ANITA status

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Topics

- Review ANITA
  - detector
  - analysis: simulation/reconstruction
  - results: neutrino/cos-ray/~~other~~
- Analysis improvements
  - ice: propagation and reflection
  - cos-ray energy scale
- Plans for ANITA-III
  - mechanical/data handling/cal sources
  - antennas
  - trigger

ANITA

- Overview
- Neutrino detection
  - ~~event generation~~
  - ~~event simulation~~
  - ANITA detector
  - analysis
  - results
- Cos-Ray detection
- ~~Monopoles~~
- ~~EVA~~

ANITA Collaboration

University of California, Irvine

Ohio State University

University of Kansas

Washington University in St. Louis

University of Delaware

~~University of Minnesota~~

University of California, Los Angeles

University of Hawaii at Manoa

National Taiwan University

University College London

Jet Propulsion Laboratory

Stanford Linear Accelerator Center

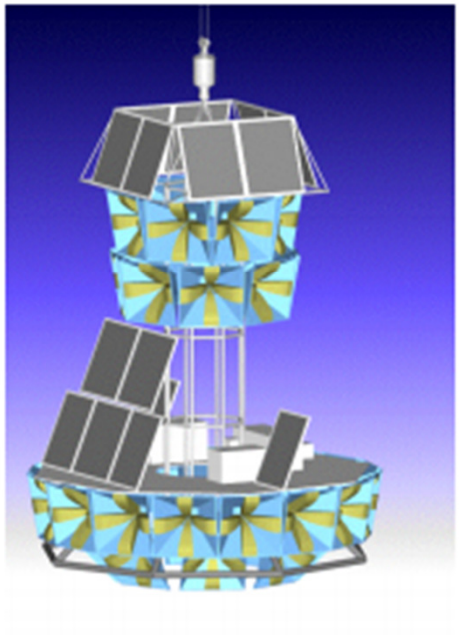
+ Chicago

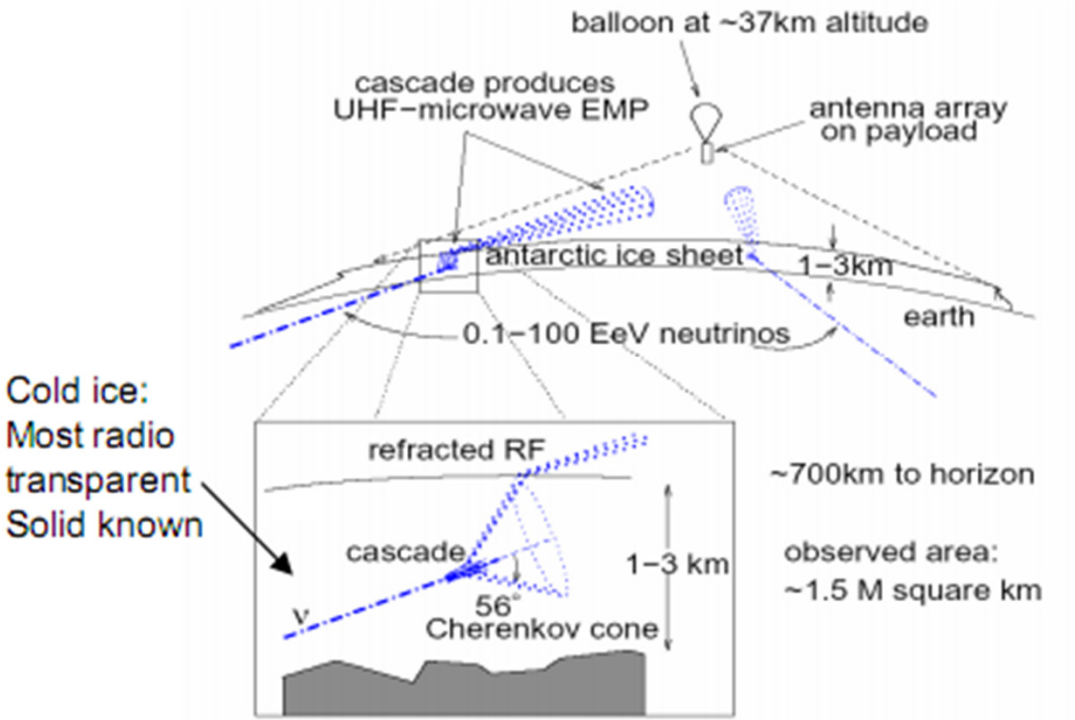
Overview

shamelessly borrowed from P. Gorham

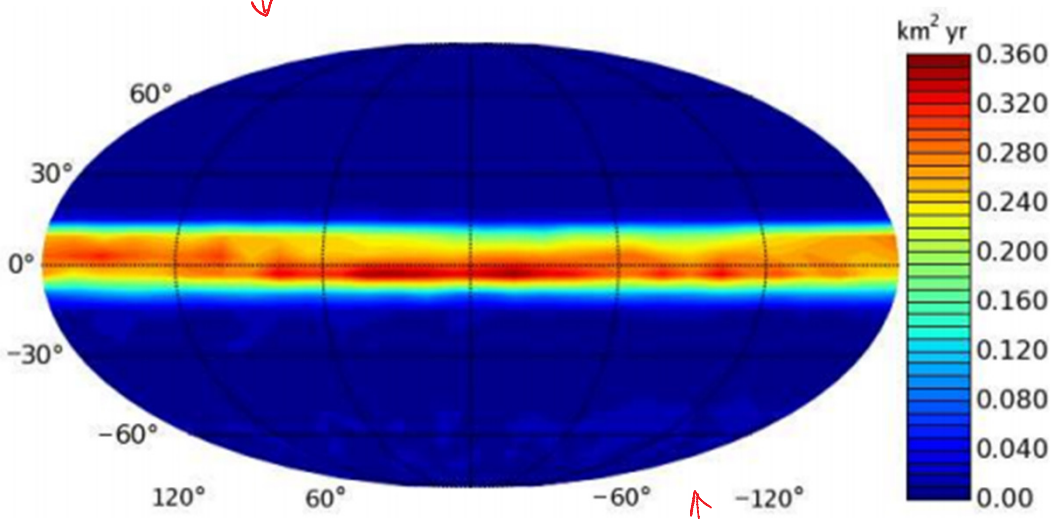
ANITA will seek the origin of the *highest energy particles in the universe*, by turning the continent of Antarctica into an enormous

Neutrino Telescope





Sky coverage



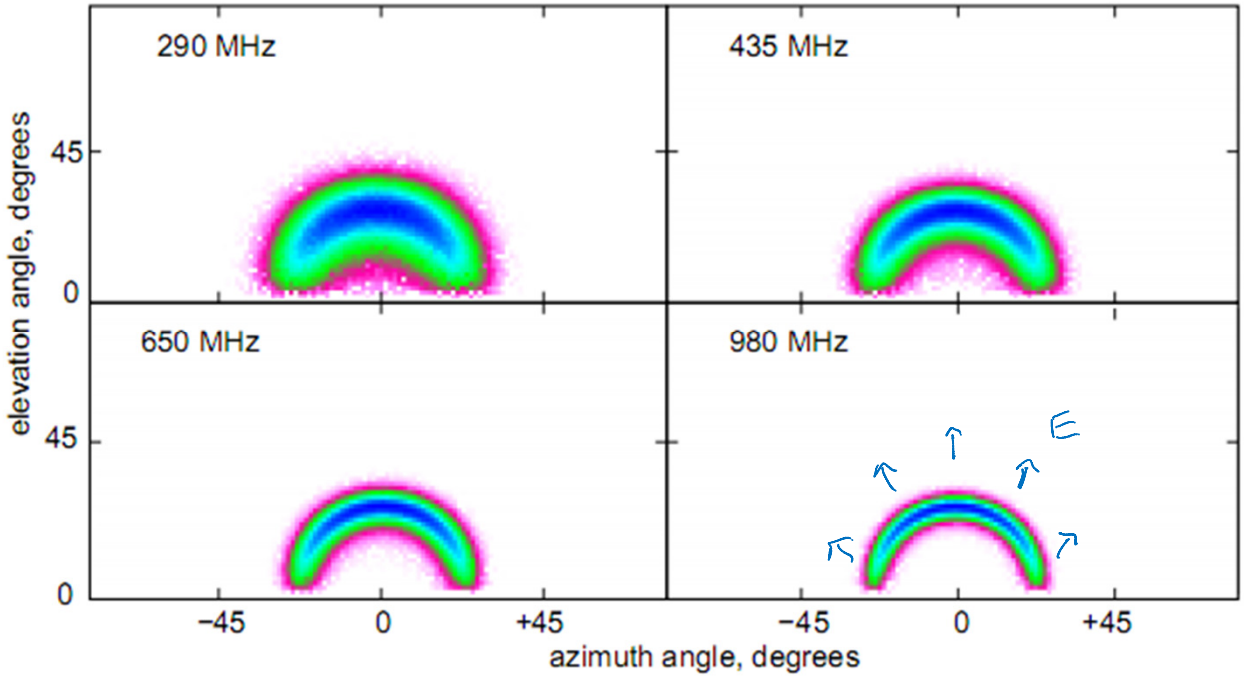
absorbed

just right

FIG. 19: A false-color map of sky exposure quantified by total neutrino aperture (here given for $E_\nu = 10^{20}$ eV) as a function of right-ascension and declination for the ANITA-1 flight.

suffers total internal reflection

Cerenkov beam exits the ice



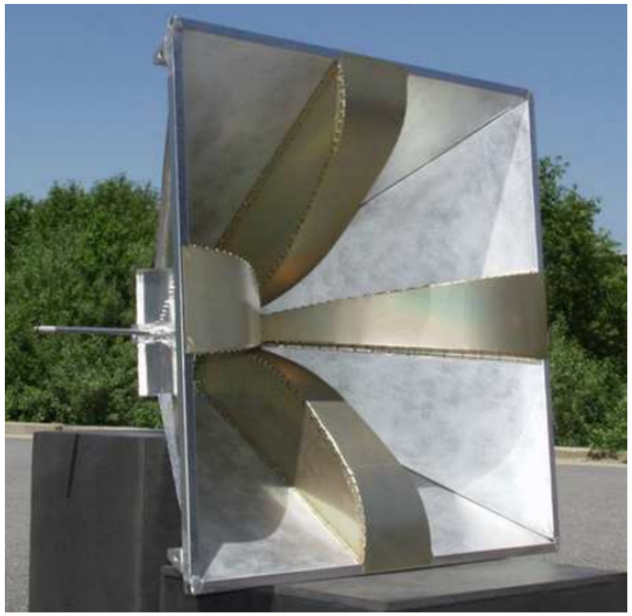
ANITA detector

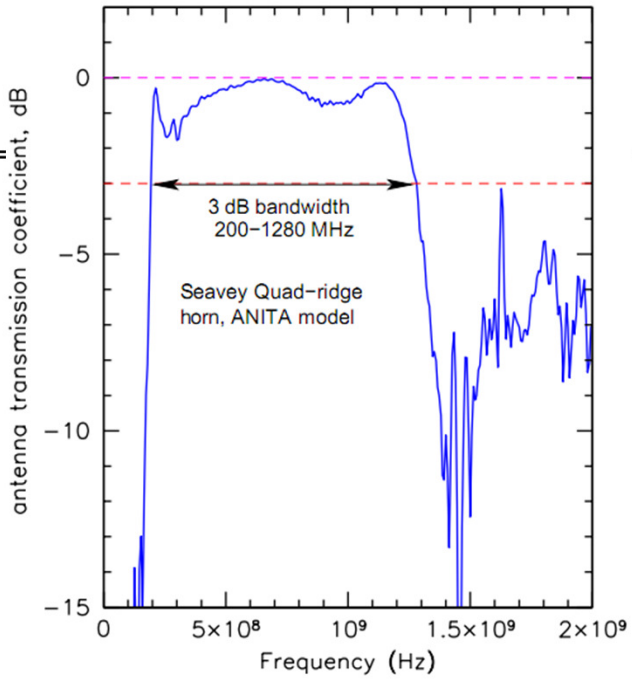
- Airframe and payload infrastructure
- Analog front end
  - Antennas
  - Low Noise Amps, filter, splitter
  - Cables/connectors/boxes
- Trigger
  - multistage, narrow dt: reduce accidentals
- Digitizer
  - Low power switched capacitor array
- Efficient data handling

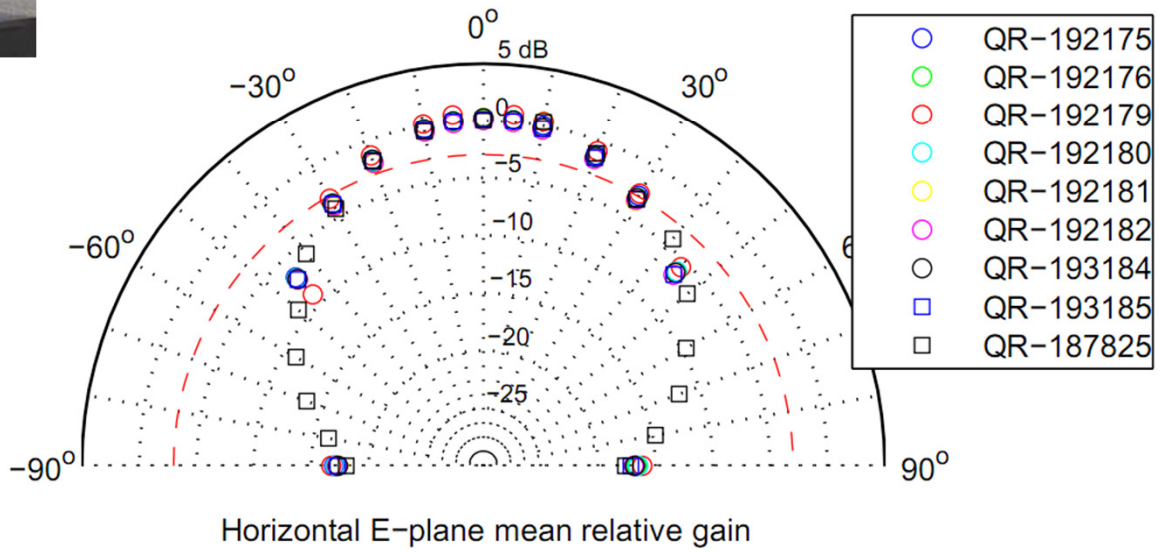
ANITA Payload

- Weight
- Rigidity
- Form-factor
- Power
- Thermal
- Remote

Front end: antennas

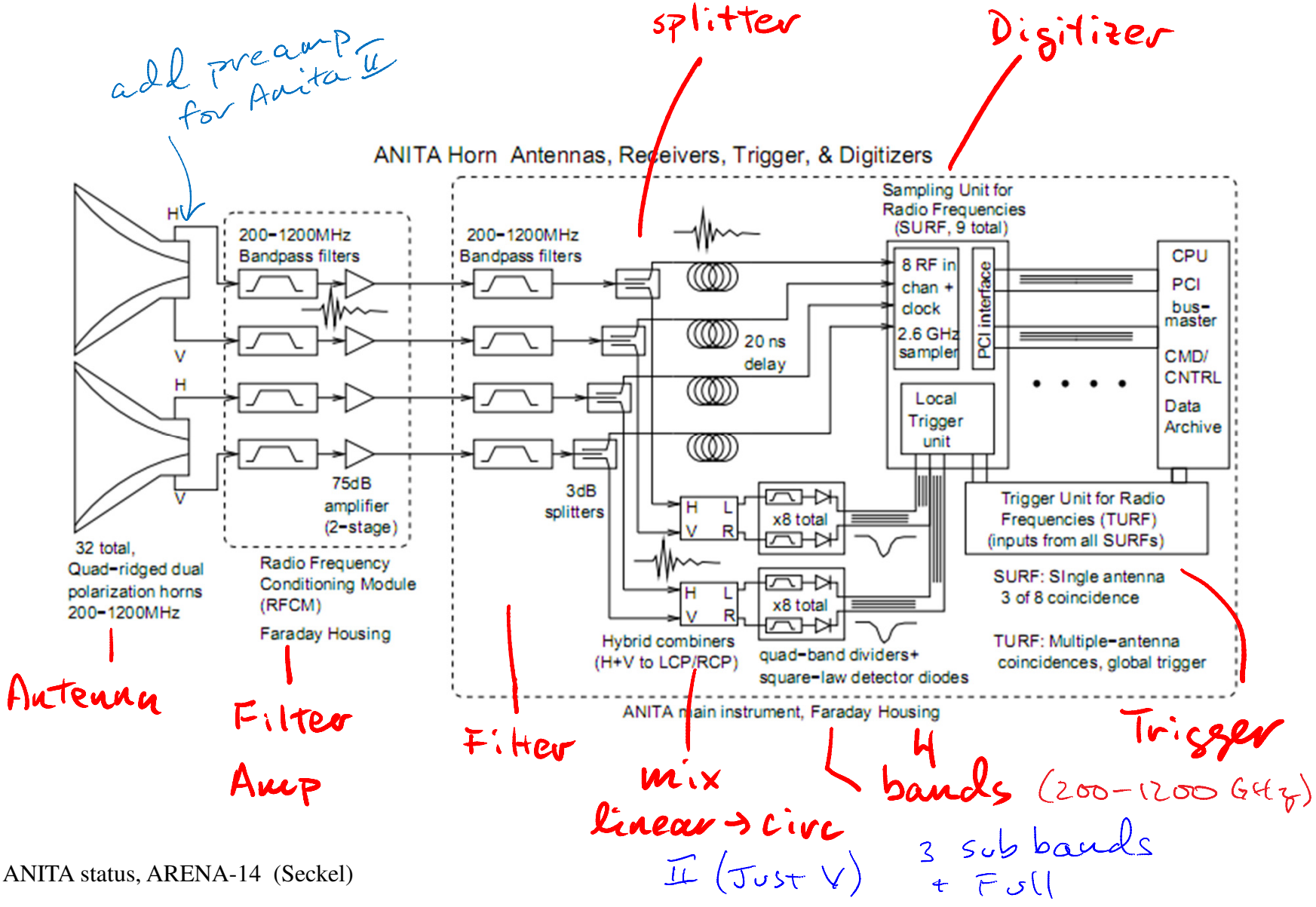




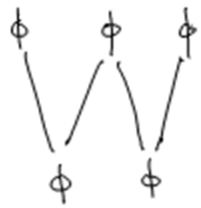


Horizontal E−plane mean relative gain

RF subsystems (ANITA-I)



Triggers

	Lϕ Pol	Lϕ Bands	L1 n/m	L2 in Ring Antenna's	L3 Top/Bottom ϕ-sectors	Focus
I	LR	4	3/8	A—A—A—A		Č is linear
II	V	3+full	2/3+full	A—A—A		ν-Geometry prefers V-pol

But bad for cos-ray

Digitizing electronics (Anita-I)

TABLE I: ANITA Electronics Specifications.

Design Parameter	**As-built Value & Comments**
# of RF channels	80 = 32 top, 32 bottom, 8 monitor
Sampling rate	2.6 GSa/s, greater than Nyquist
Sample resolution	$\geq$ 9 bits = 3 bits noise + dynamic range
Samples in window	260 for a 100 ns window
Buffer depth	4 to allow rapid re-trigger
Power/channel	$<$ 10W including LNA & triggering
# of Trigger bands	4, with roughly equal power per band
# of Trigger channels	8 per antenna (4 bands x 2 pols.)
Trigger threshold	$\leq 2.3\sigma$ above Gaussian thermal noise
Accidental trigger rate	$\leq$ 5 Hz, gives 'heartbeat' rate
Raw event size	$\sim$ 35 kB, uncompressed waveform samples

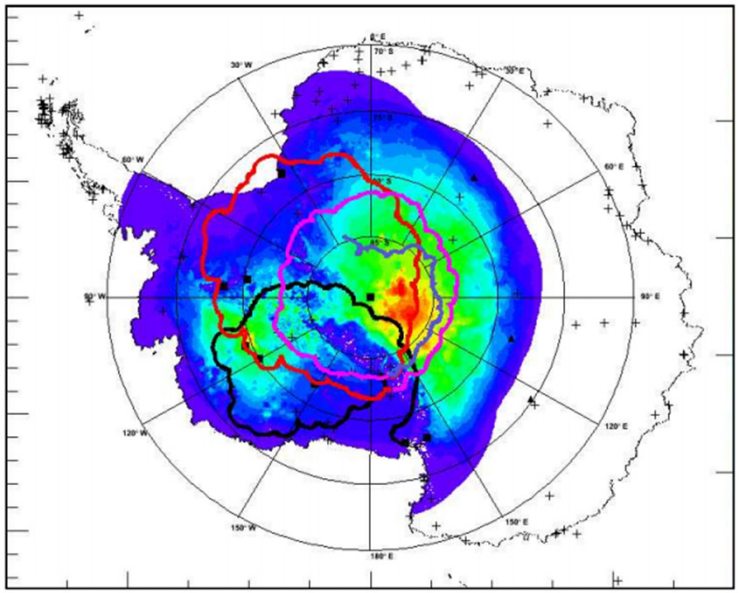
- Key component: Switched Capacitor Array (SCA) by G. Varner.

Operations

- Campaign operations
  - NH preparations
  - McMurdo
  - Flight
  - Recovery
  - Taylor Dome
- C^3

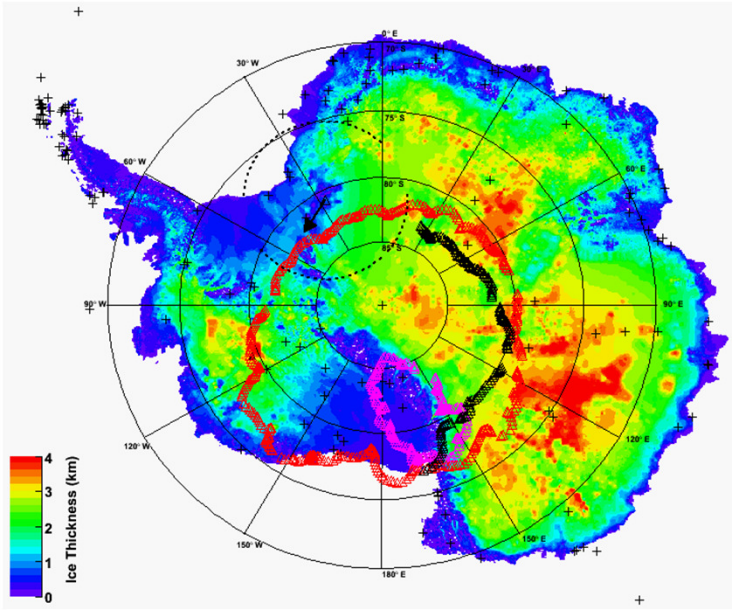
ANITA flight(s)

ANITA-I



- 3 orbits (3 x 14 days)
- ice depth 0-4 km
- bases

ANITA-II (1 week before end)

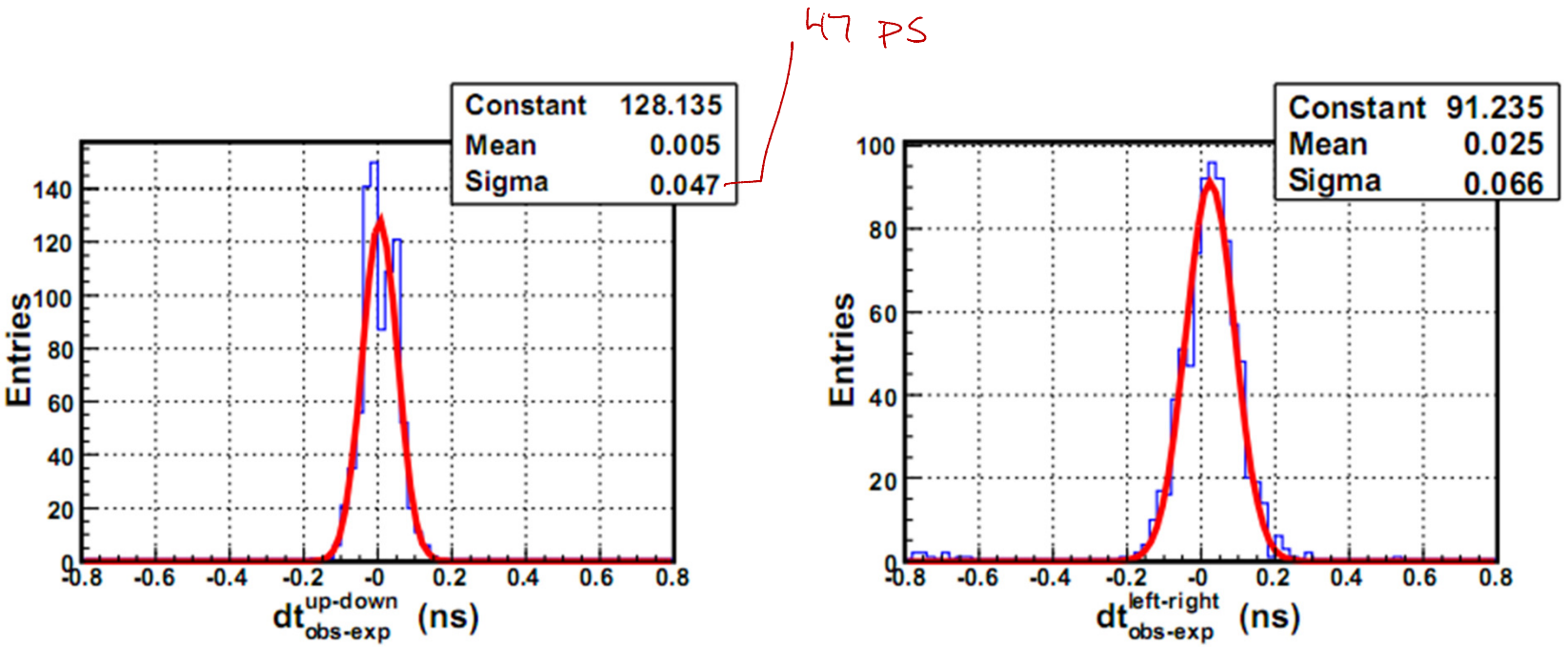


Also: ANITA-LITE

Analysis

- Timing Calibration
- Interferometry
- Backgrounds
  - Thermal (reconstruction amplitude)
  - Anthropogenic (clustering)
- I: 0 neutrino candidates
- II: 1 neutrino candidate
- Limits

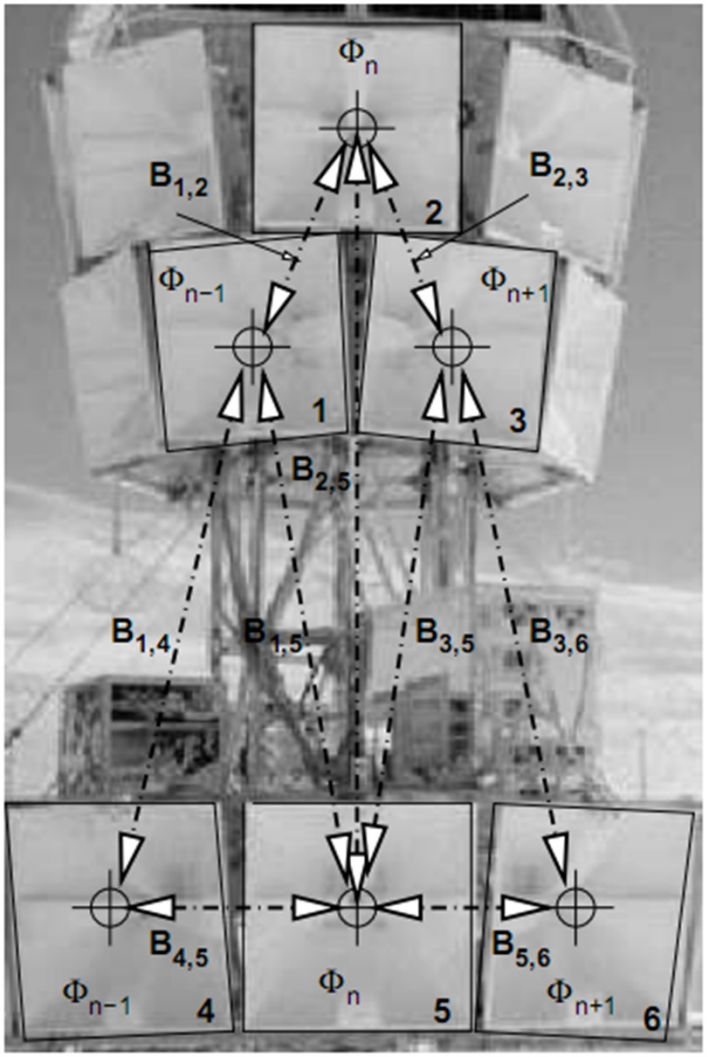
Calibration



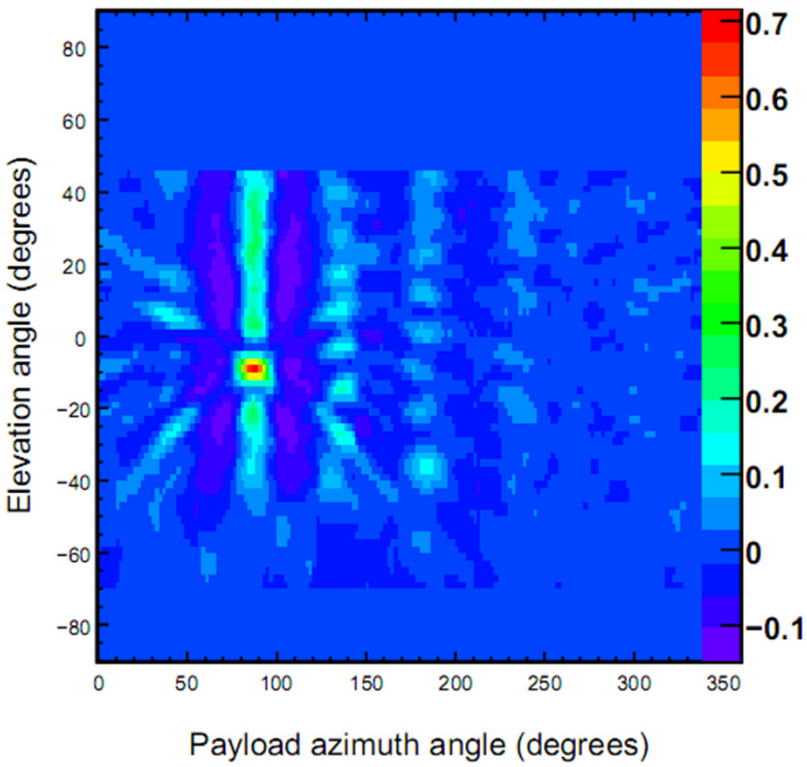
same ϕ sector

Different ϕ

Interferometry (see talk by A. Romero-Wolf)



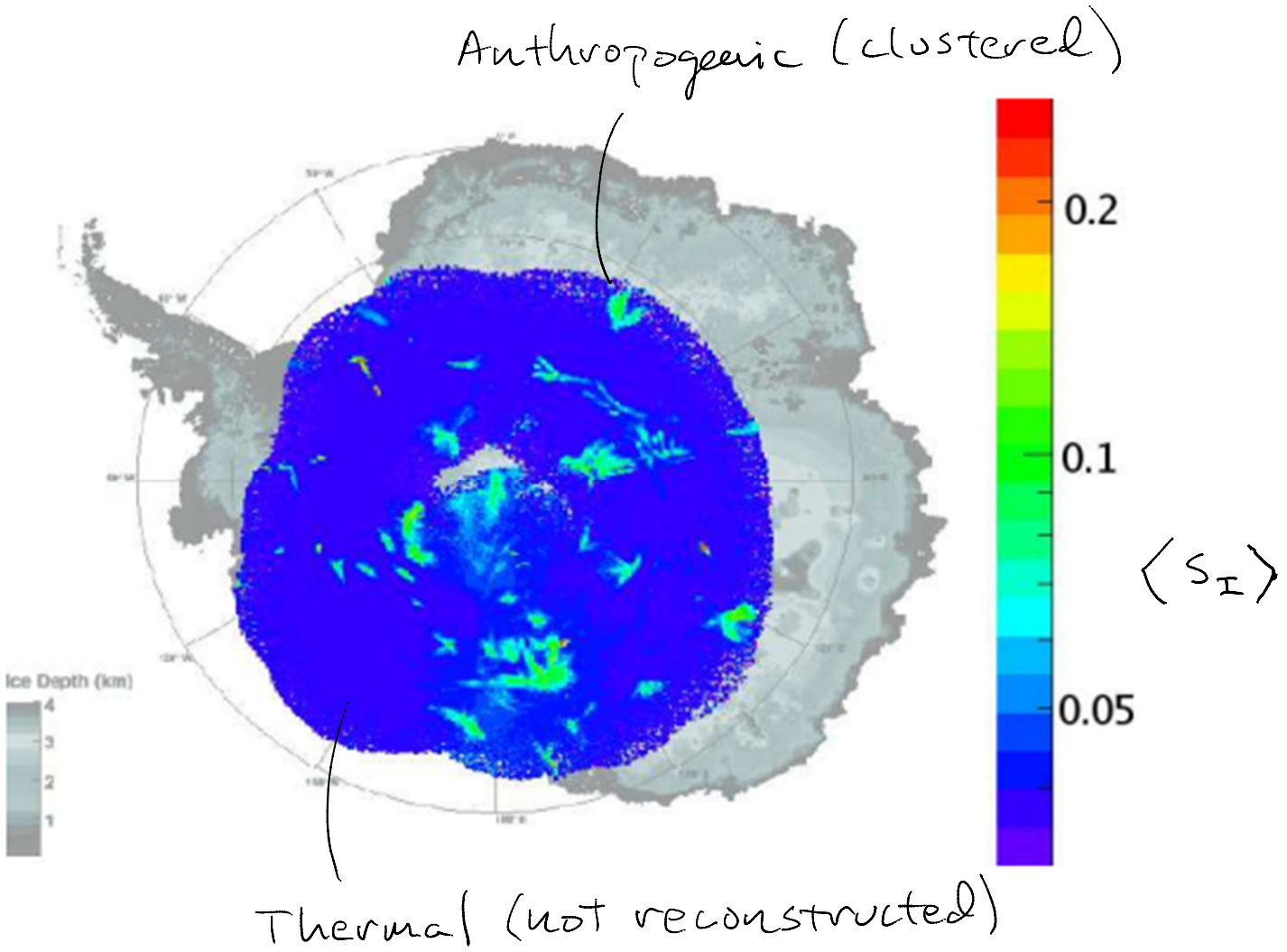
Ground pulser



$\Delta\theta$ 0.2 - 0.4 deg

$\Delta\phi$ 0.5 - 1.1 deg

Backgrounds



Clustering

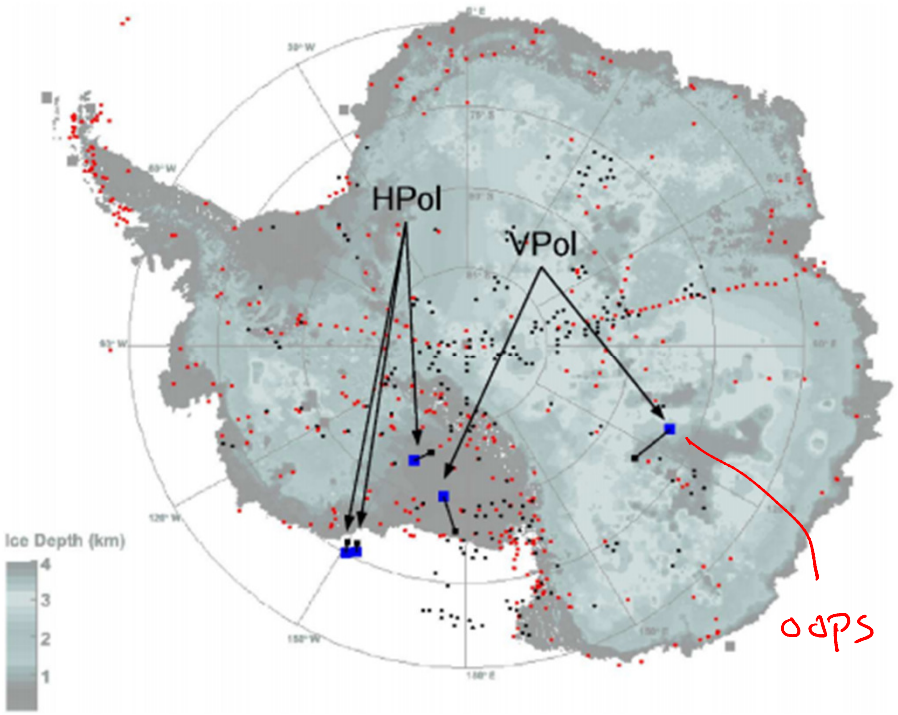


TABLE I: Event totals vs. analysis cuts and estimated signal efficiencies for ESS spectral shape [10].

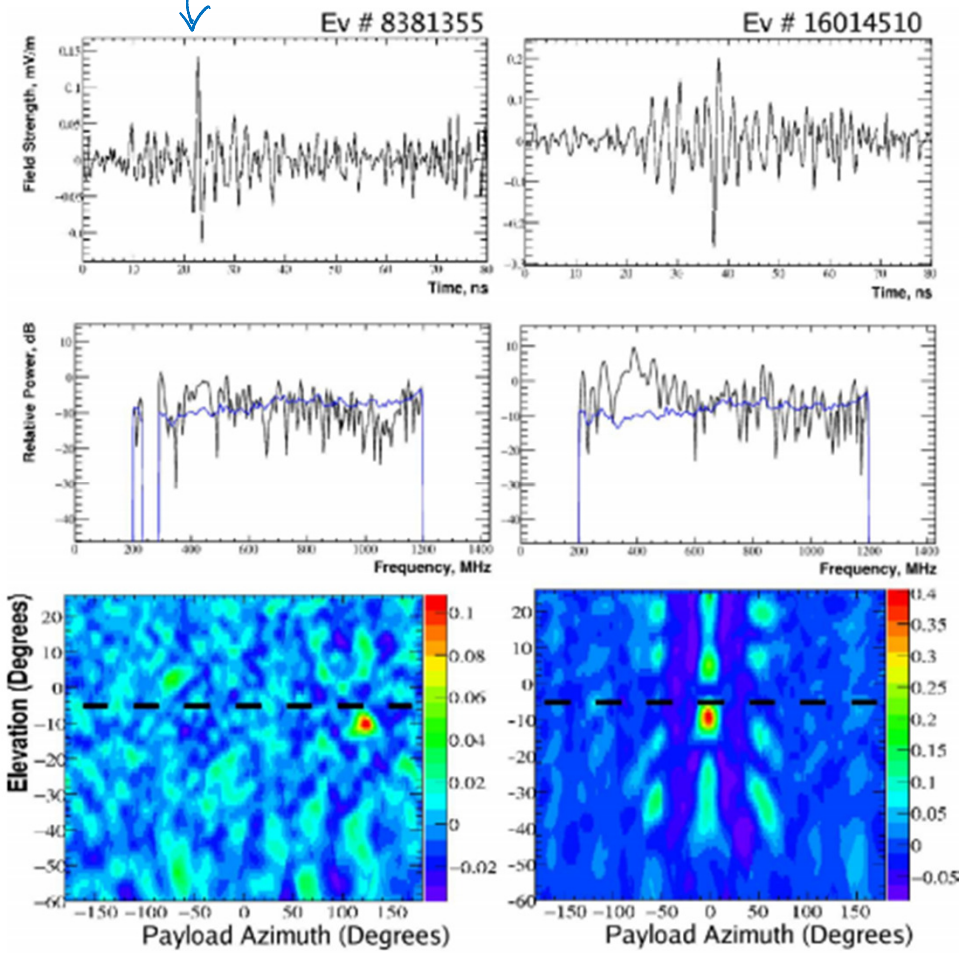
Cut requirement	Passed		Efficiency
	Vpol	Hpol	
Hardware-Triggered Events	~ 26.7M		-
(1) Quality Events	~ 21.2M		1.00
(2) Reconstructed Events	320,722		0.96
(3) Not Traverses and Aircraft	314,358		1.00
(4) In Clusters <100 Events	444		-
(5) Isolated Singles	7	4	0.64
(6) Not Misreconstructions	5	3	1.00
(7) Not of Payload Origin	2	3	1.00
Total Efficiency			0.61

cut on S_I

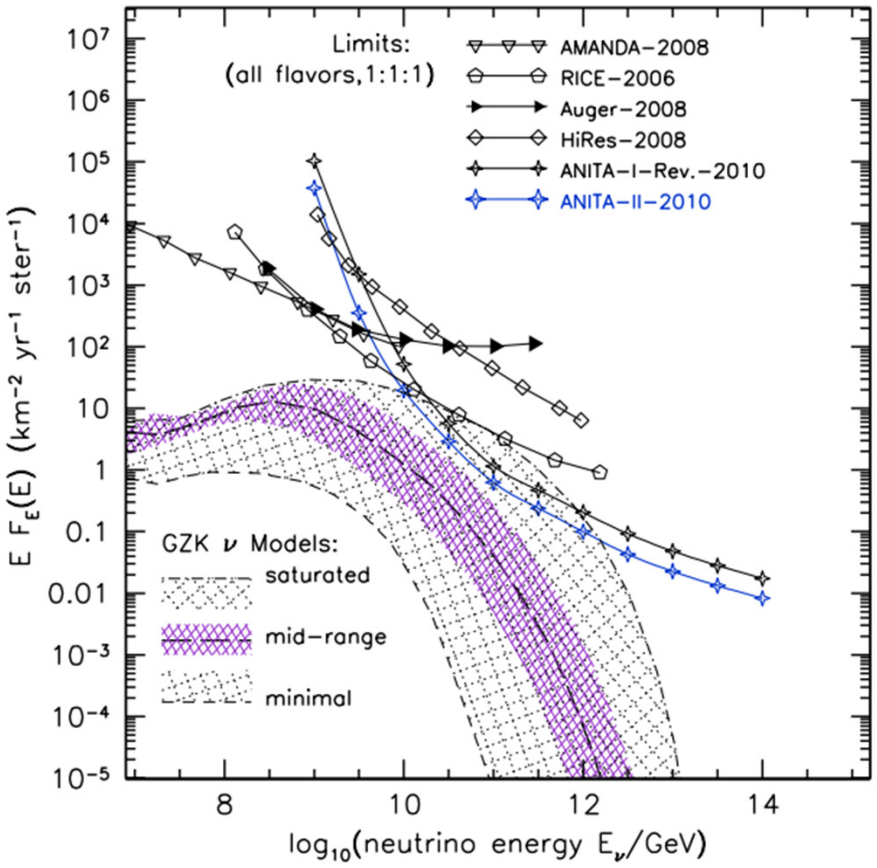
Cluster Multiplicity	Number of Clusters	
	Camp	Not Camp
10-100	8	1
5-9	7	1
4	1	0
3	0	0
2	1	1
1	7	5 (Signal Region)

Candidate events

inserted ground pulser event



ANITA GZK flux limit



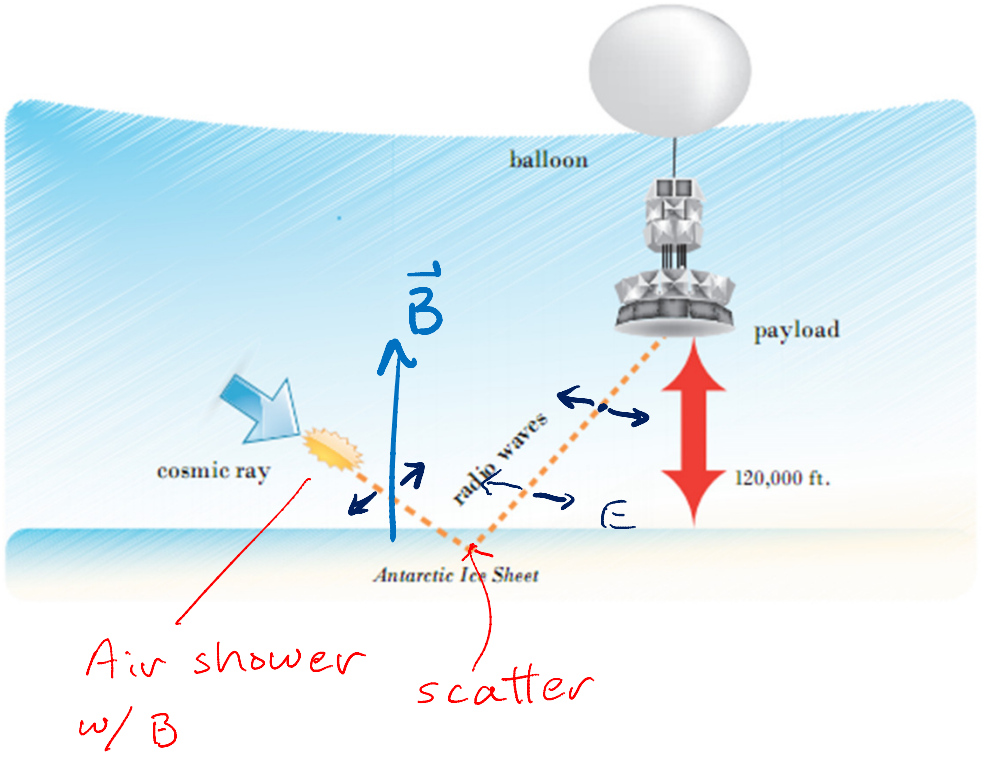
Model & references	predicted N_ν	CL,%
Baseline models:		
Various	0.3-1.0	...
Strong source evolution models:		
Aramo *et al.* 2005	2.4	85
Berezinsky 2005	5.1	98
Kalashev *et al.* 2002	5.6	99
Barger, Huber, & Marfatia 2006	3.5	93
Yuksel & Kistler 2007	1.7	74
Models that saturate all bounds:		
Yoshida *et al.* 1997	30	> 99.999
Kalashev *et al.* 2002	19	> 99.999
Aramo *et al.* 2005	16	99.999
Waxman-Bahcall fluxes:		
Waxman, Bahcall 1999, evolved sources	1.4	...
Waxman, Bahcall 1999, standard	0.5	...

Also – no news from GRBs

TABLE 1
LIST OF THE 12 GRBS INCLUDED IN THE BLIND ANALYSIS

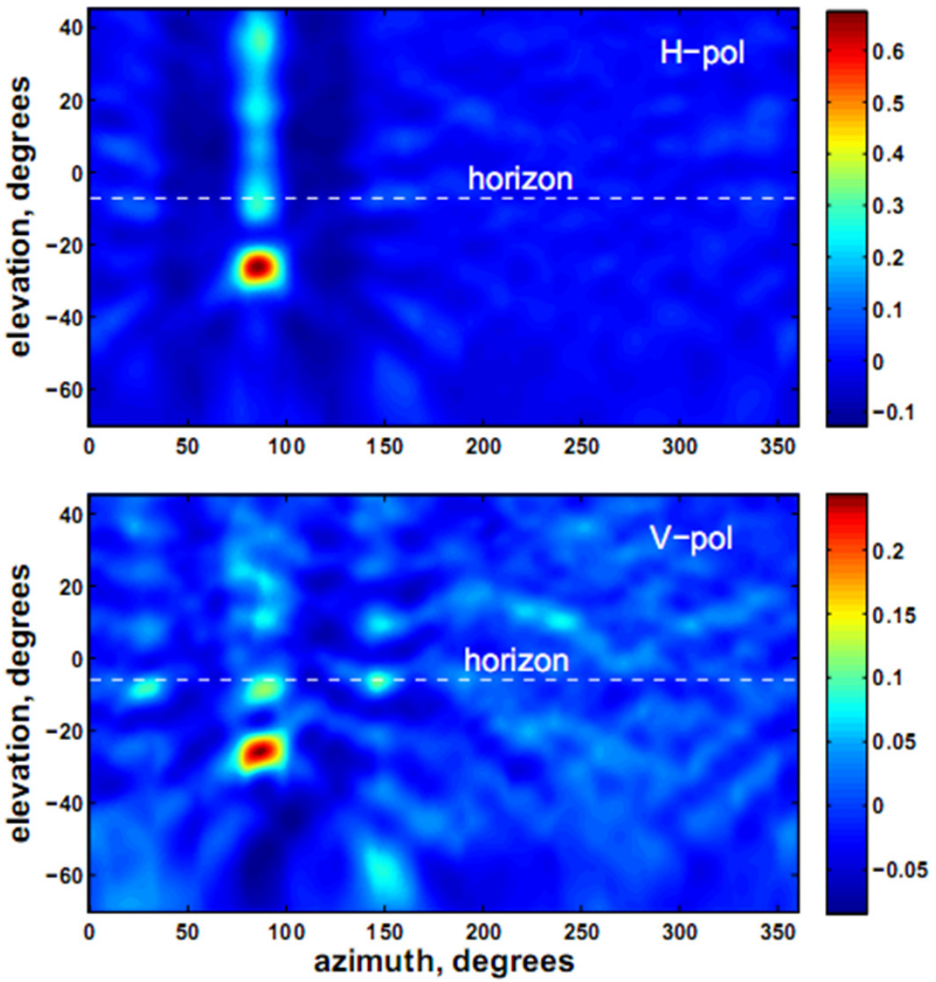
GRB	Date & Time (UTC)	Right Ascension	Declination	Payload Elevation Angle (degrees)
081228	2008 Dec 28 01:17:40	$2^h37^m50^s.94$	$30°51'10\ 50''$	-41.1
081229	2008 Dec 29 04:29:01.88	$11^h22^m0^s$	$55°6'0''$	-55.9
081230	2008 Dec 30 20:36:12	$2^h29^m19^s.51$	$-25°8'49\ 95''$	28.8
081231	2008 Dec 31 03:21:01.93	$14^h35^m0^s$	$-38°43'0''$	47.0
090102	2009 Jan 2 02:55:36	$8^h32^m58^s.54$	$33°6'51\ 10''$	-26.3
090108B	2009 Jan 8 07:43:23.36	$0^h15^m0^s$	$-32°12'0''$	42.9
090109	2009 Jan 9 07:58:29.49	$8^h11^m0^s$	$54°48'0''$	-59.2
090111	2009 Jan 11 23:58:21	$16^h46^m42^s.14$	$0°4'38\ 21''$	1.7
090112A	2009 Jan 12 07:57:23.11	$7^h27^m0^s$	$-30°17'0''$	23.5
090112B	2009 Jan 12 17:30:15.45	$12^h51^m0^s$	$22°12'0''$	-26.8
090113	2009 Jan 13 18:40:39	$2^h8^m13^s.63$	$33°25'42\ 85''$	-25.7
090117B	2009 Jan 17 08:02:02.23	$15^h32^m0^s$	$27°36'0''$	-28.1

Cosmic Ray Detection



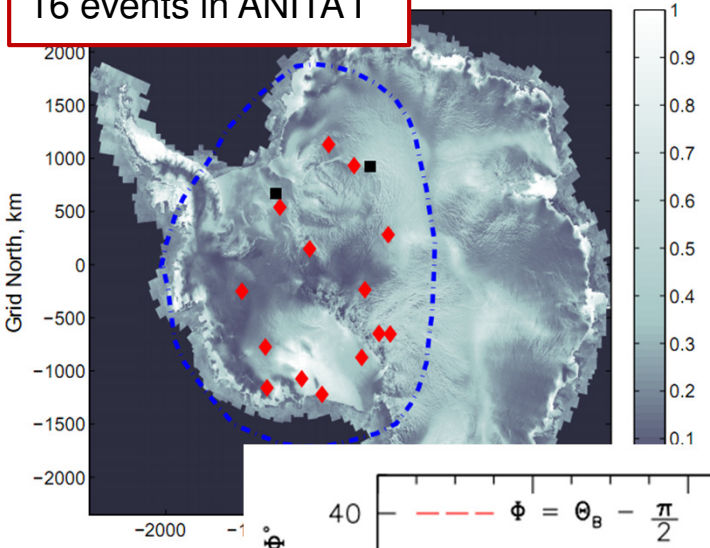
ANITA-I analysis

- Event selection
- Strong interferometric amplitude
- 16 events
  - 14 below horizon
  - 2 above
- Consistent waveforms w/reflection
- Correlated with B

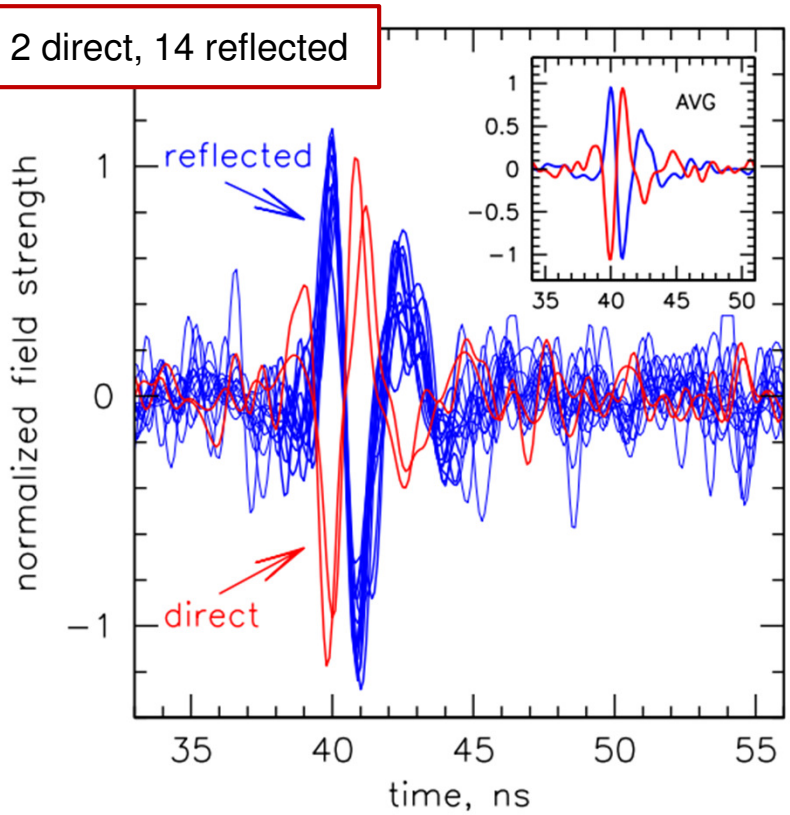


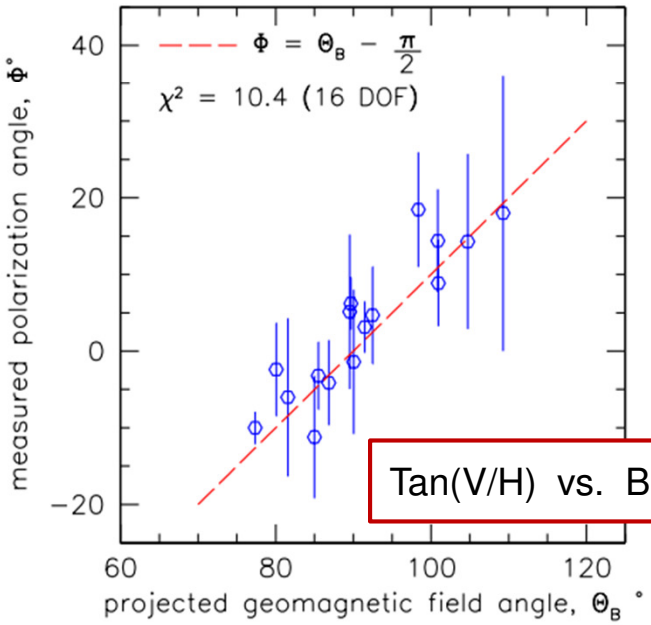
Air shower highlites

16 events in ANITA I



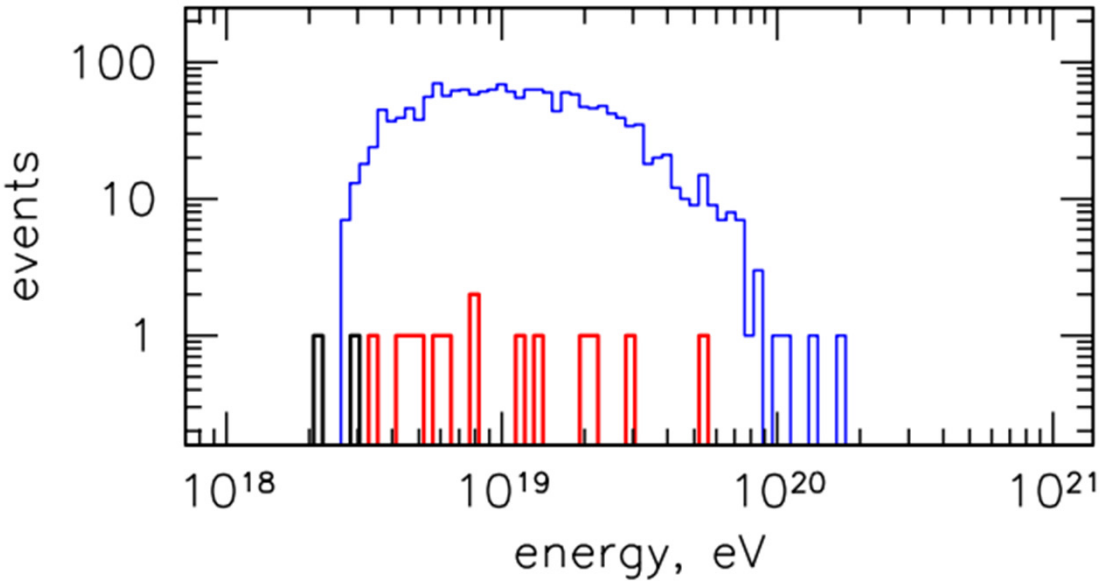
WaveForms: 2 direct, 14 reflected





Tan(V/H) vs. B

MC and Energy Scale



- exposure
- reflection w/roughness
- freq-spectrum
- E-spectrum
- angular offset

- $N \propto \Omega \int_{E_T} \phi(E)\, dE = \Theta^2 / E_T^2$ for E^{-3}

- $\Rightarrow$ if $\Theta \downarrow$ then $E \downarrow$

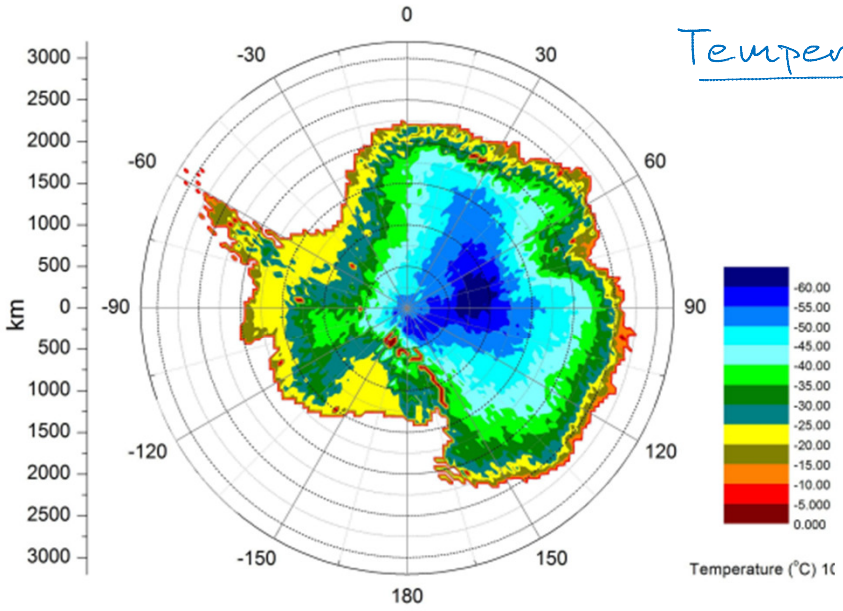
- $E(\gamma, \Theta)$ reasonable but extrapolated

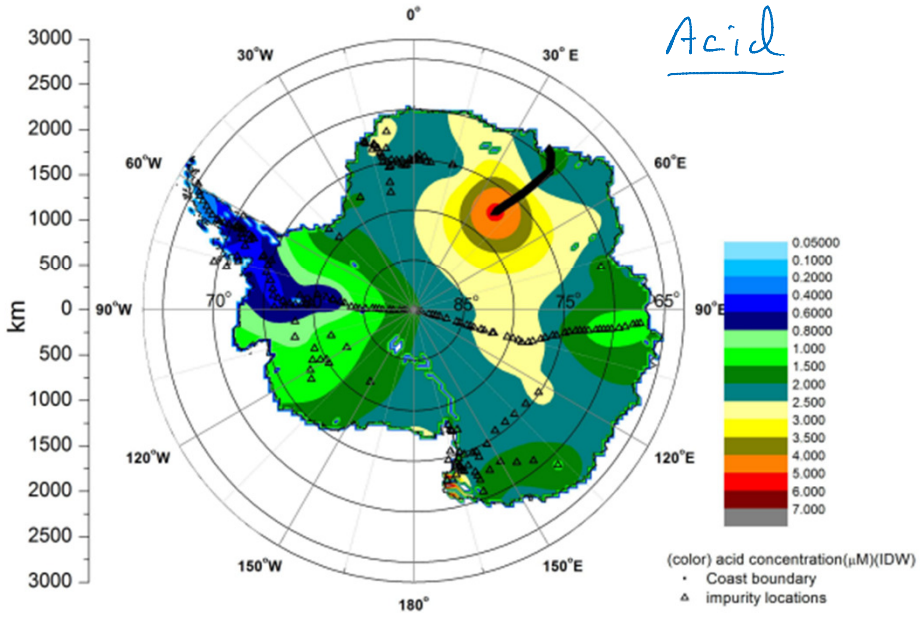
- Issues w/ REAS 2

Analysis improvements

- ice: attenuation (M Stockham)
  - attenuation models based on temp and impurities (from Javaid)
  - validation with CRESIS RDS data
- ice: reflection (J Stockham)
  - attempt model of antarctic surface roughness
- cos-ray energy scale (Zas)

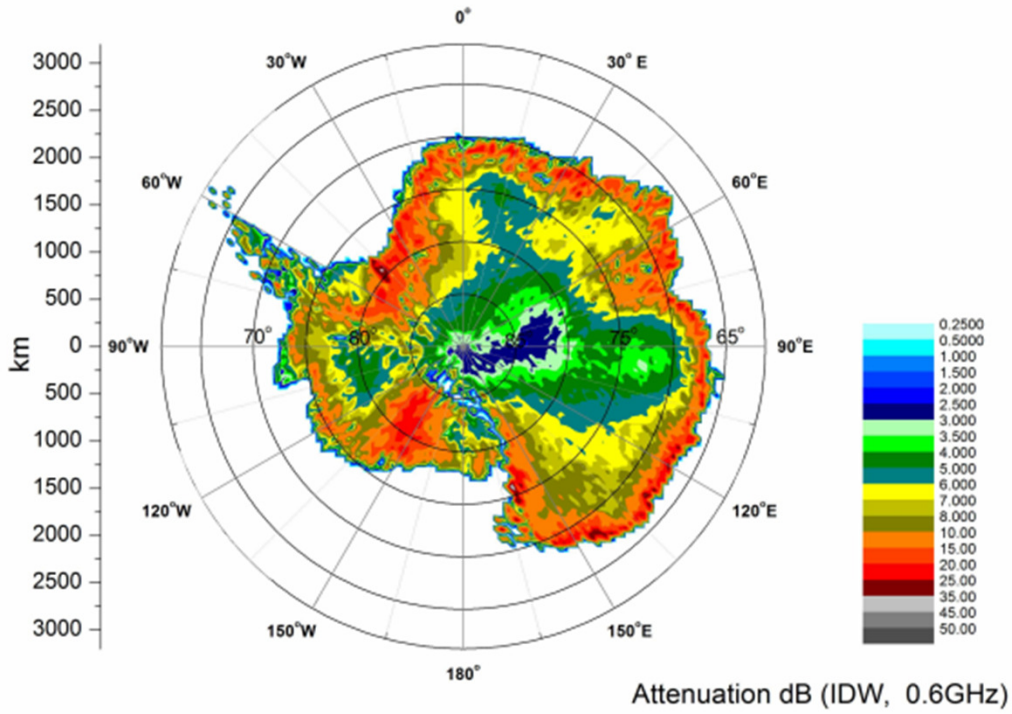
Attenuation (Amir Javaid)

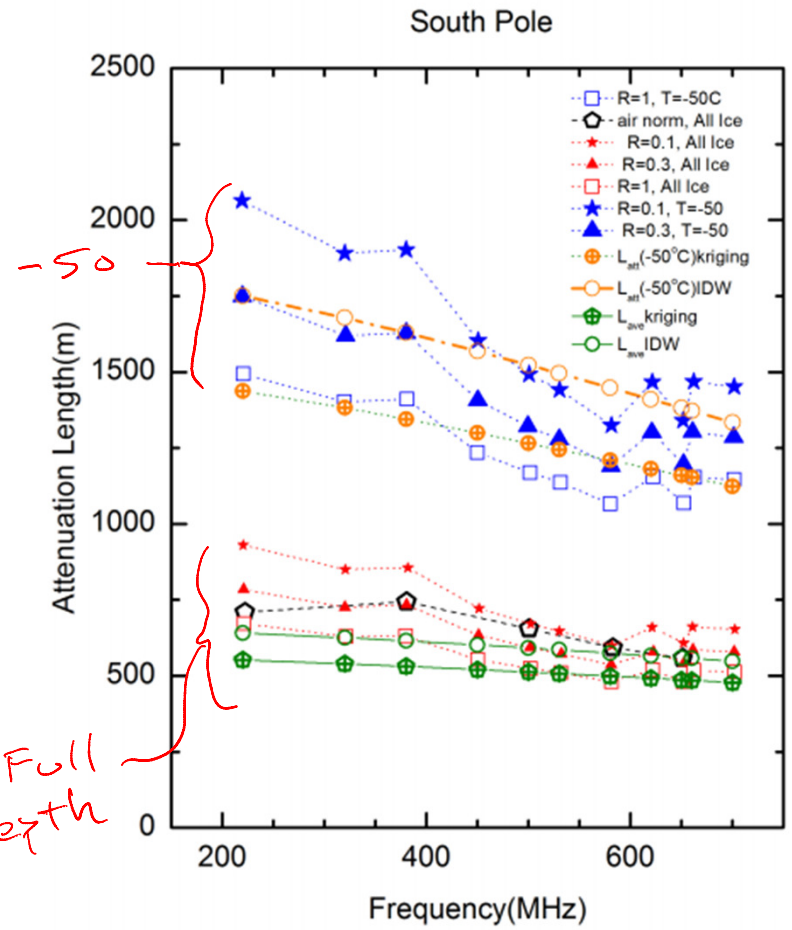




Attenuation

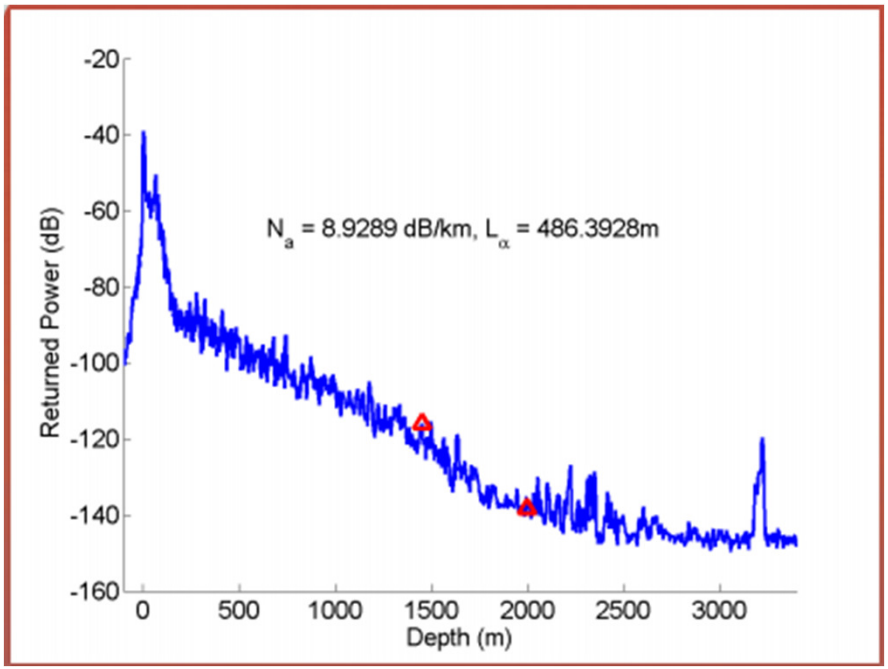
Top 1 km





Ice attenuation (M Stockham)

- Center for Remote Sensing of Ice Sheets (CReSIS)
- Radar Depth Sounding (RDS) from West Antarctica
- Model scattering + attenuation to fit RDS.



Reevaluate cos-ray energy scale

- why …

$$\Gamma = \int_{E_T} d\Omega \; E^{-\alpha} \, dE = \Omega \, E_T^{1-\alpha} = \Omega \, E_T^{-2}$$

$$\Rightarrow \quad E_T \sim \left(\frac{\Omega}{\Gamma}\right)^{1/2}$$

PRL: $n=1$ spot $\quad \theta \simeq 1.5^\circ \quad \Omega \simeq 7$ sd

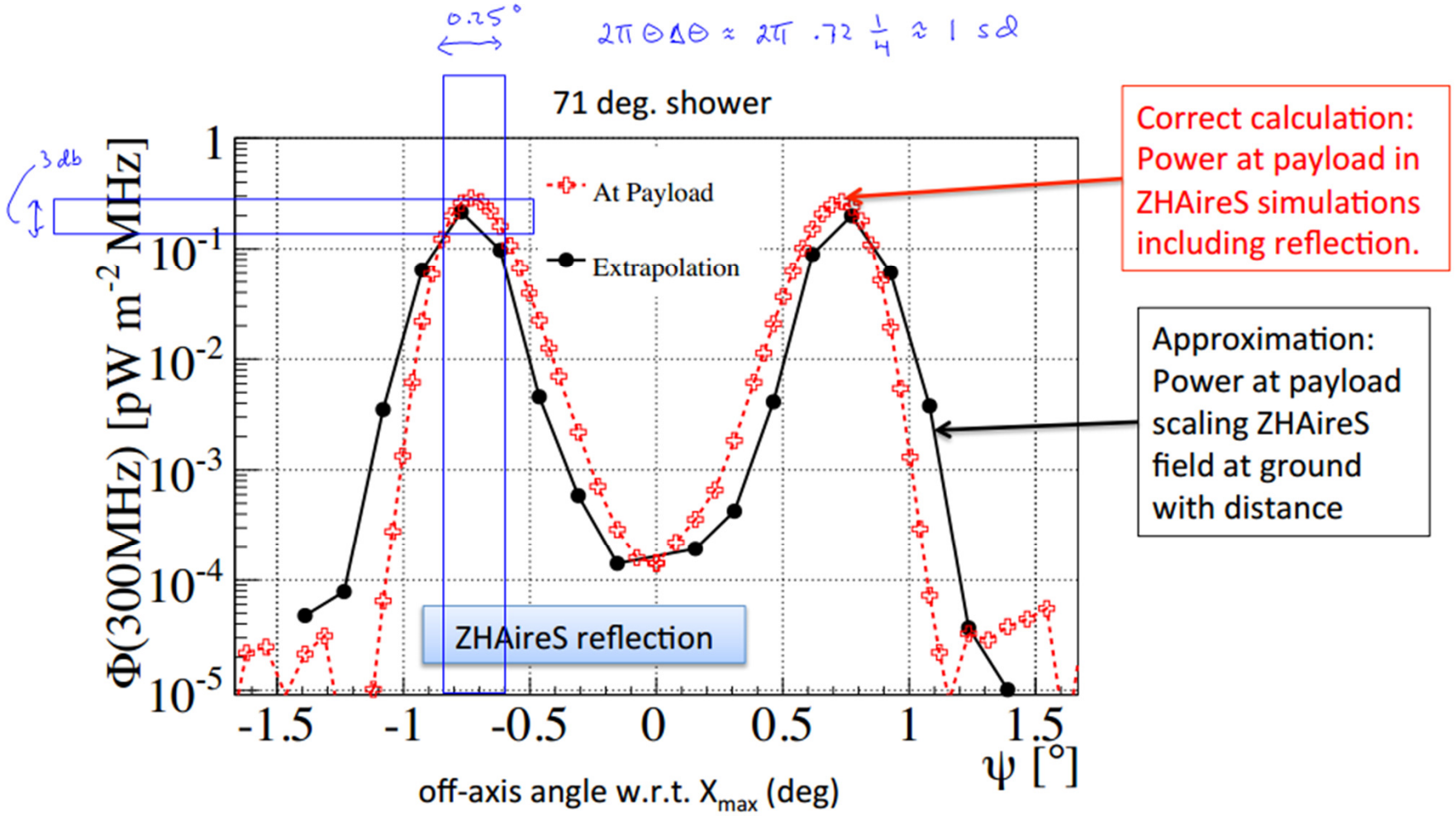
modern: $n>1$ ring $\quad 2\pi\theta\,\Delta\theta$

- SLAC T-510 (Mulrey, Zilles)
- ZHAireS development (Zas)

SLAC T-510 (Mulrey, Zilles)

- Cherenkov behavior for radiation from “Hall” currents
- Validate scaling with B
- Absolute calibration of charge excess and geomagnetic radiation

Cerenkov Ring suggests <E> down by ~ 3.



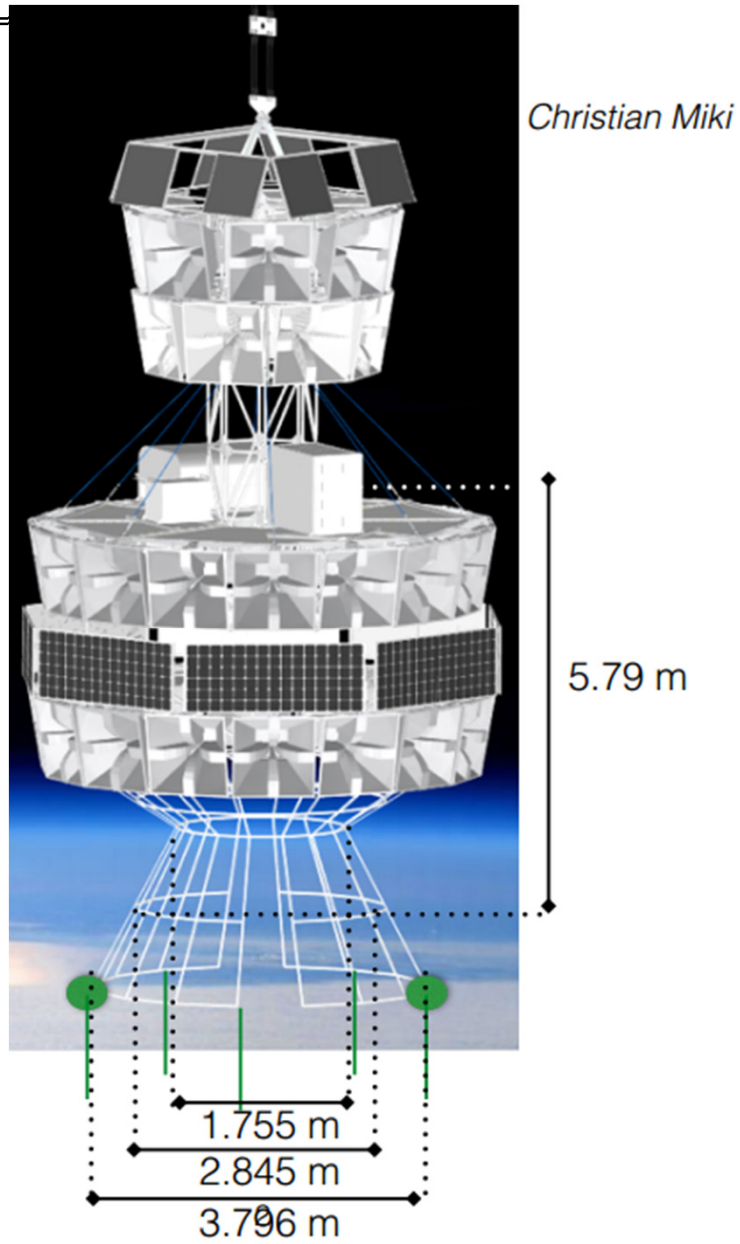
Adapted from Zas, ARENA 14

ANITA-III (2014/15): improvements

- Mechanical/data handling/cal sources
  - carbon fiber airframe, Li-ion batteries, misc: -450 lbs
  - 10 x storage capacity
  - 10 x bandwidth (Iridium open port)
  - more ground pulsers + HiCal: pulser mounted on second balloon (?)
- Antennas
  - 8 more horns
  - ALFA: ANITA Low Frequency Antenna
- Trigger
  - separate neutrino/cos-ray triggers
  - improved majority logic trigger
  - dynamic beam forming trigger

ANITA-III antennas

- +8 horns in bottom ring
- Big ALFA
  - (ANITA Low Frequency Antenna)

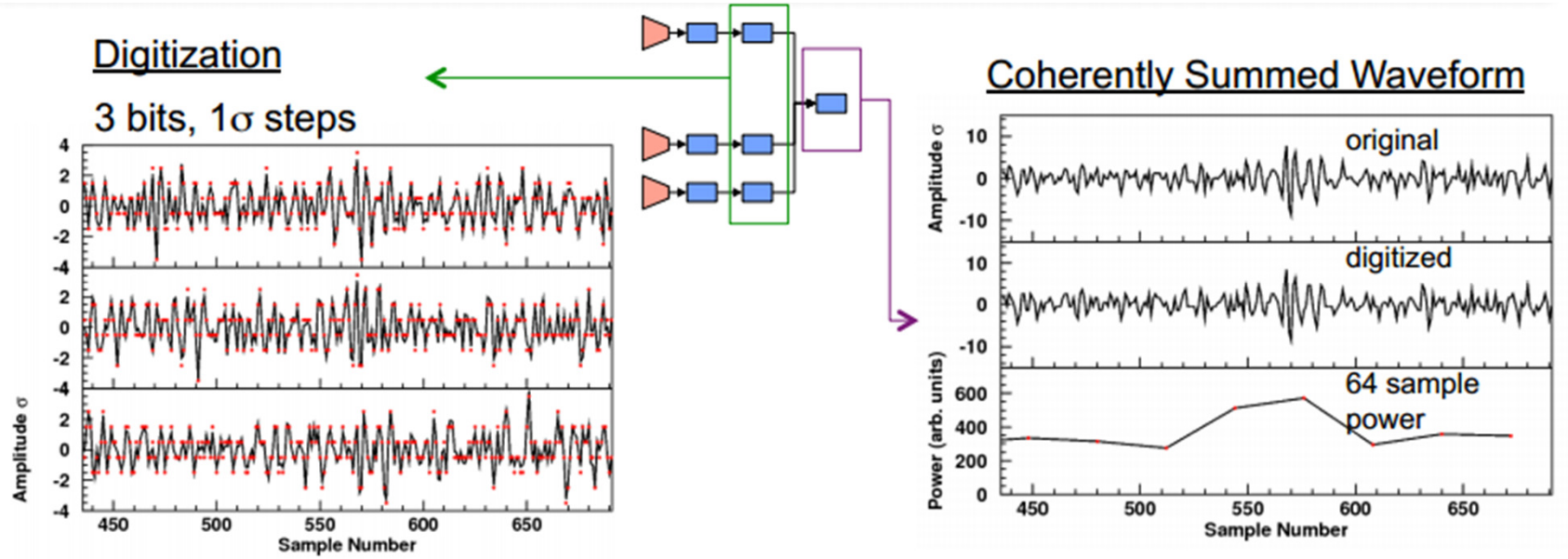


ANITA-III trigger (A. Romero-Wolf)

- Separate V/H triggers for neutrinos/cos-ray events
- Improved multi-level majority logic trigger
- Real time beam forming trigger

Real time beam forming trigger (A. Romero-Wolf)

- combine signals from antennas with same field of view to improve signal to noise – choose best Δt's



Summary

- ANITA-I cosmic-ray detection f > 200 MHz
- ANITA-II best neutrino sensitivity for $E>10^{19}$ eV

- Reanalysis of cosmic ray energy scale
  - air index of refraction
  - reflection geometry

- ANITA-III enhancements
  - airframe/data handling/calibration sources
  - antennas: +8 horns/ALFA
  - trigger
    - separate V/H
    - improved majority logic trigger
    - dynamic beam trigger