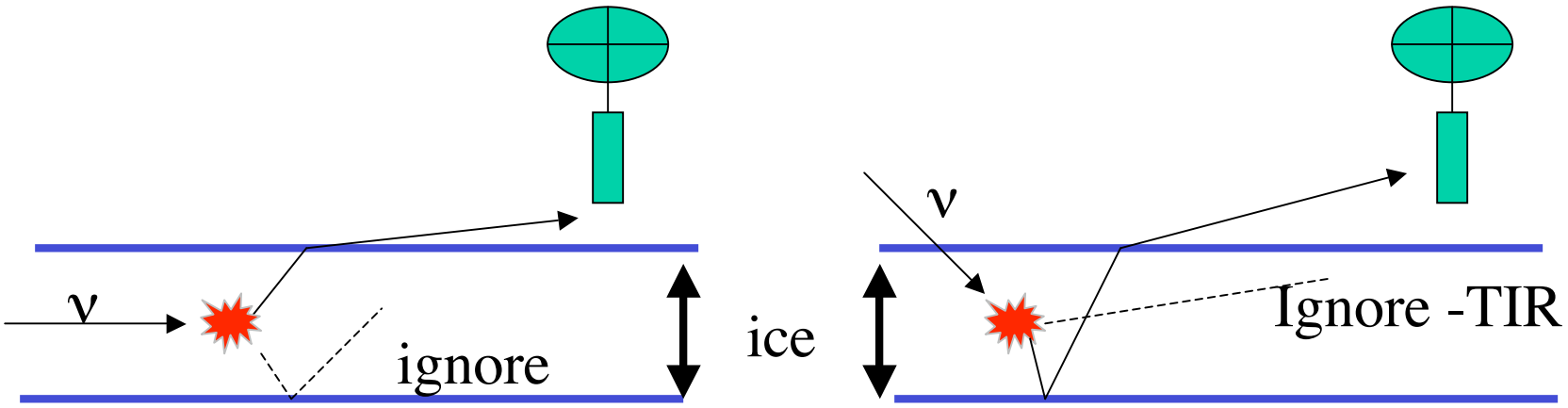


ANITA sensitivity:
(45 days)

- ν_μ & ν_e included, full-mixing
- 1.5-2 orders of magnitude gain
- 5 events for flux models on lower GZK boundary

Probing Physics Beyond Standard Model w/ ANITA

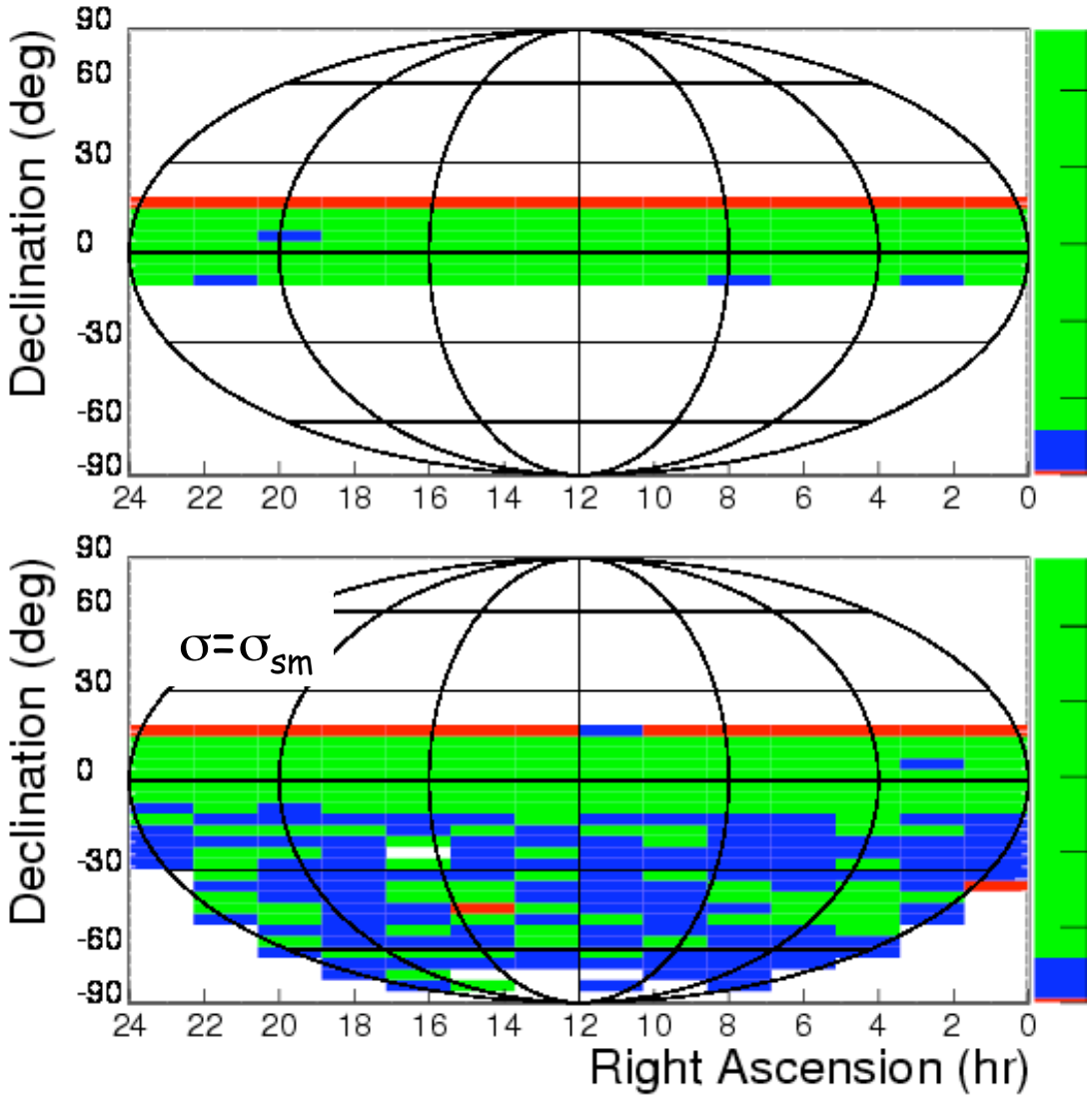
Reflected and Direct Events



Direct

Reflected

Sky coverage increases for reflected events



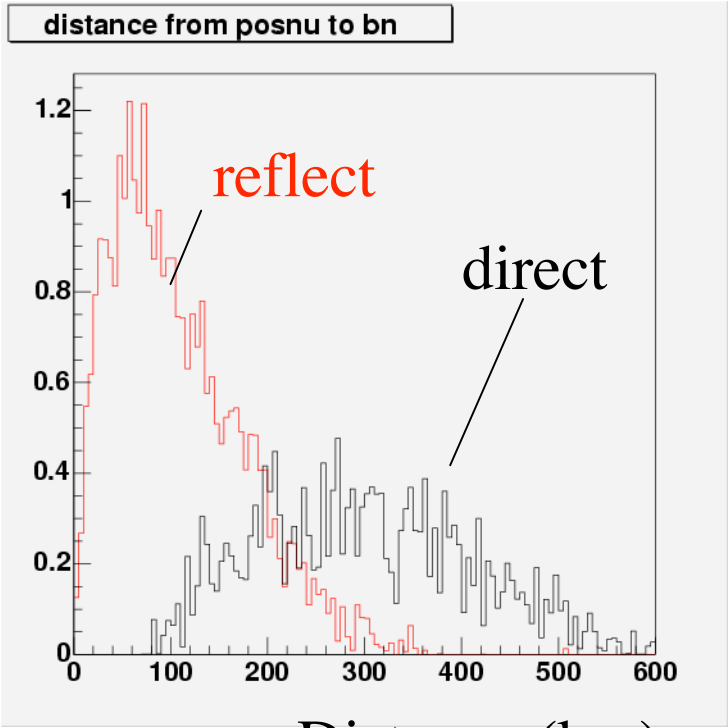
Direct Events

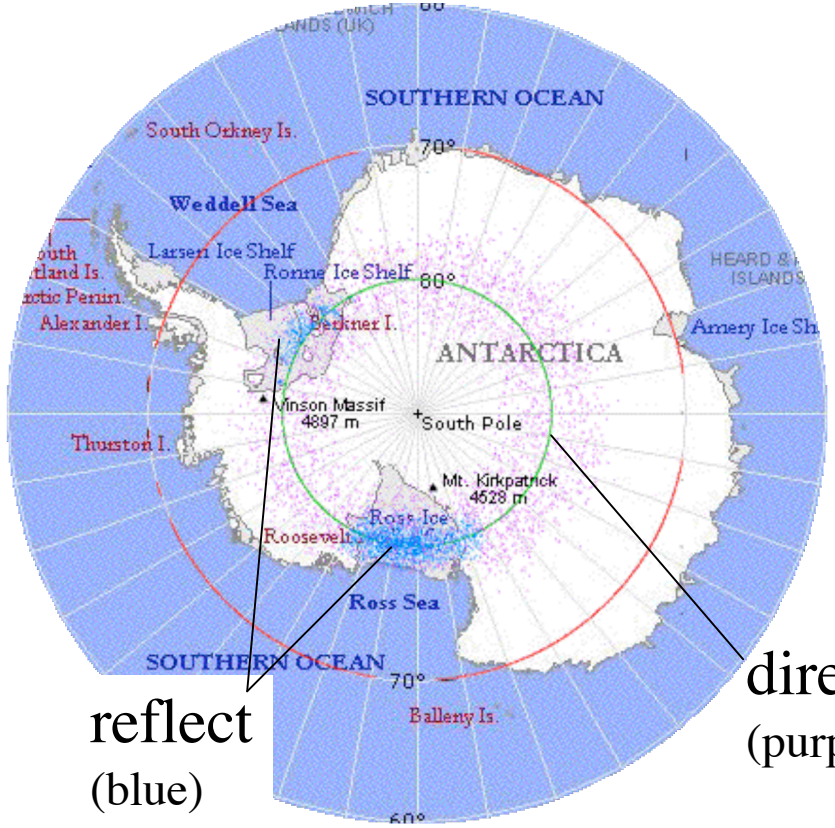
Reflected and Direct Events

Event ID : Reflected or Direct?

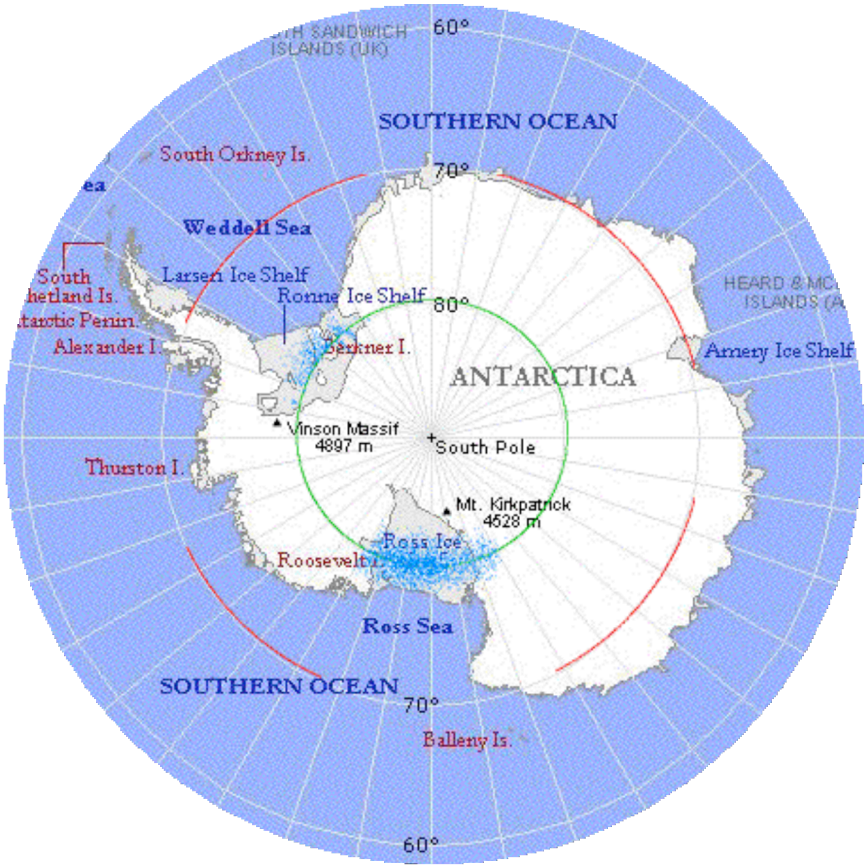
- Based on Topology and distance
- Develop likelihood function to separate reflected from direct events

$E_\nu = 10^{20}$ eV, $R_{ice} = 1\%$, $R_{ross} = 100\%$, $\sigma = 100\sigma_{sm}$

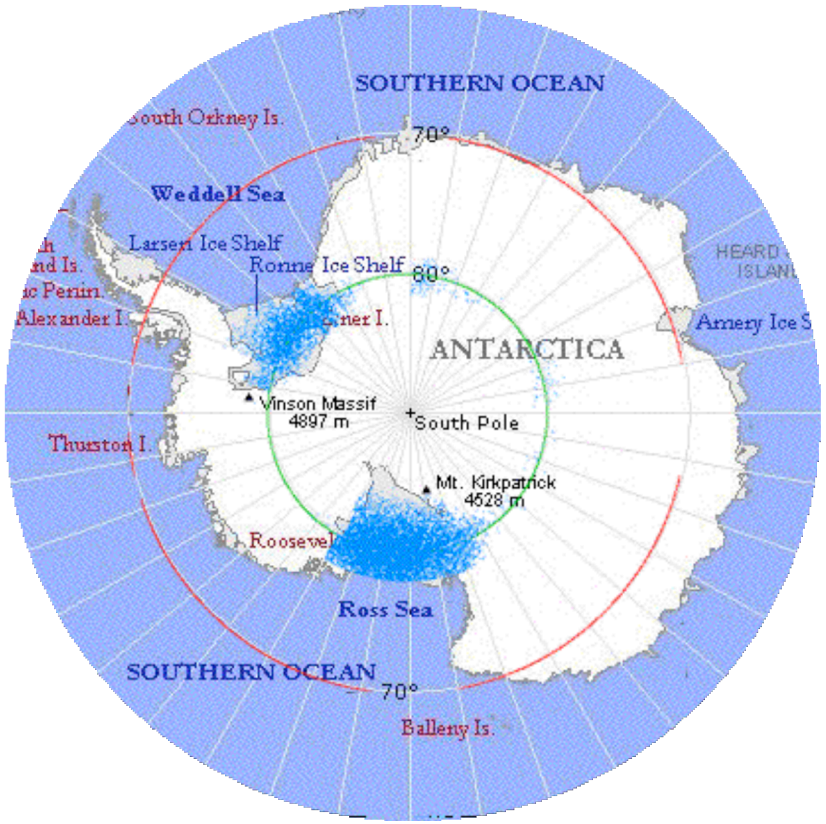




Topological Distribution of Reflected Events depends on L_att

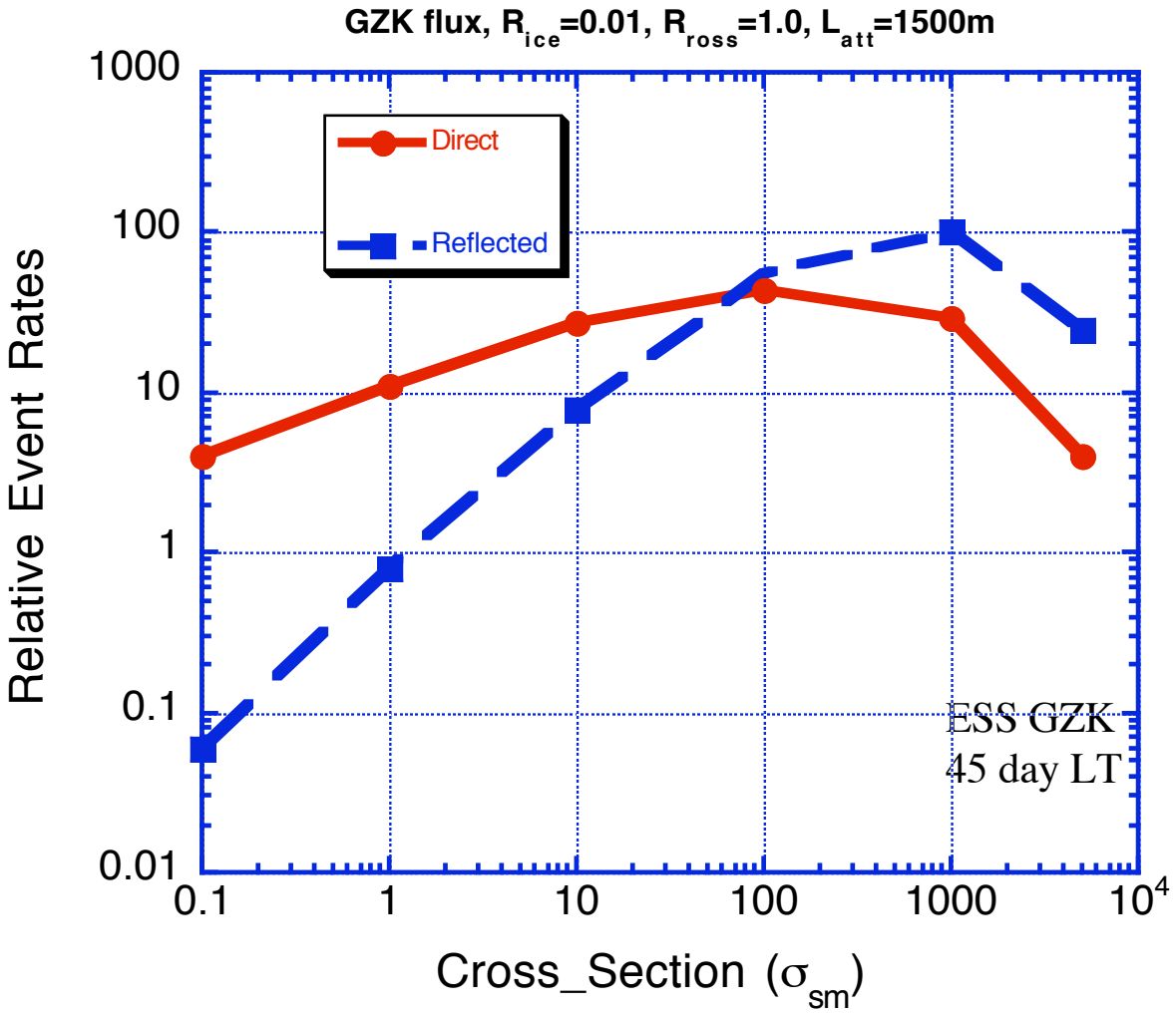


L_att= 1500m @-50C



L_att=3000m @ -50C

Direct and Reflected Event Rates

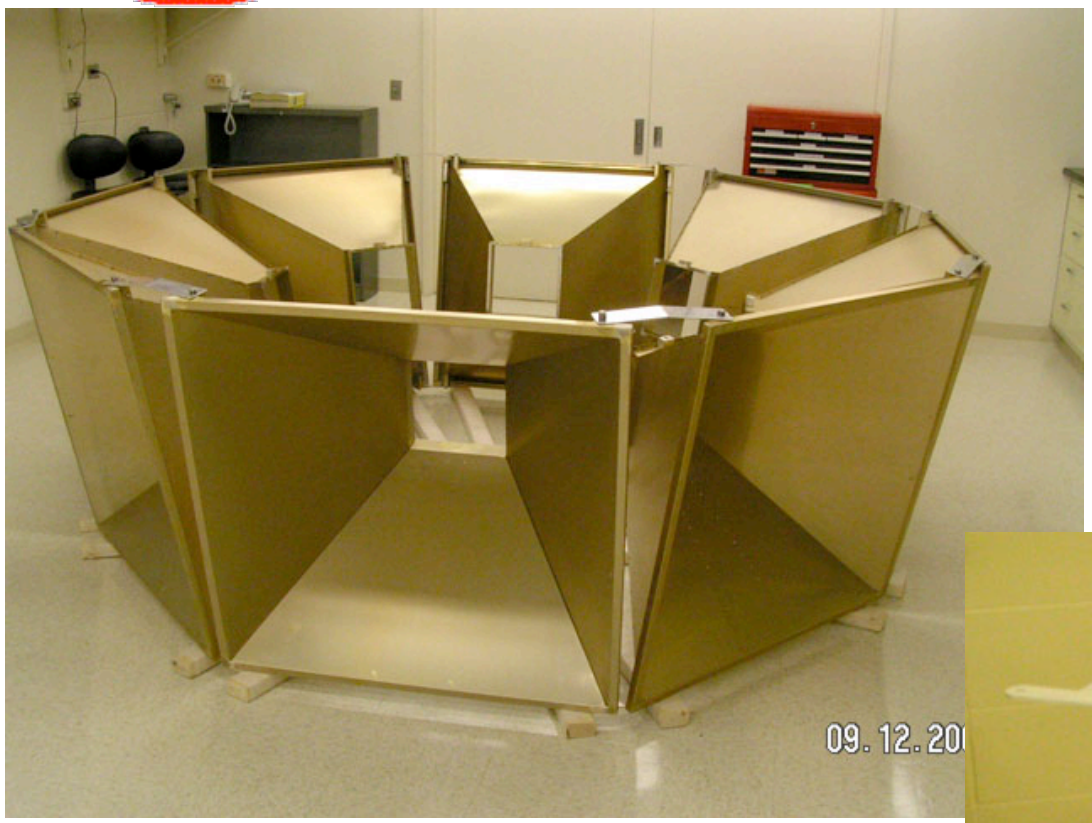


Reflected rates are negligible at small cross-sections

Direct rates do not depend strongly on σ.

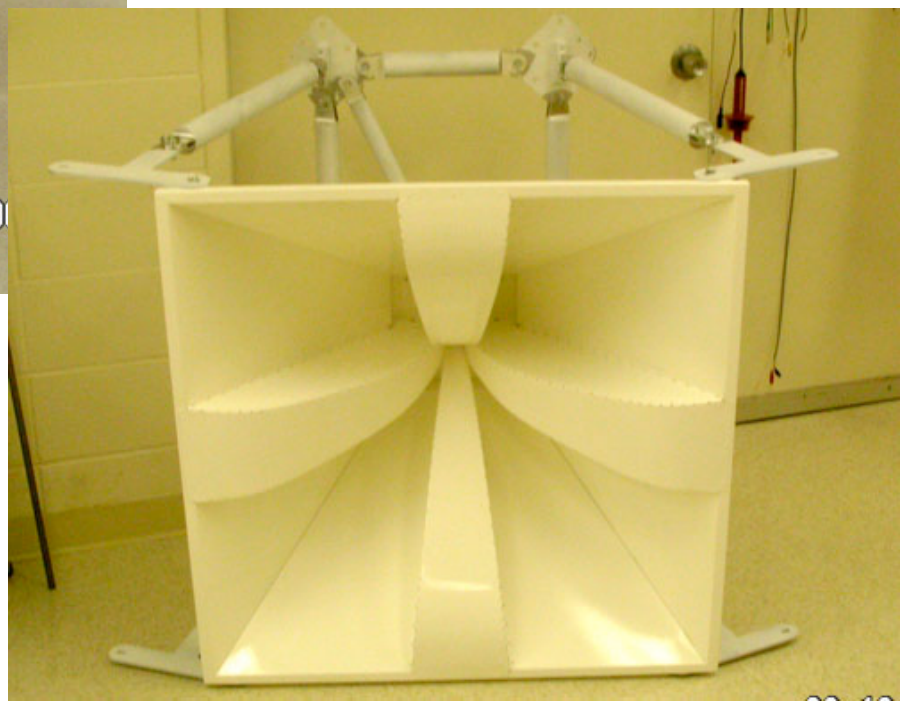
Reflected rates depend sensitively on σ.

ANITA construction



Upper Ring Assembly

Antenna and Frame



Why is ANITA a good idea?

- Frontier Science and very exciting
  - Win-win with GZK neutrinos
- Scans ice over 600km radius, and enormous detector volume!
- Radio signal can be calculated precisely and has been measured at high energy lab - unique signature!
- Energy resolution is relatively good
- Antenna can be absolutely calibrated by man-made radio transmitter embedded in deep hole (eg. Vostok)
- Clean signal
  - Linearly polarized, must originate in ice, distinct few ns time structure of pulse, "beam-off" in directions over water
- Balloon flight path is far from sources of confusing background

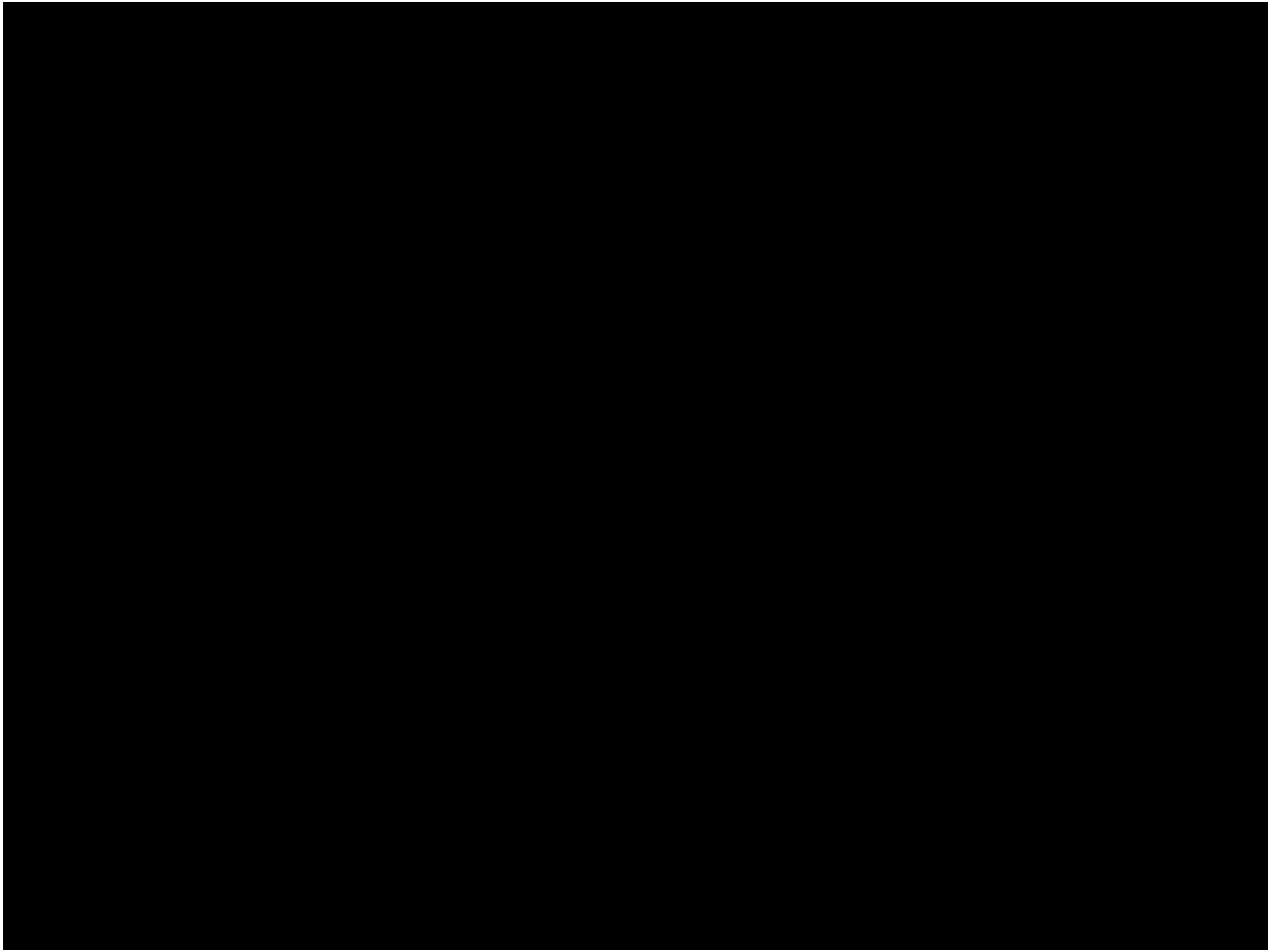
Revolutionary concept in EHE neutrino detection!

Outlook

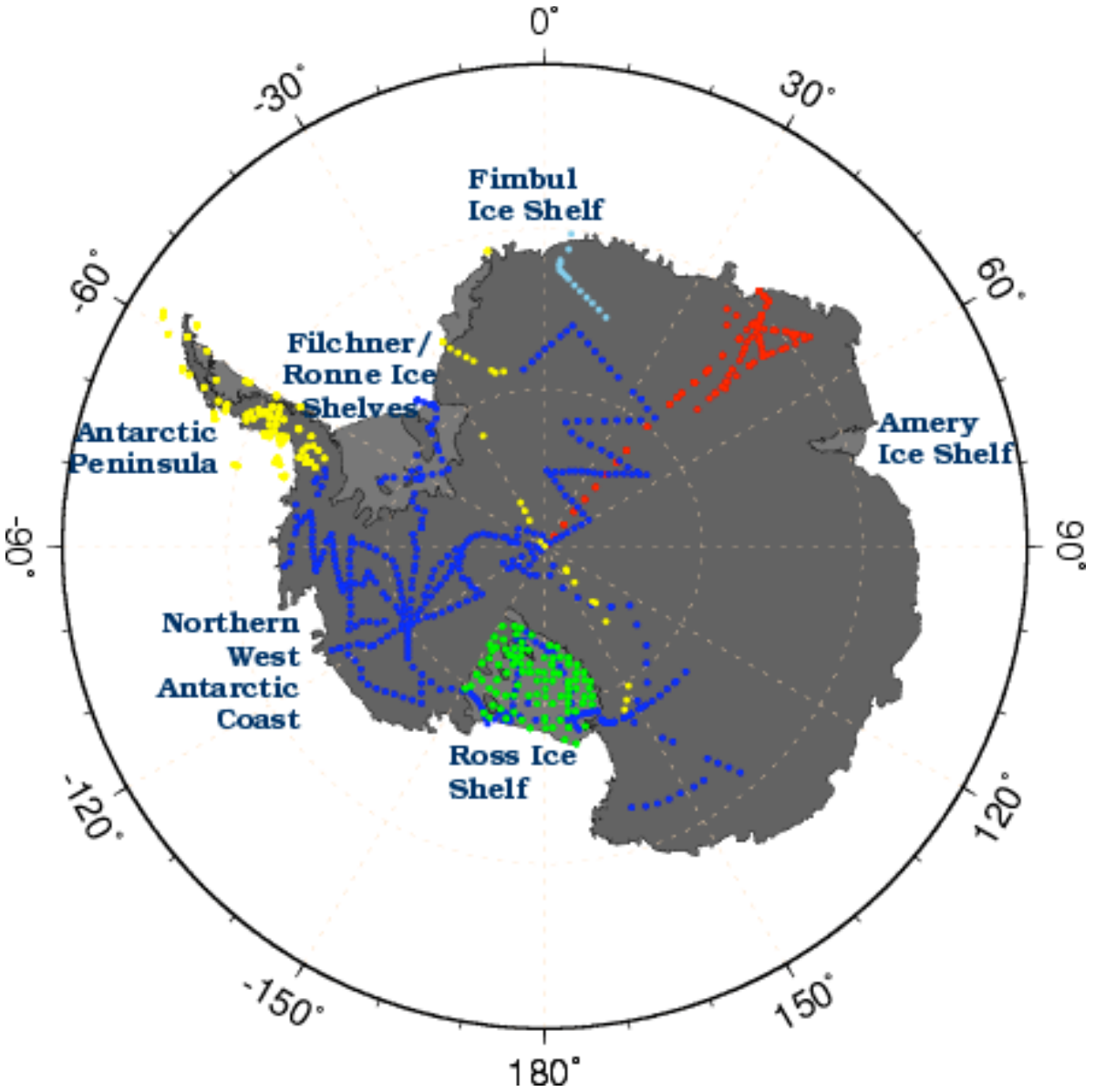
- With AMANDA-II, the requisite tools to inaugurate multi-messenger astronomy are available.

- To probe the neutrino fluxes at highest energies, new techniques are being developed based on radio cherenkov detection.

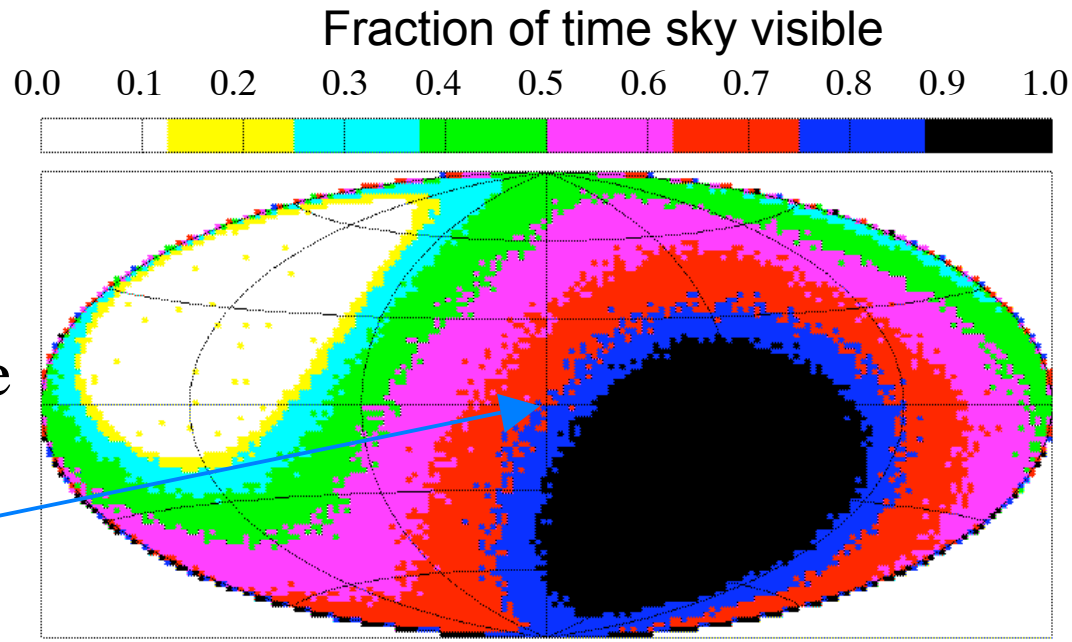
- ANITA extends search volume to 10^6 km^3.



Surface Temperatures

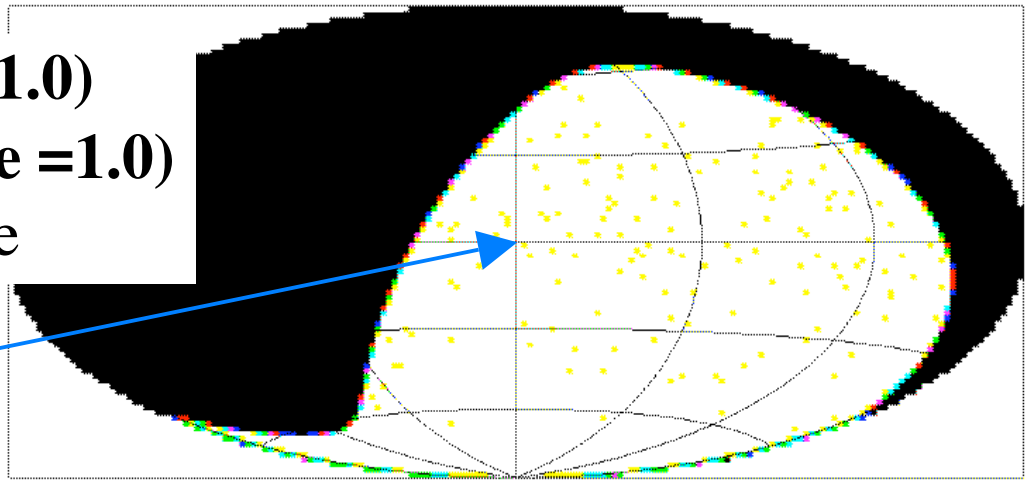


Northern/Southern Sky Complementarity



ANTARES
Northern Hemisphere

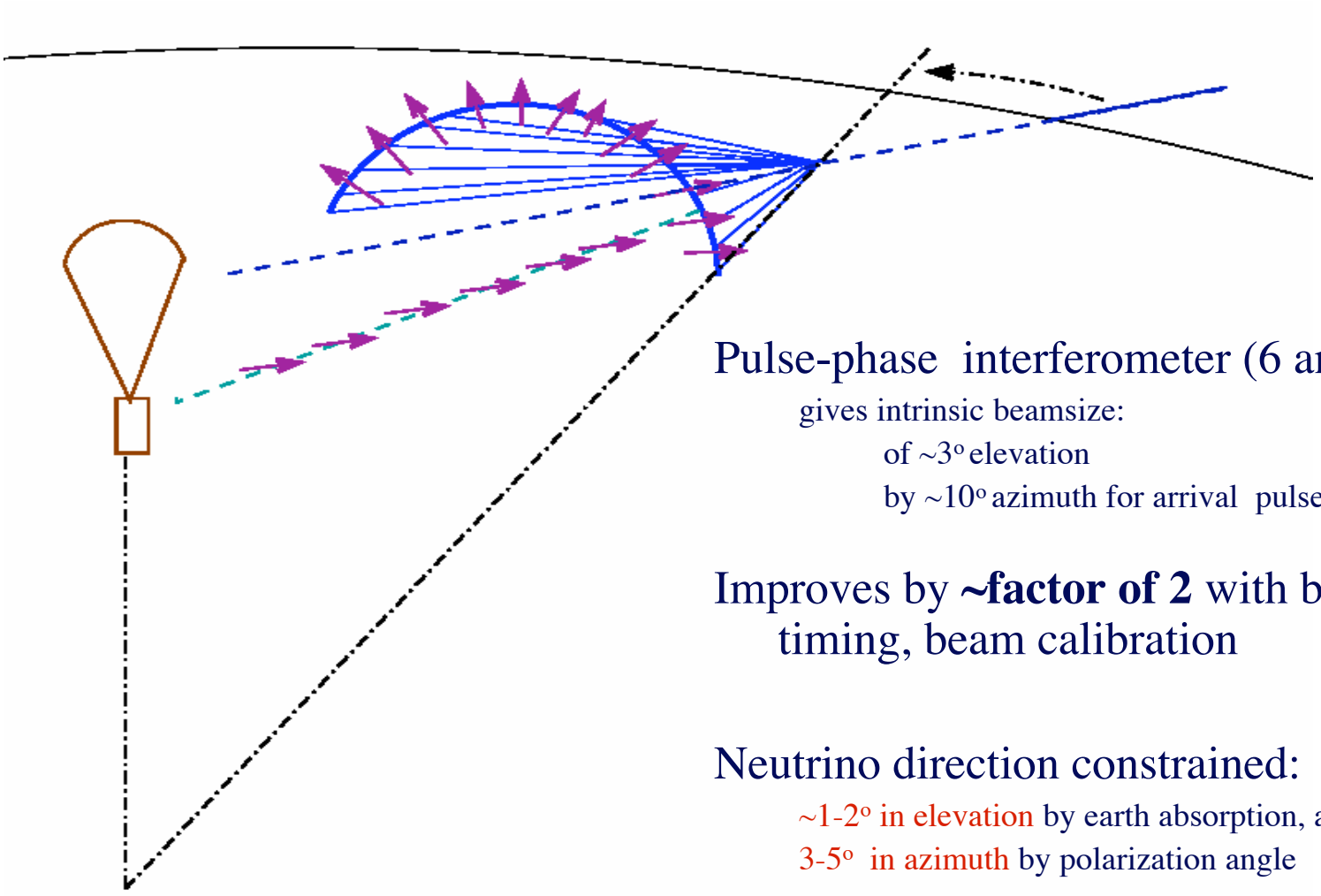
Galactic Center
seen 80% of time



ν_μ AMANDA (black=1.0)
~ANITA w/Reflect (white =1.0)
Southern Hemisphere

Galactic Center

ANITA as a neutrino telescope



Pulse-phase interferometer (6 antennas):

gives intrinsic beamsize:

of ~3° elevation

by ~10° azimuth for arrival pulse

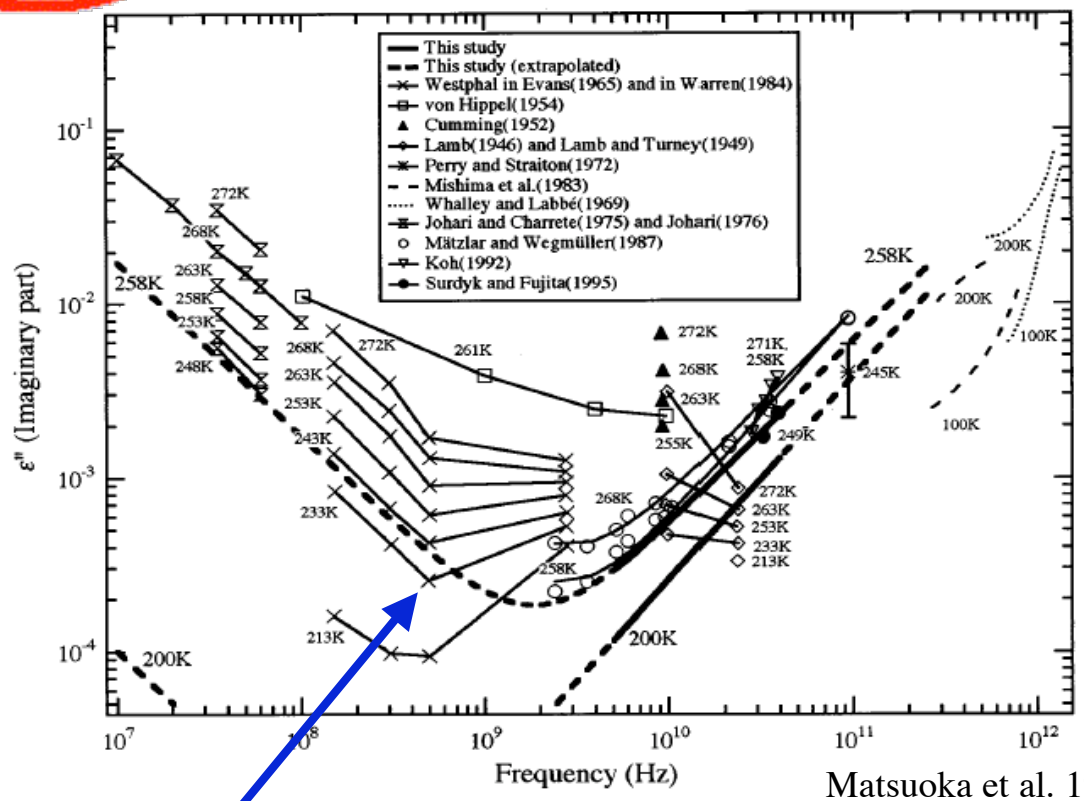
Improves by **~factor of 2** with better pulse timing, beam calibration

Neutrino direction constrained:

~1-2° in elevation by earth absorption, and

3-5° in azimuth by polarization angle

Ice transparency



Matsuoka et al. 1996

FIG. 7. The ε'' plotted logarithmically against frequency with temperature as a parameter. The bold lines represent fitted lines in this study with the parameters $B=1.747\times10^{-5}$, $C=1.168$ and $B=4.696\times10^{-5}$, $C=1.056$ at 200 and 258 K, respectively. The previous reported values are from Warren (Ref. 2).

Loss tangent a strong function of temperature

For cold ice, UHF (0.1-1GHz) best

Antarctic data approaches pure ice values

$L_\alpha = \lambda\,[\pi n\,(\varepsilon''/\varepsilon')]^{-1} \sim 6$ km at 300 MHz & -60C (pure ice, theory)

Schedule for ANITA

03/04	Fly ANITA-lite, measure attenuation lengths in ice
04	analyze data, complete gondola and instrument design
05	Jan :Begin assembly and integration June: test partial instrument in New Mexico, mechanical Aug: Begin final integration and testing
06	June: NSBF integration in Palestine, TX Sept: Ship to Antarctica Dec : Integrate and Launch ANITA payload
07	Jan : Recover payload, ship back to mainland

Commensurate with graduate student lifetime!