Current Status of the ANITA experiment

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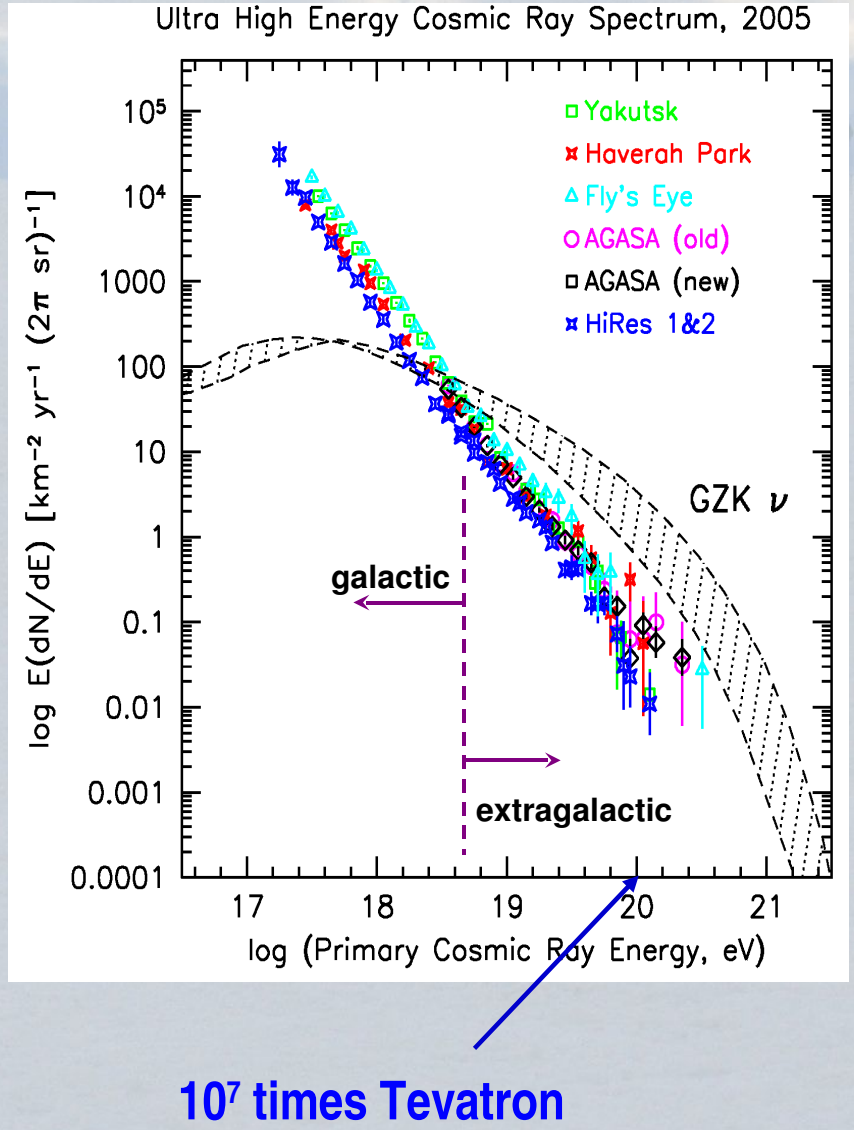
ANITA collaboration

(Antarctic Impulsive Transient Antenna)

- Bartol : J. Clem, A. Javai, D. Seckel
- UC Irvine : S. Barwick, D. Goldstein, K. Kuehn, J. Nam, F. Wu
- UCLA : A. Connolly, S. Hoover, A. Goodhue, D. Saltsberg
- U. Hawaii : P. Gorham, J. Learned, J. Kowalski, S. Matsuno, R. Milincic, P. Miocinovic, M. Rosen, A. Romero-Wolf, G. Verner
- JPL : K. Liewer, C. Naudet
- Kansan : D. Besson
- U. Minnesota : M. DuVernois, E. Lusczek
- NASA : D. Gregory, J Link
- Ohio State : J. Beatty, B. Mercurino, R. Nichol, K. Palladino
- SLAC : P. Chen, C. Field, C. Hast, J. Ng, K. Reil
- Washington U., St. Louis : R. Binns, P. Dowkontt, M. Isreal, M. Olevitch

High Energy Astroparticle Physics

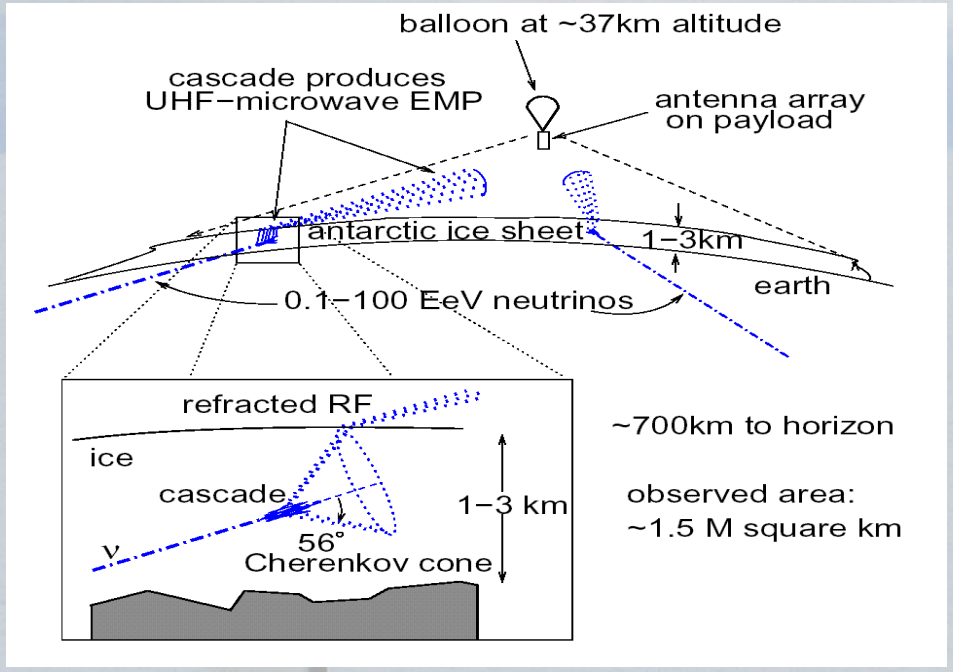
- For cosmic rays above 10^{19} eV,origin nor acceleration mechanism not well known
  - No nearby sources observed
  - distant sources excluded due to GZK process
- Neutrinos at $10^{17\text{-}19}$ eV required by standard-model physics* through the GZK process -- observing them is crucial to resolving the GZK paradox
- 2006 update: UHECR spectra fits (HiRes) indicate that CR sources follow a quasar/star-formation-like distribution (eg. GRBs?)

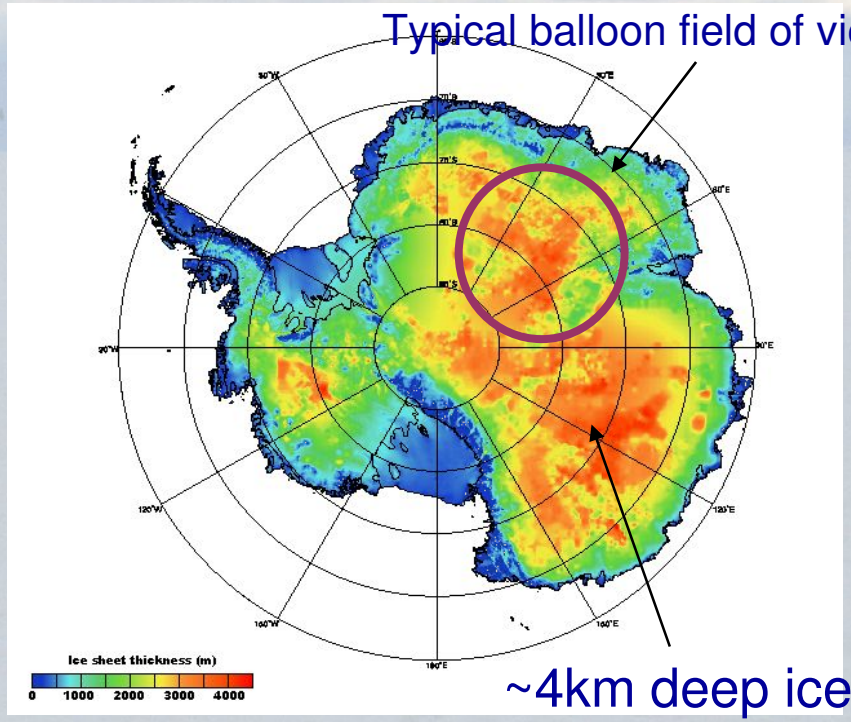


* Berezinsky et al. 1971.

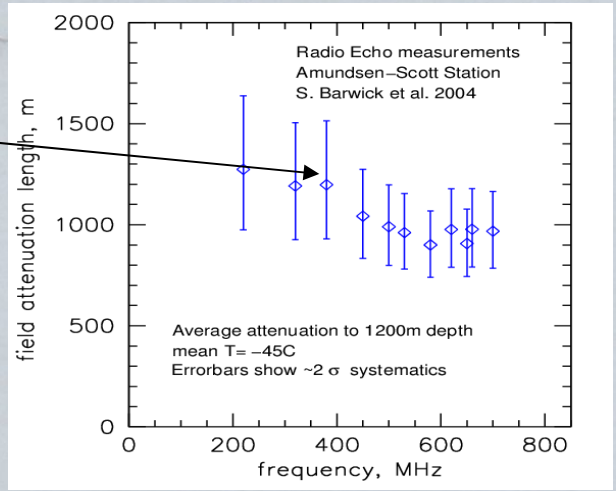
ANITA concept

"detect UHE neutrinos from a balloon by using radio Cerenkov signal from Antarctic ice sheet"





Ice RF clarity:
~1.2km(!)
attenuation
length

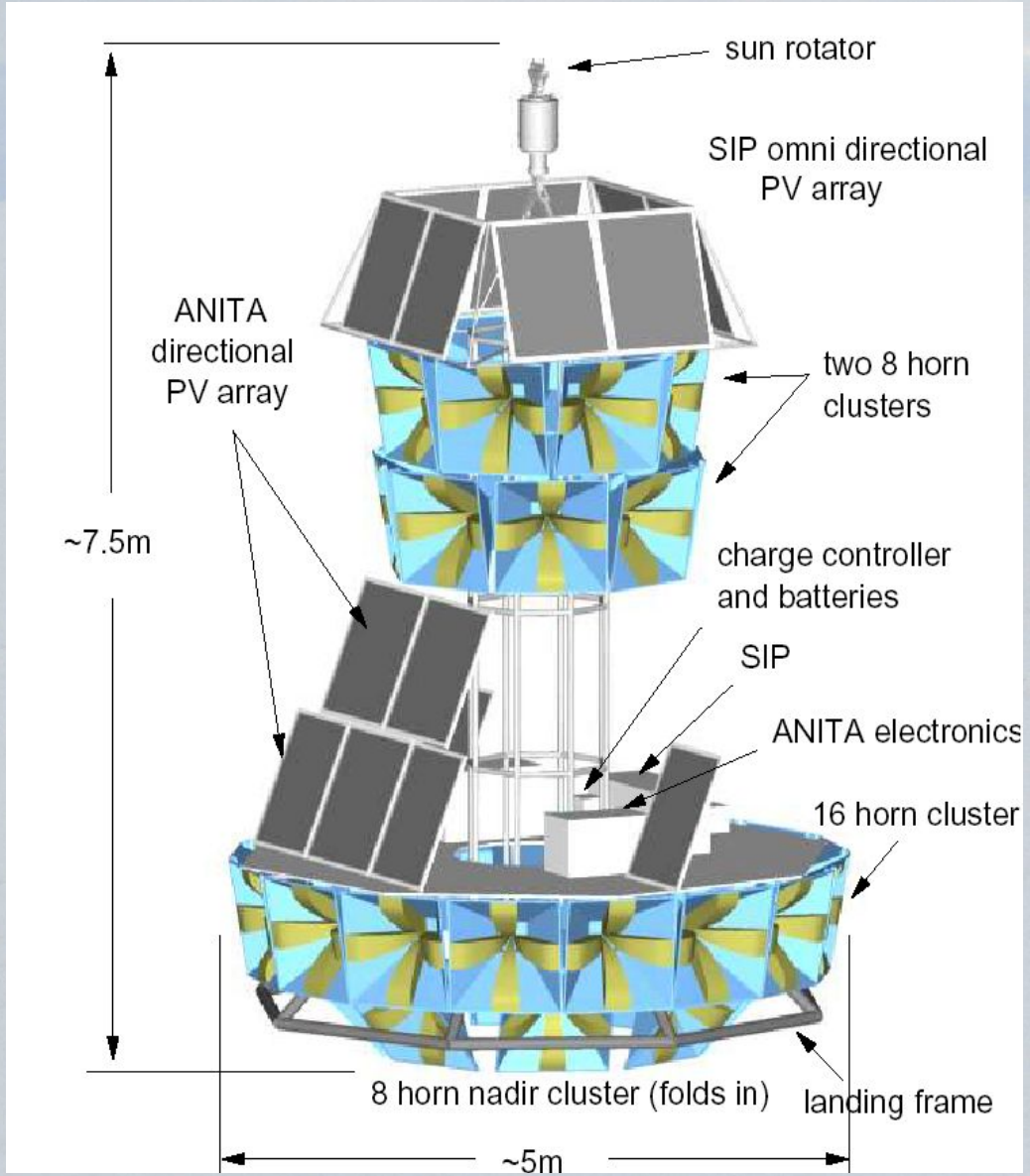


Effective "telescope" aperture:

- ~250 km^3 sr @ 10^{18} eV
- ~10^4 km^3 sr @10^{19} eV

(compare to ~1 km^3 at lower E)

ANITA Payload

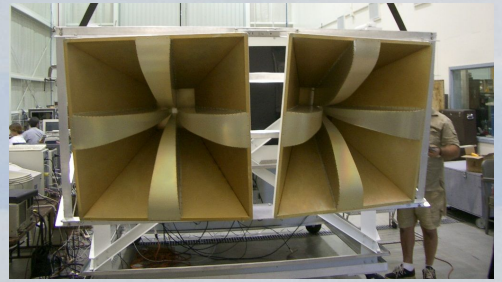


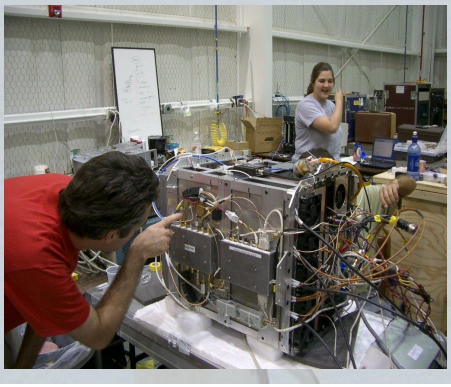
- 32 horn antennas (H and V polarities) view > 2π sr with 60° overlapping beam width
- Intensity gradiometry, interferometry, polarimetry used to determine pulse direction & thus original neutrino track orientation
- Angular resolution:
  0.5° for elevation and 1.5° for azimuth (for radio pulse),
  ~2° and 3~5° (for neutrino)
- weight ~1,600 kg,
  total power ~500W

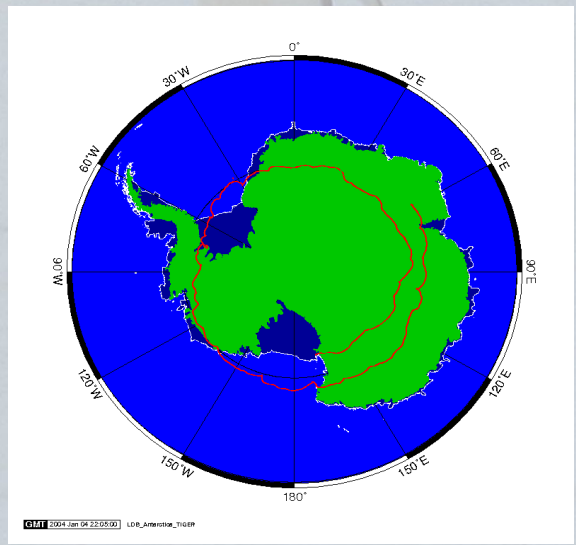
ANITA timeline

- 2002 ; forming ANITA collaboration
- Jan-03 ; ice transparency / RF noise measurement @ South Pole
- Dec-03 ; ANITA-lite flight from McMurdo station, Antarctica, after passing hang test in July
- Aug-05 ; ANITA-EM flight from Ft. Sumner, NM
- Jul-06 ; beam test & hang test of full ANITA system @SLAC, after an instrument integration @ UCI
- Dec-06 ; ANITA launched for its 1st flight @ McMurdo
- Jan-07 ; ANITA data and instrument recovered after 35 days of flight
- current ; Data analysis is underway

ANITA-lite Prototype flight





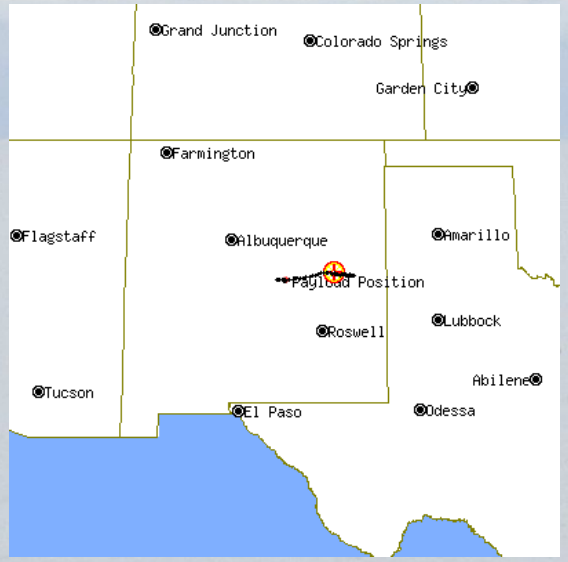


- Piggyback Mission of Opportunity on the 03-04 TIGER* flight, completed early-January 04
- ANITA prototypes & off-the-shelf hardware used
  - 2 dual-pol. ANITA antennas w/ low-noise amps
  - 4 channels at 1 GHz RF bandwidth, 2 GHz sampling
- 18.4 days flight time, 40% net livetime due to slow (4sec per event) GPS time readout
- "Heartbeat" event rate of several per minute, with~100K events recorded:
  - payload generated EMI + thermal noise + calibration triggers + forced/timeout triggers
- Set a new limit on UHE neutrino flux (ν limit page)

astro-ph/0551265 ; PRL 96 (2006) 171101

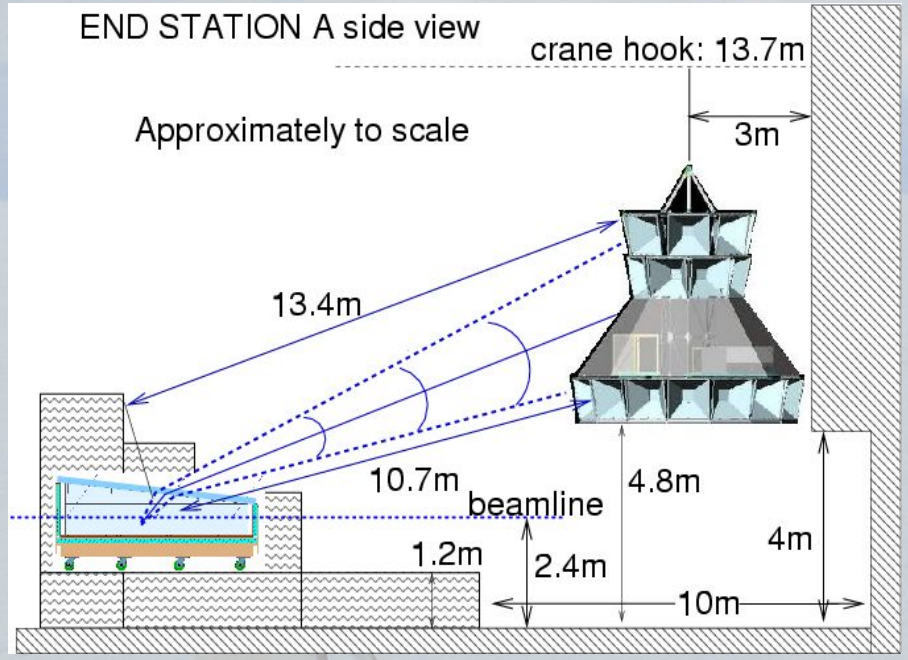
*Trans-Iron Galactic Element Recorder

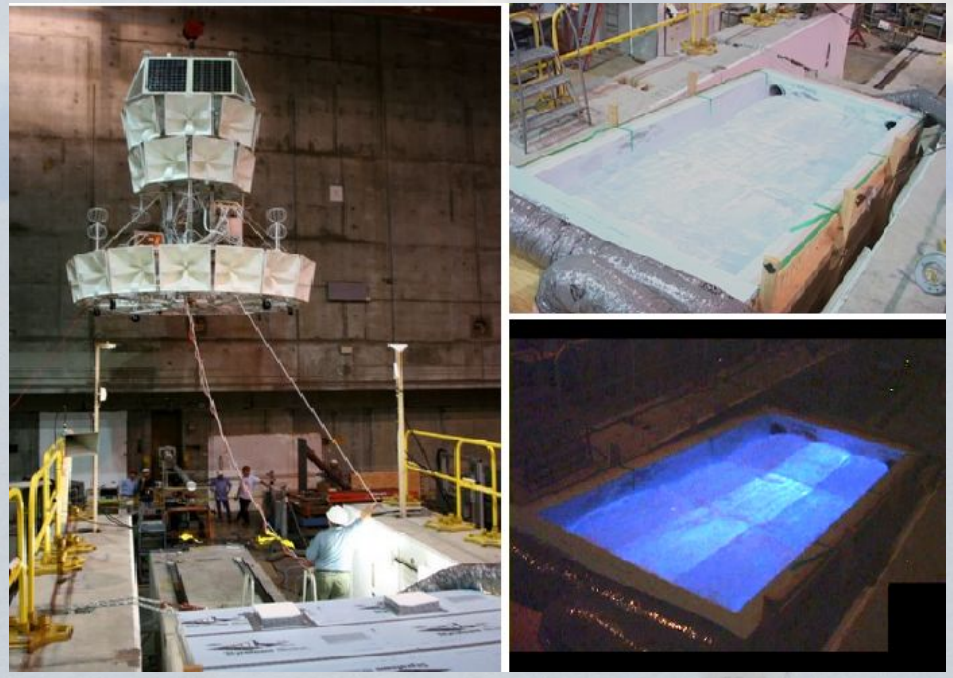
ANITA EM (engineering model) flight

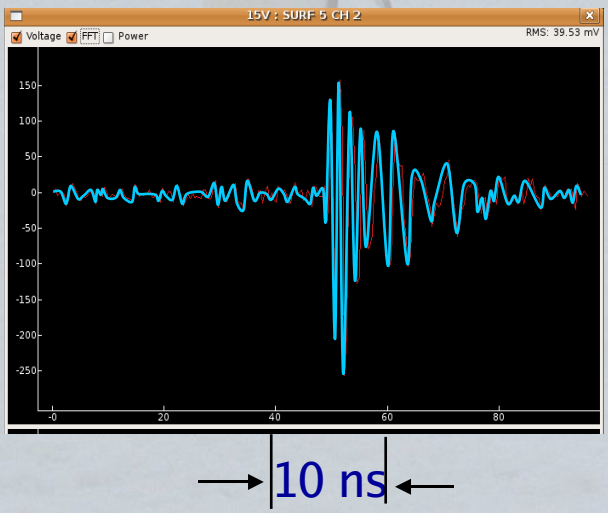


- EM flight @ Ft. Sumner, NM in August 2005
- test gondola design, assembling procedure, and electronics in a real flight condition
- Gondola rotator found to be very noisy in RF
  ⇒ design changed to use “omni” PV array.

SLAC T486 (Jul '06): Askaryan effect in ice

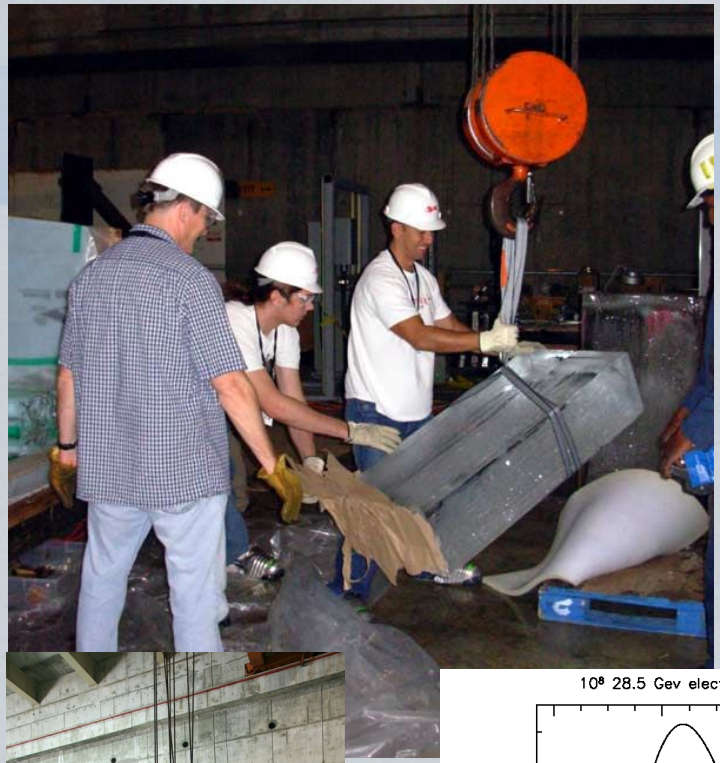


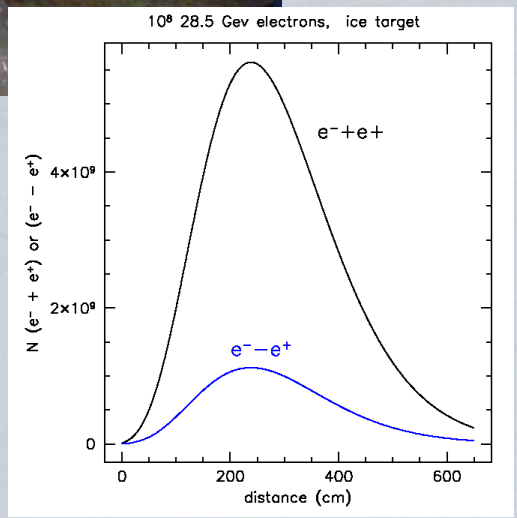




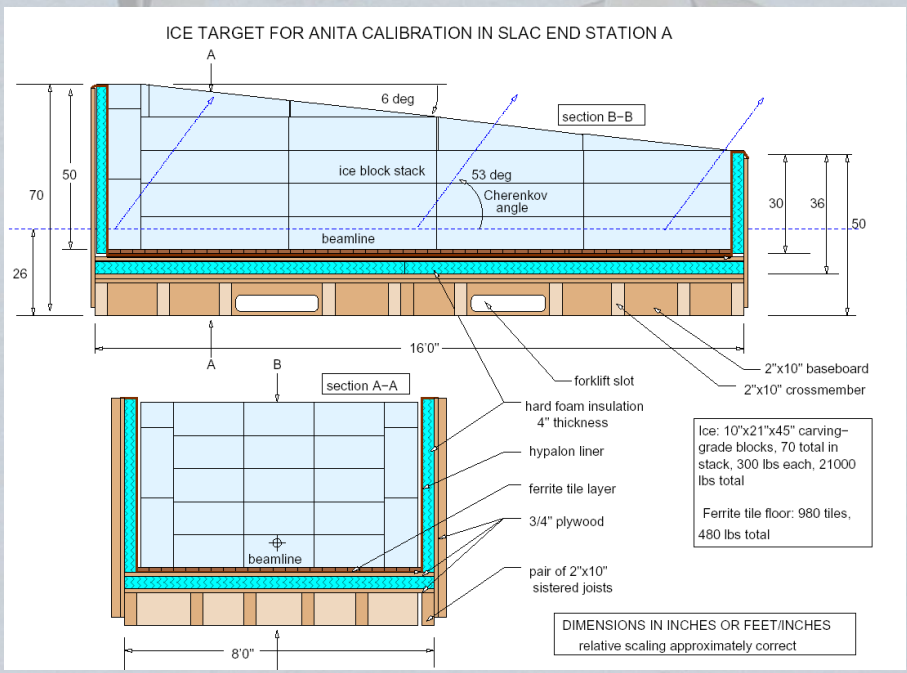
- Opportunity to test the effect in a medium relevant to several current and future experiments: ANITA, RICE, etc.
- 12-tons of ice + ANITA + End Station A + SLAC beam = Ideal ANITA calibration + comprehensive validation of Askaryan effect

T486: ice target

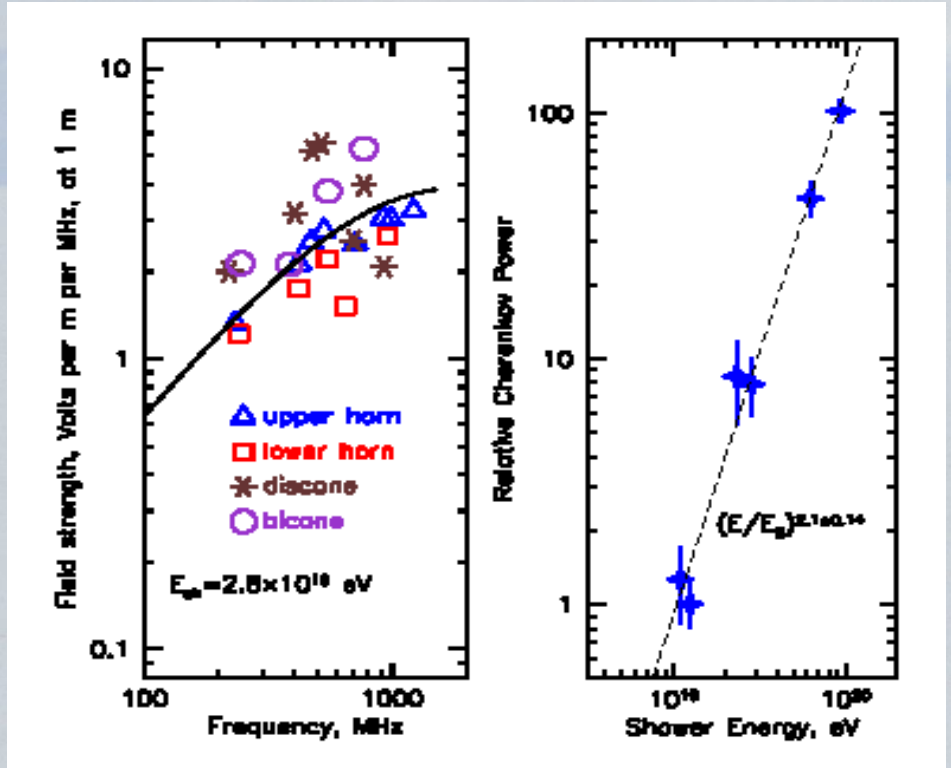


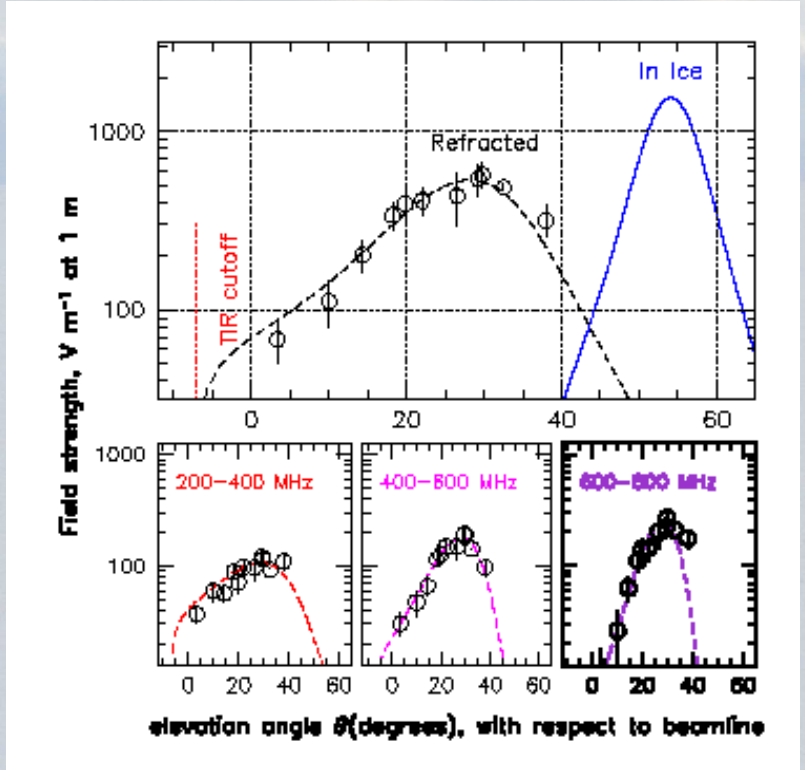


- Carver-grade ice, very pure
- 300 lb blocks, about 70 used to make target with >0.6 λ (in ice) at >200MHz in all directions around beam axis
- Target length: 12 radiation lengths=5 m of ice



SLAC T486: Results



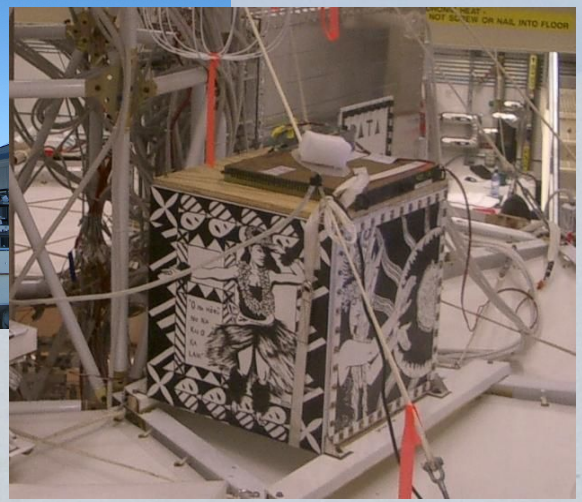


- Radio coherence: quadratic power vs. beam current as predicted
- Frequency dependence and total power: as predicted by Askaryan's theory
  (in Zas-Halzen-Stanev form)
- Report available : *arXiv.org hep-ex/0611008*

ANITA's 1st Flight over Antarctica

- ANITA launched from LDBF in Williams field outside of the McMurdo station on 15-Dec-2006
- Flight terminated on 19-Jan-2007 and ANITA landed ~500km from south pole
- Recovery of instrument took place on 27-Jan
- Instruments back to the US in early Feb.

Photos of 06-07 flight preparation in Willy field

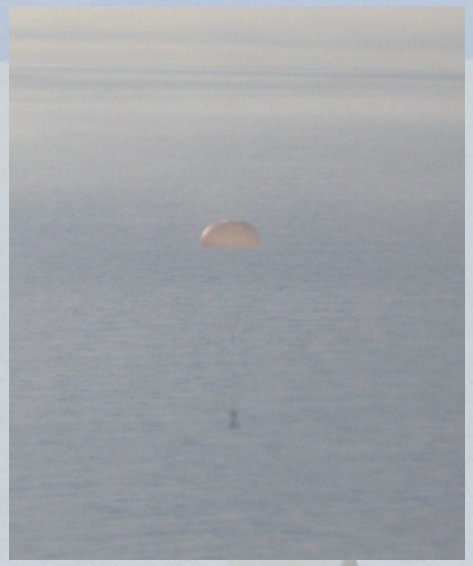


LDBF in Willy Field, about 10 km from the McMurdo

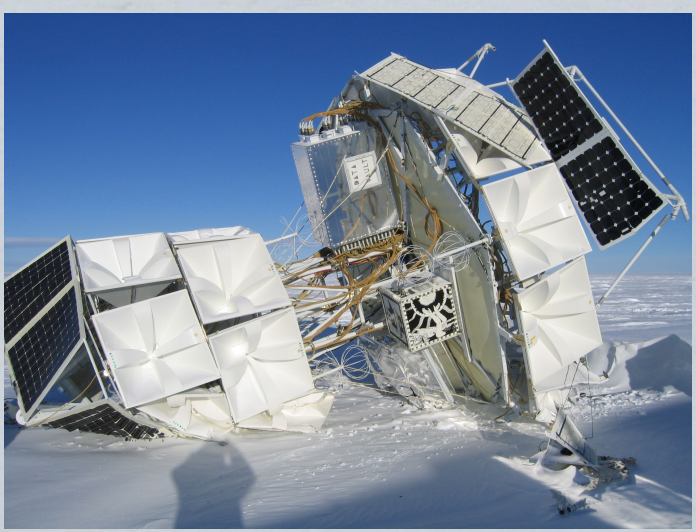
ANITA launch from LDBF, Antarctica

Launched on 15-Dec-06

ANITA flight termination and recovery



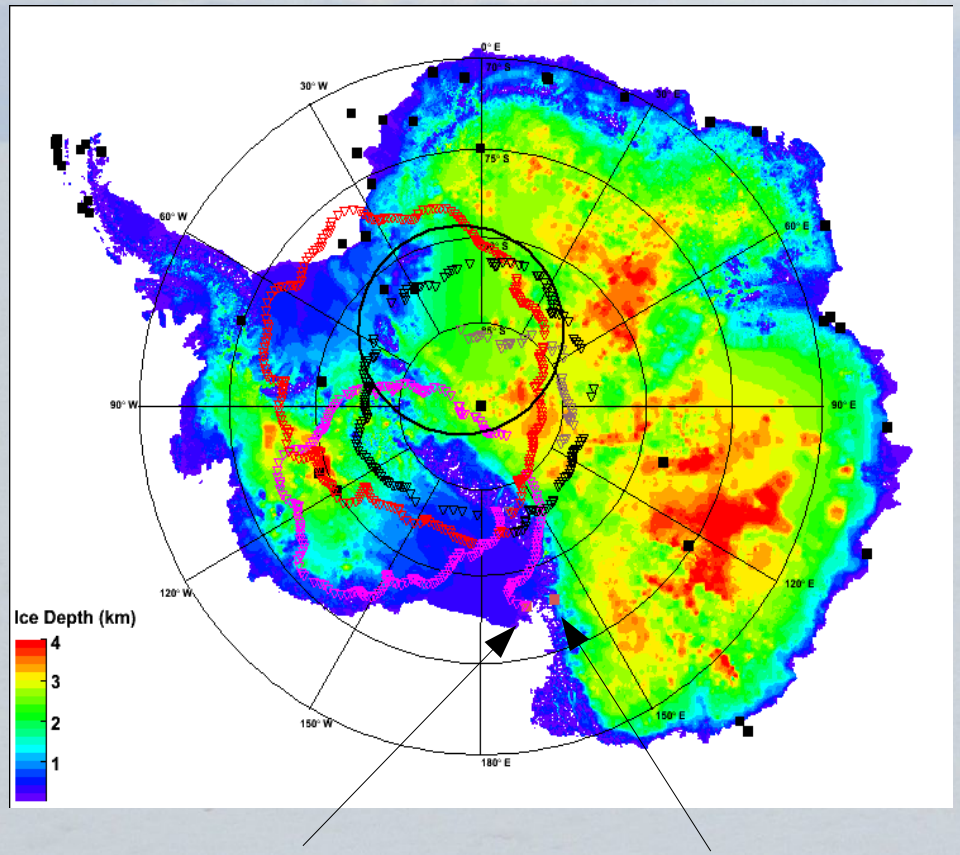
flight terminated on 19-Jan-07 and instruments recovered on 27-Jan.



ANITA flight over Antarctica from 15-Dec-06 to 19-Jan-07

- good news
  - 35 days of successful 1st flight of full ANITA system
  - instruments worked as designed (trigger rate ~5Hz)
  - ~100 G Byte of data accumulated, including bore hole calibration pulses
- bad news
  - did not see deep eastern antarctic ice
  - a lot of noise from McMurdo and SP stations
  - last part of flight hampered by HDD problem

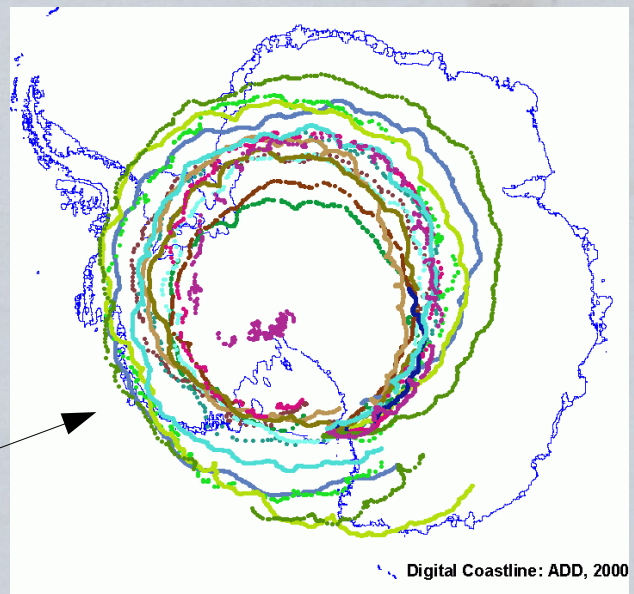
ANITA 06-07 flight trajectory



McMurdo station
(Willy field LDBF)

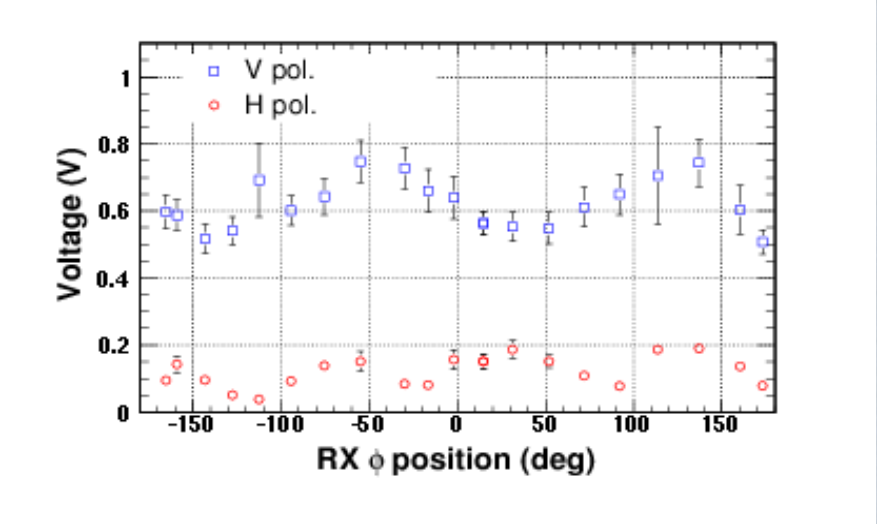
TDM bore hole site

- took rather unusual course centered in western Antarctica and failed to fly over eastern Antarctica ice sheet
- closest approach to the TDM bore hole site ~ 350km and McMurdo was still in ANITA's field of view, then



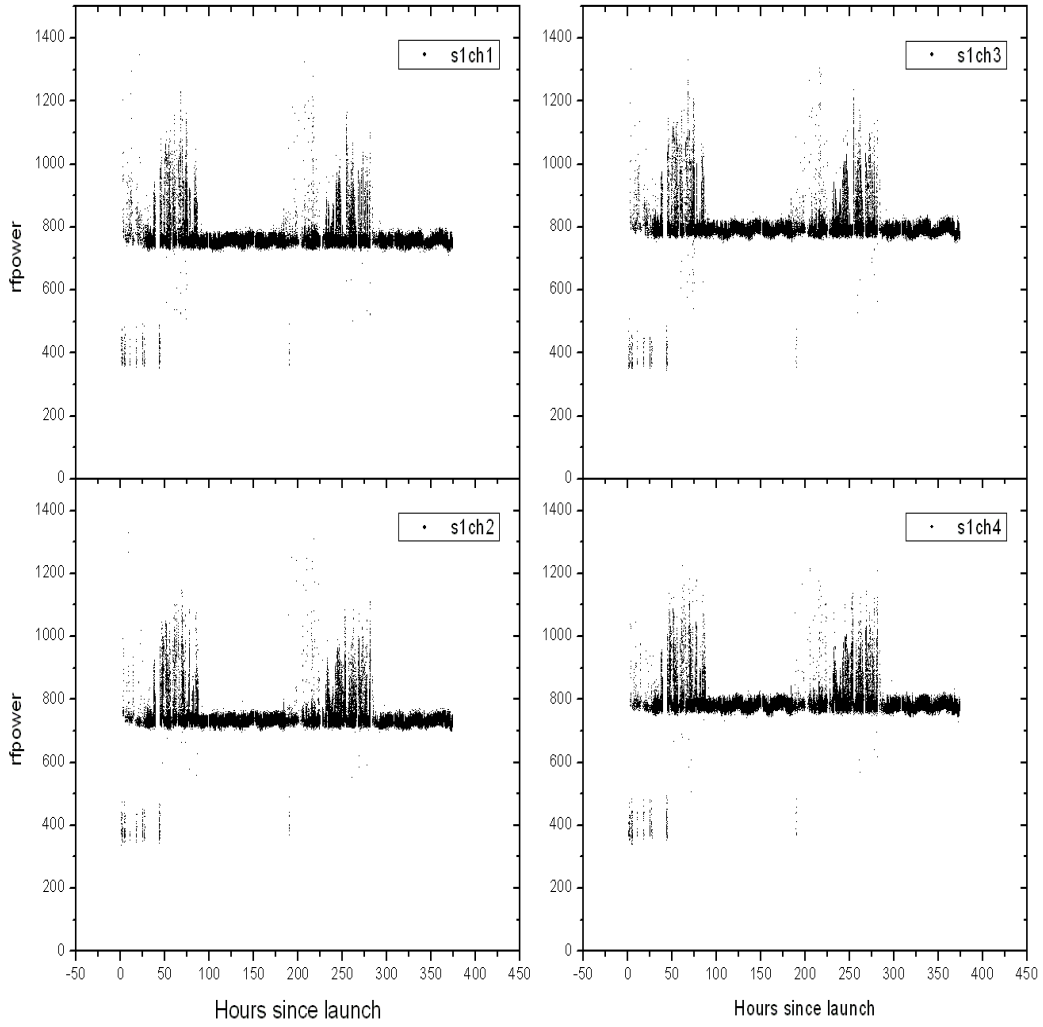
past balloon trajectories

Taylor dome (TDM) bore hole site

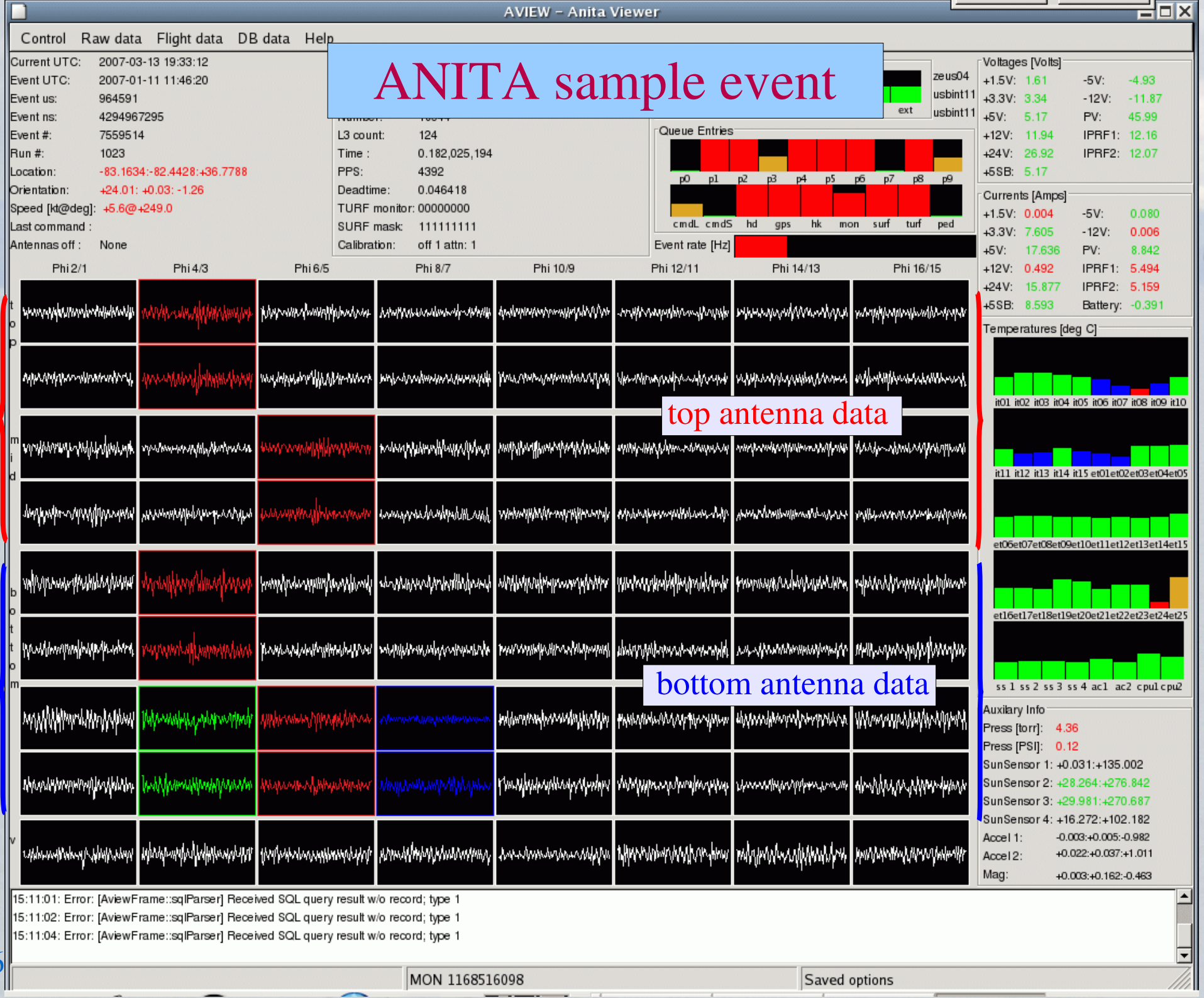


- 200km west of McMurdo station
- 100m deep bore hole with a discone antenna @95m (ice is measured 950m deep by RF reflection)
- HV pulser (2kV, 1ns wide) triggered by GPS 1PPS pulse
- hone monitoring antenna (the same one used for ANITA)
- tried to send radio pulses to calibrate trigger/detection efficiency
- ϕ dep. measured on ice surface

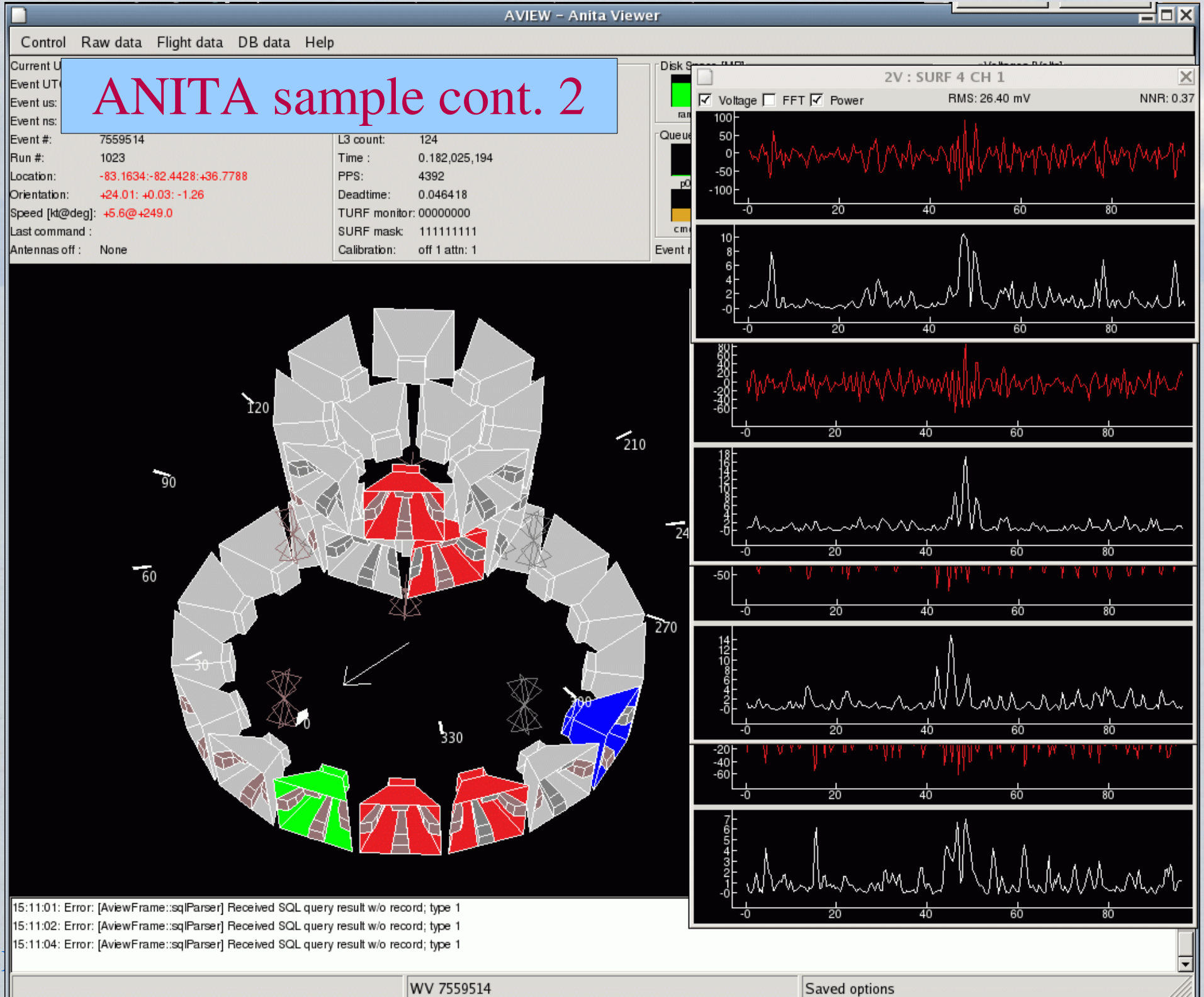
RF noise from McMurdo and South Pole



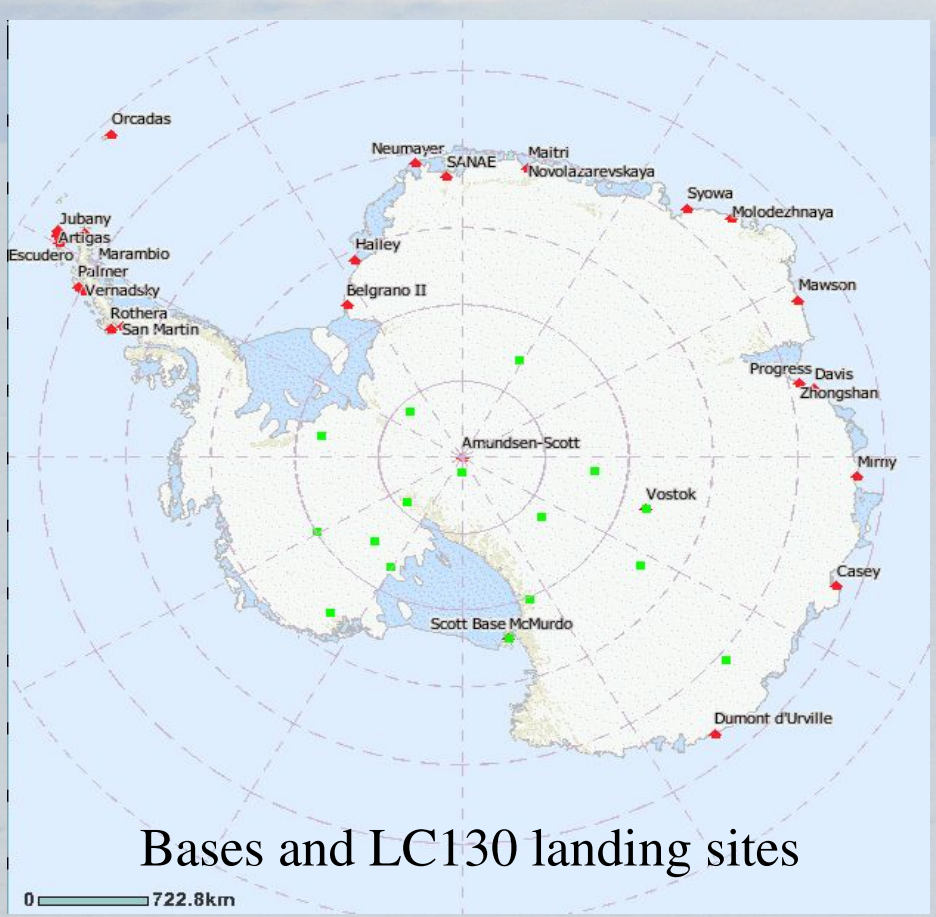
- first 400 hours of flight is shown here
- RF noise from McMurdo and S.P. stations dominated data flow in 0-40 and 200-300 hour.
- had to raise thresholds to reduce trigger rate down (need time to estimate a hit on sensitivity).


AVIEW – Anita Viewer
Control Raw data Flight data DB data Help
ANITA sample event
Current UTC: 2007-03-13 19:33:12
Event UTC: 2007-01-11 11:46:20
Event us: 964591
Event ns: 4294967295
Event #: 7559514
Run #: 1023
Location: -83.1634:-82.4428:+36.7788
Orientation: +24.01: +0.03: -1.26
Speed [kt@deg]: +5.6@+249.0
Last command :
Antennas off : None
L3 count: 124
Time : 0.182,025,194
PPS: 4392
Deadtime: 0.046418
TURF monitor: 00000000
SURF mask: 111111111
Calibration: off 1 attn: 1
zeus04
usbint11
usbint11
ext
Queue Entries
p0 p1 p2 p3 p4 p5 p6 p7 p8 p9
cmdL cmdS hd gps hk mon surf turf ped
Event rate [Hz]
Voltages [Volts]
+1.5V: 1.61 -5V: -4.93
+3.3V: 3.34 -12V: -11.87
+5V: 5.17 PV: 45.99
+12V: 11.94 IPRF1: 12.16
+24V: 26.92 IPRF2: 12.07
+5SB: 5.17
Currents [Amps]
+1.5V: 0.004 -5V: 0.080
+3.3V: 7.605 -12V: 0.006
+5V: 17.636 PV: 8.842
+12V: 0.492 IPRF1: 5.494
+24V: 15.877 IPRF2: 5.159
+5SB: 8.593 Battery: -0.391
Phi 2/1 Phi 4/3 Phi 6/5 Phi 8/7 Phi 10/9 Phi 12/11 Phi 14/13 Phi 16/15
top
mid
bottom
v
top antenna data
bottom antenna data
Temperatures [deg C]
it01 it02 it03 it04 it05 it06 it07 it08 it09 it10
it11 it12 it13 it14 it15 et01et02et03et04et05
et06et07et08et09et10et11et12et13et14et15
et16et17et18et19et20et21et22et23et24et25
ss 1 ss 2 ss 3 ss 4 ac1 ac2 cpu1 cpu2
Auxilary Info
Press [torr]: 4.36
Press [PSI]: 0.12
SunSensor 1: +0.031:+135.002
SunSensor 2: +28.264:+276.842
SunSensor 3: +29.981:+270.687
SunSensor 4: +16.272:+102.182
Accel 1: -0.003:+0.005:-0.982
Accel 2: +0.022:+0.037:+1.011
Mag: +0.003:+0.162:-0.463
15:11:01: Error: [AviewFrame::sqlParser] Received SQL query result w/o record; type 1
15:11:02: Error: [AviewFrame::sqlParser] Received SQL query result w/o record; type 1
15:11:04: Error: [AviewFrame::sqlParser] Received SQL query result w/o record; type 1
MON 1168516098
Saved options

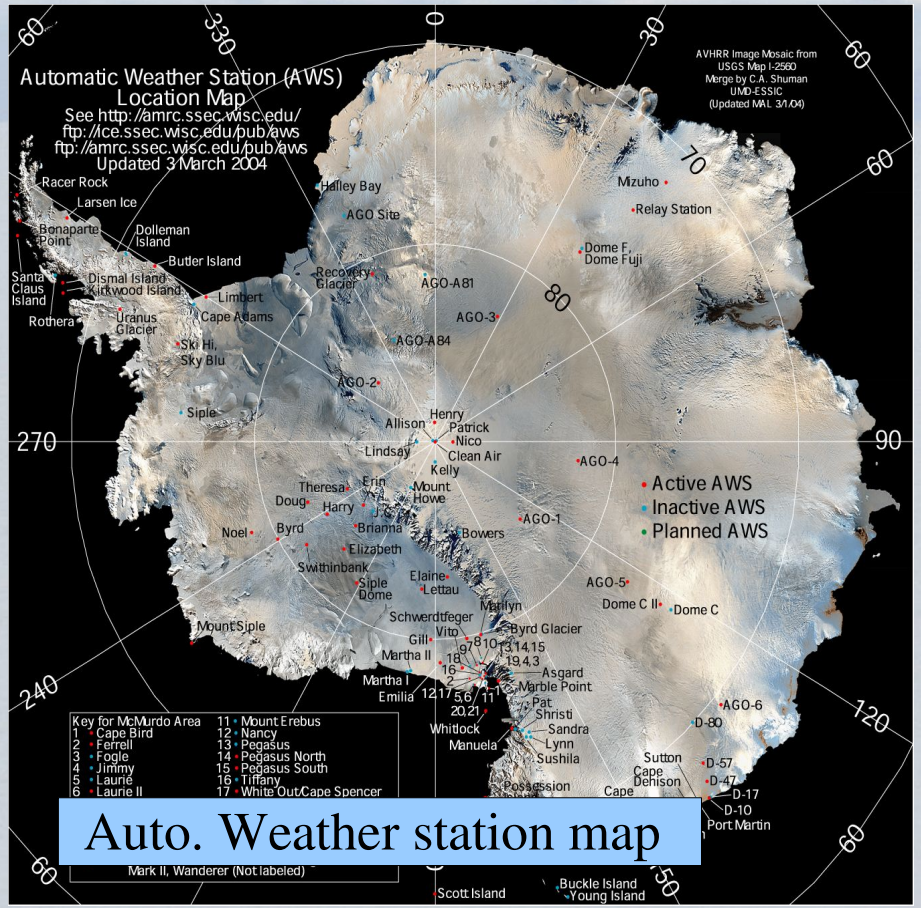
ANITA sample cont. 2



Increasing noise sources in Antarctica



Bases and LC130 landing sites

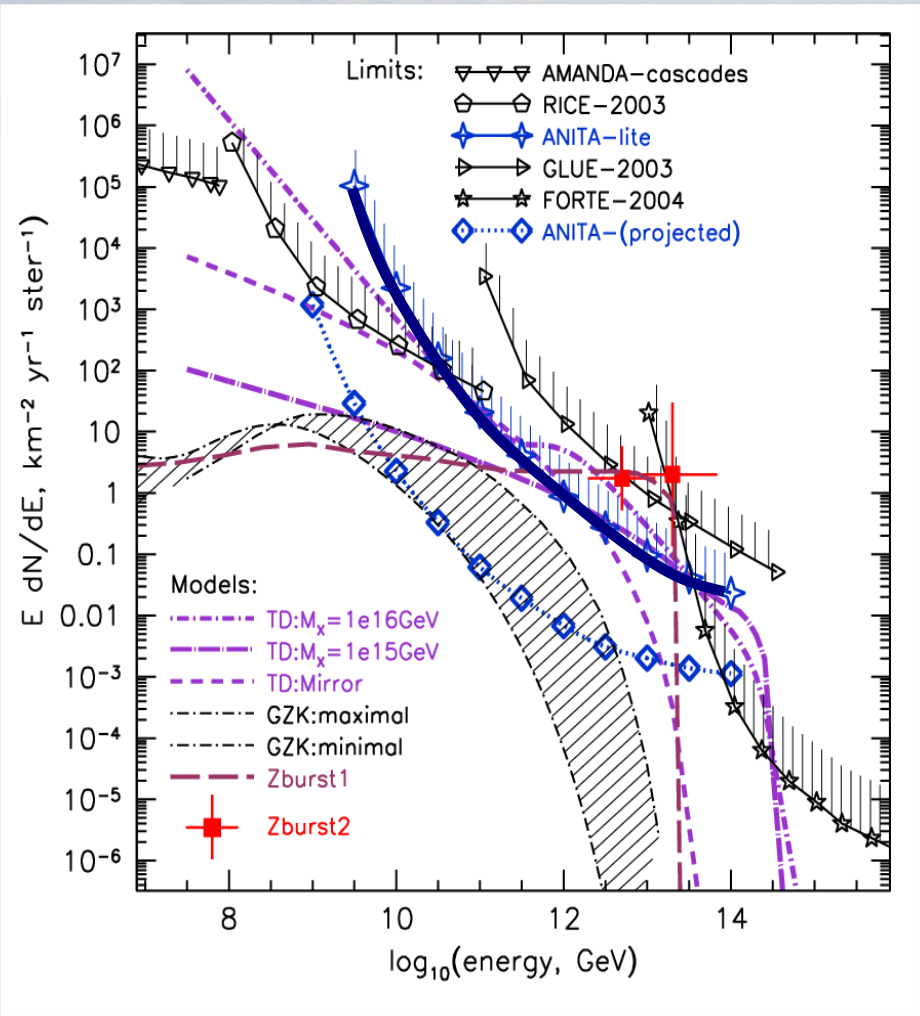


Auto. Weather station map

Have to contend with not only manned camps but also autonomous ones

(use satellite data communication using 400 MHz band).

UHE neutrino limits & projections

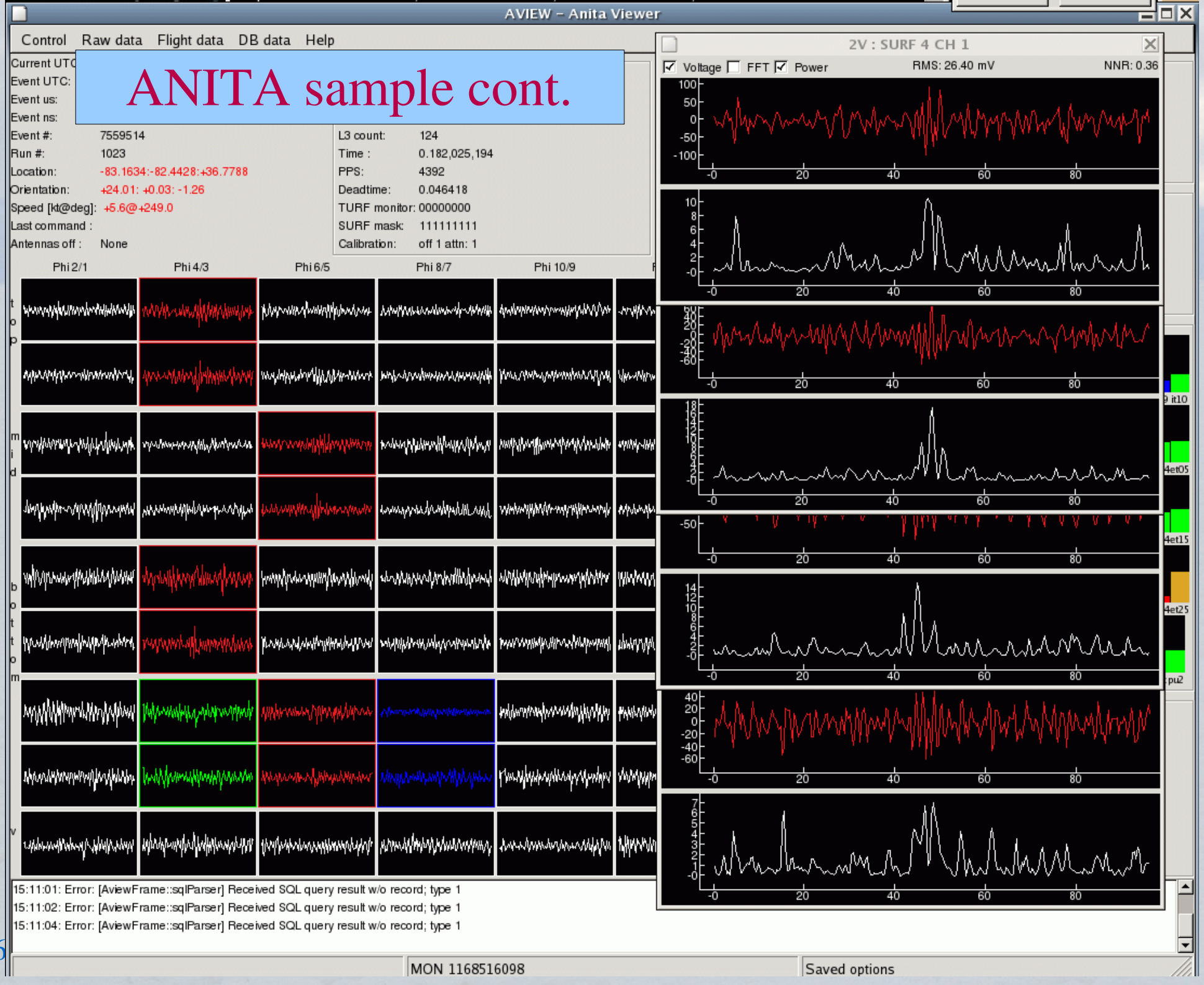


Strongest limits: all radio

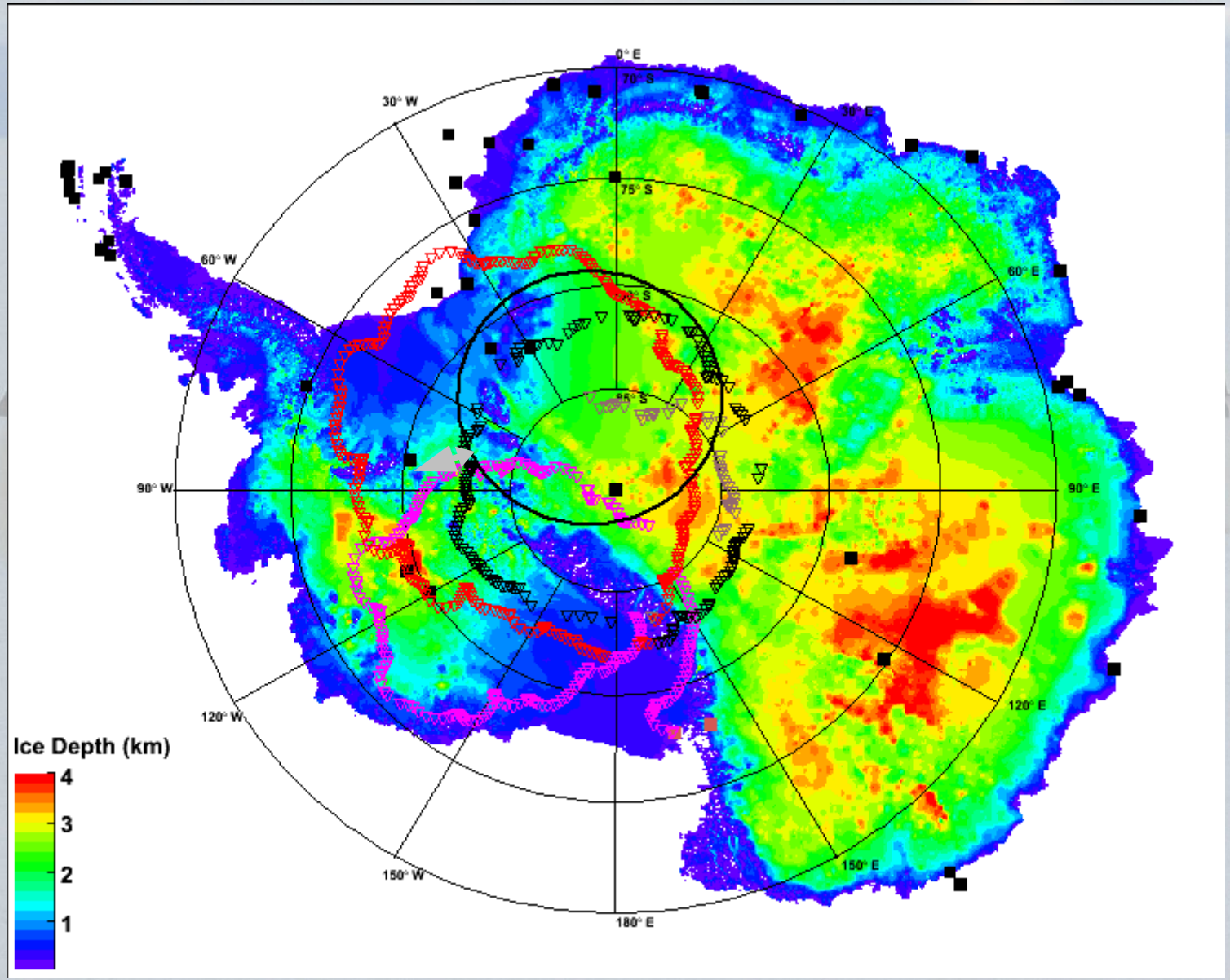
- **RICE** limits for 3500 hours livetime
- **GLUE** limits 120 hours livetime
- **FORTE** limits on 3.8 days of livetime
- **ANITA-lite**: 18.4 days of data, net 40% livetime with 60% analysis efficiency for detection
  - No candidates survive
  - Z-burst UHECR model (νν annihilation --> hadrons) excluded:
    - we expect 6-50 events, saw none
  - Highest Topological defect models also excluded
- **ANITA projected sensitivity (45 days):**
  - ν_e ν_μ ν_τ included, full-mixing assumed
  - **1.5-2.5 orders of magnitude gain!**

Summary

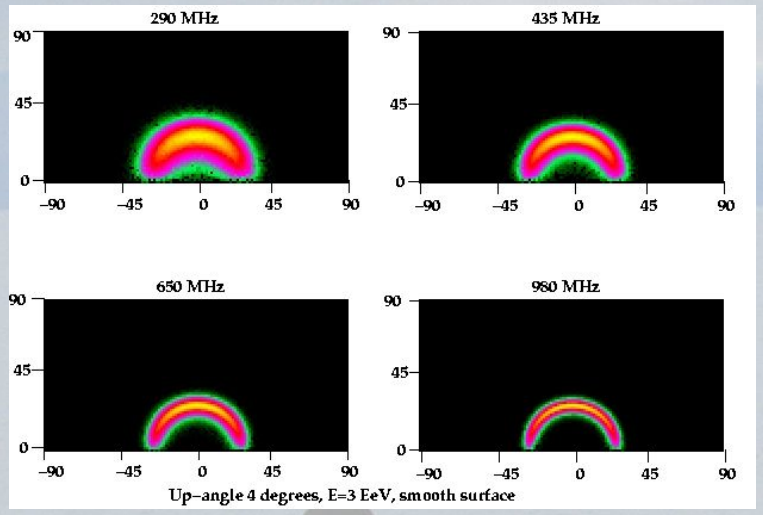
- ANITA project has been progressing in amazing pace
- instrument has been well tested, understood, and calibrated with SLAC electron beam
- ANITA's 1st flight over Antarctica took place in 06-07 season
  - 35 days of successful flight, though a little hampered by unusual flight trajectory and noise from SP station
  - data and instrument were fully recovered
  - Data analysis is underway; stay tuned.
- Preparing a proposal for another flight in 2008-9 season.

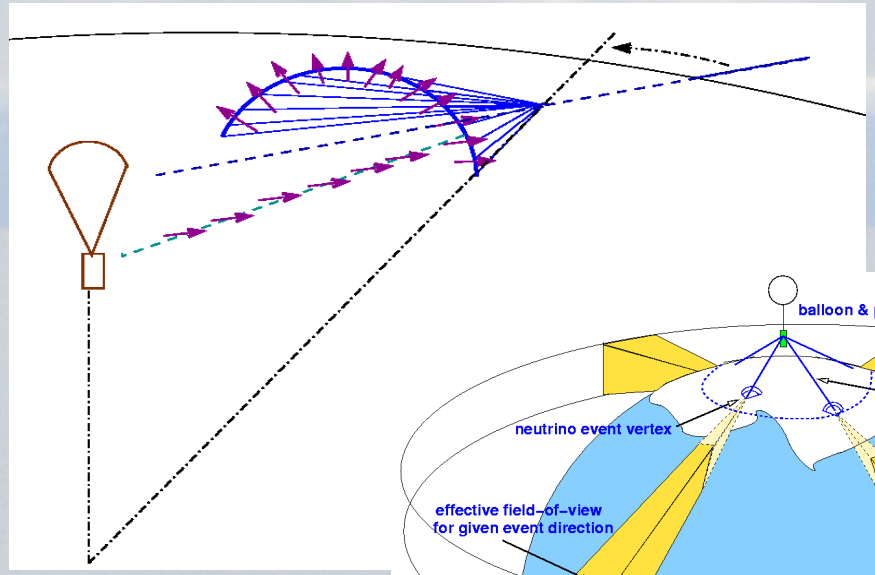

AVIEW – Anita Viewer
Control
Raw data
Flight data
DB data
Help
ANITA sample cont.
Current UTC
Event UTC:
Event us:
Event ns:
Event #: 7559514
Run #: 1023
Location: -83.1634:-82.4428:+36.7788
Orientation: +24.01: +0.03: -1.26
Speed [kt@deg]: +5.6@+249.0
Last command :
Antennas off : None
L3 count: 124
Time : 0.182,025,194
PPS: 4392
Deadtime: 0.046418
TURF monitor: 00000000
SURF mask: 111111111
Calibration: off 1 attn: 1
Phi 2/1
Phi 4/3
Phi 6/5
Phi 8/7
Phi 10/9
top
mid
bottom
2V : SURF 4 CH 1
Voltage
FFT
Power
RMS: 26.40 mV
NNR: 0.36
15:11:01: Error: [AviewFrame::sqlParser] Received SQL query result w/o record; type 1
15:11:02: Error: [AviewFrame::sqlParser] Received SQL query result w/o record; type 1
15:11:04: Error: [AviewFrame::sqlParser] Received SQL query result w/o record; type 1
MON 1168516098
Saved options

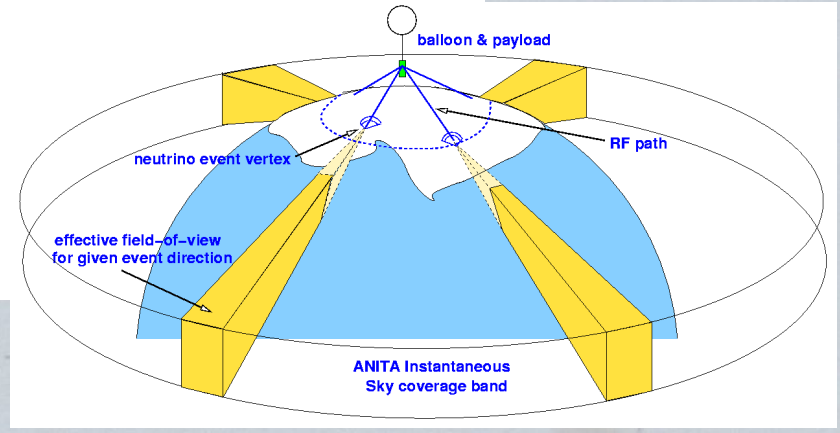
ANITA position and event direction

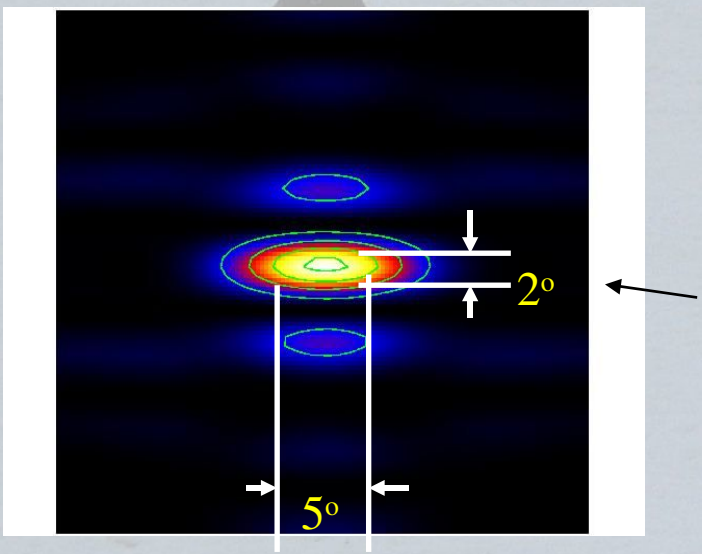


ANITA as a neutrino telescope





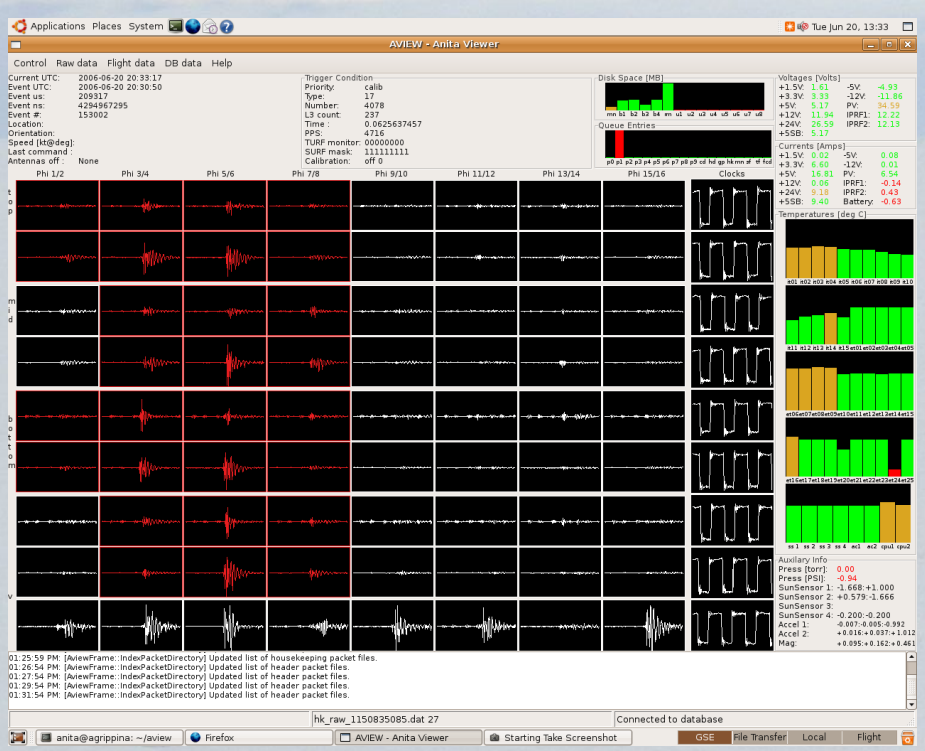


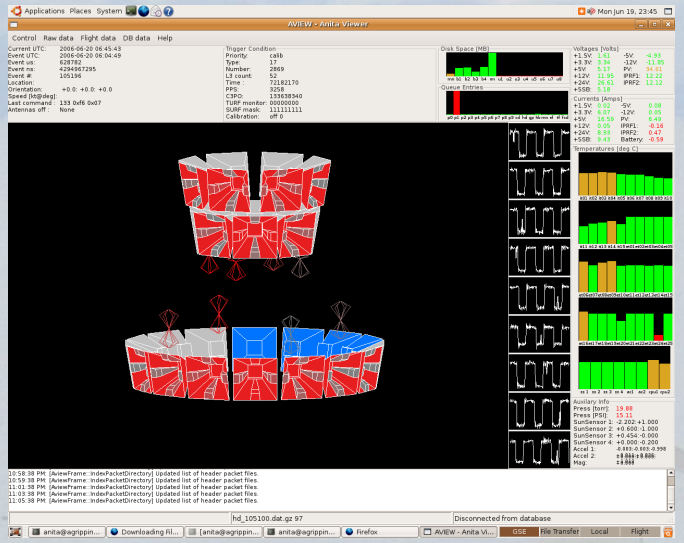


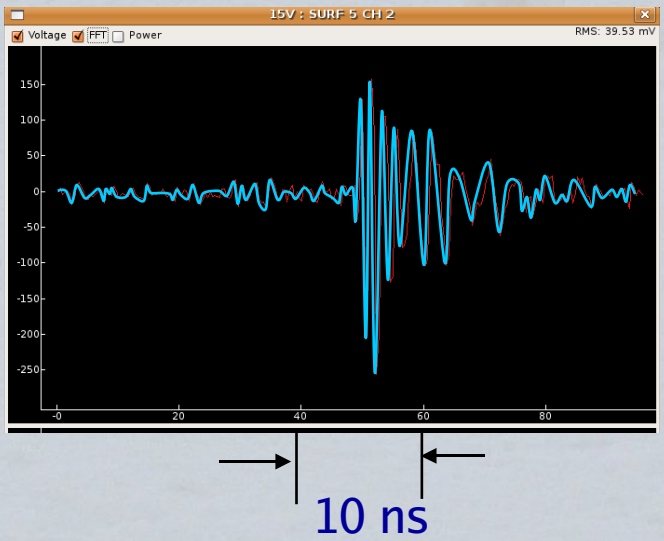
- Pulse-phase interferometer (150ps timing) gives intrinsic resolution of <1° elevation by ~1° azimuth for **arrival direction** of radio pulse

- **Neutrino direction** constrained to ~<2° in elevation by earth absorption, and by ~3-5° in azimuth by polarization angle

Full Ground software system tested:
First observations of Askaryan effect in ice







- Impulses are band-limited, highly polarized, as expected
- Very strong--need 20dB pads on inputs (eg, -95dB compared to Antarctic configuration)

Astronomy at the highest energies

- Universe optically thick to photons above ~10 TeV
- Protons probably extragalactic above 10 EeV, but cannot propagate more than a few tens of Mpc GZK cutoff
- Astronomy above ~10 TeV can only be done with neutrinos
- GZK process itself is a great ν source