OVERVIEW of the ANITA EXPERIMENT

David Saltzberg (UCLA) Venice ν Telescopes Meeting March 11, 2009

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Galileo → Astromical Telescope

Objective





> 1,000,000 km², > 1,000,000 km³ (~20,000 km³ –sr)

Calm, Clear and Cold

Dome Argus, the site chosen for the Plato observatory, may have the best conditions on Earth for an observing site.

HIGH ALTITUDE, CALM WINDS Dome Argus is the highest point on the East Antarctic Plateau, and one of the least windy.

CLEAR SKIES

100 FEET OF AIR TURBULENCE

3,000

2.000

-1.000

500

Atmospheric turbulence causes images of stars to blur and shimmer. The only turbulence at Dome Argus is close to the ground, and easily surmountable by a tower-mounted telescope.

LOW TEMPERATURES

At 90 degrees below zero in winter, Dome Argus is one of the coldest places on Earth.

Lowest temperature recorded at Dome Argus — (-116.5 degrees, July 2005)

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Dome Argus

> –128.6 Lowest temperature recorded on Earth (Vostok station, Antarctica, July 1983)

McMurdo. Station Dome Argus

13,400 feet

Dome Charlie

WIND SPEED.

IN MILES PER HOUR

20

Zhongshan Station

10

30

40

Vertical scale exaggerated

Sources: Andrew J. Monaghan (wind speed); Mark R. Swain and Hubert Gallée (turbulence); Australian Antarctic Division (temperature); Publications of the Astronomical Society of the Pacific; University of New South Wales

THE NEW YORK TIMES

Validation at SLAC

~7.5 metric tons ice



Gorham et al., PRL 99, 171101 (2007) see also: PRE 62, 8590 (2000), PRL 86, 2802 (2001), PRD 72, 023002 (2005) PRD 74, 043002 (2006)



Askaryan Effect in the Lab



Askaryan Effect at SLAC



Amplitude expected

- 100% linearly polarized
- Cherenkov angle

GZK-induced Neutrinos



 $\delta\theta \sim 10 Mpc/1000 Mpc \sim 30$ arcminutes

Some Particle Physics: z=1 is a VERY long baseline

One experimental parameter: $(L/E)|_{experiment} \propto t_{proper}^{v}$

- Determines (largely) the sensitivity to :
 - Δm^2 , <u>decays</u> (eg majoron emission), decoherence ...

Order of magnitude:

type	L/E	$t_{proper} \sim (L/c)(m_{\nu}/E)$	
CERN SpS/WANF	500 m/25 GeV	3 attoseconds	
Stopped μ (LAMPF)	30 m/ 40 MeV	130 attoseconds	
NUMI	735 km/ 4 GeV	30 femtoseconds	
Reactor (KamLAND)	150 km/5 MeV	800 femtoseconds	>
Atmospheric	10,000 km/1 GeV	2 picoseconds	
Sun	150.000.000 km/5 MeV	800 nanoseconds	
GZK	1 Gpc/100 PeV	50 milliseconds	J
SN-1987a	50 kpc/15 MeV	1 hour	

available

• Decays alter flavor ratios: Beacom,Bell,Hooper,Pakvasa,Weiler, PRL 90,181301 (2003) Recent review: Pakvasa, Phys. Atom. Nucl., 67, 1154 (2004)



The Faces Behind ANITA



University of California, Irvine Ohio State University University of Kansas

Washington University in St. Louis

University of Delaware

University of Minnesota

Vashington University in St.Louis University of Hawai'i M Ă N O A

UCL



University of California, Los Angeles University of Hawaii at Manoa National Taiwan University University College London Jet Propulsion Laboratory Stanford Linear Accelerator Center









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Jet Propulsion Laboratory



- 2 months in Palestine Texas for 2 months at UC Irvine for Anita-Lite
 ANITA-1
- 3 months in Antarctica (ANITAlite)
- UC Irvine prep for Eng. flight
- 2 months in Ft. Sumner NM (Eng flight)
- 1 month at SLAC for ANITA-1 cal.
 - 3 mo. Anita-1 in Antarctica
 - Anita-2 in Hawaii
 - 2 mo. Anita-2 in Palestine
 - 3 mo. Anita-2 in Antarctica

ANITA & L.D.B.

- NASA's Columbia Scientific Ballooning Facility's Long-Duration (Antarctic) Ballooning is a perfect match:
 - 24-hour sun → stable altitude, 24/7 power
 - 70 % of world's fresh water is in Antarctica *
 - Antarctica is \sim most radio-quiet place on Earth *

* = Lucky Coincidence



ANITA-1 Flight



35 Days
Second longest LDB flight ever
Not much time over deep ice (abnormal)
Away from bases, saw thermal noise levels.
17.3 days livetime

ANITA-1 Data

Data (ground pulser)



End-to-End Simulation:



Triggering

Example: West Antarctica camp noise

- Yellow, L1: multiple bands above thermal noise for one antenna; ~150 kHz
- Green, L2: coincidence between adjacent L1 in the same ring; ~40kHz
- Blue, L3: coincidence between L2 triggers in same phi sector; ~5Hz

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Deep Field Under-Ice Pulser

Transmitter in 100m deep borehole + multiple pulsers near McMurdo

ANITA-I Data: Particle physicists can do interferometry too



<< degree pointing

Payload azimuth angle (degrees)

Direction Resolutions



Ground Pulsers

make even very small effects stand out (and are corrected)

Measured payload phi vs. error in theta χ^2/ndf 0.1094/42Pitch 0.2808 ± 0.01089 Error in elevation (degrees) Roll -0.2968± 0.01089 Constant Offset -0.02677 ± 0.007702 0.4 0.2 Ο -0.2 -0.4Ο 50 100 150 200 300 350 250

Measured azimuth (degrees)

ANITA 1 Data

- 8.2 M hardware triggers
- First analysis: ~20,000 impulses point well to ice



ANITA 1 Data

Analysis cuts determined with 10% data set. Require upcoming plane wave, isolated from camps and other events.



New "Deep Analyses" in progress

Background Estimate

Thermal Noise

- \rightarrow Well simulated
- \rightarrow << 1 event after all cuts
- Anthropogenic Impulsive Noise

 \rightarrow E.g., Iridium phones, spark plugs, spark gaps, discharge from structures...

ANITA-1 Results

- 6 H-pol, 0 V-pol survive cuts
 - H-pol originate above ice sheet (not v candidates)
 - Fresnel transmission
 - Askaryan impulse generation
- ANITA has first/best constraints GZK v production models



ANITA-1 Sky Map Sensitivity

- Expect GZK ν to be isotropic
- (RA, Dec) For 10²⁰ eV neutrinos, 17.3 days



The Start of ANITA-2

ANITA-2 Upgrades...

- More typical flight path
- Change L1 trigger
 - only trigger on V-pol signal,
 - 3 narrow-band channels + 1 full band
 - Move preamps to the antenna (-20K)
- New preamps (-20K)
- New front end filters (-20K)
- Faster CPU & discs
- New GPS
- Dynamic Azimuth masking

Efficiency Comparison



New trigger board



New preamp



New front end filter





ANITA-2 Ready Dec. 2008



8 "drop down" antennas

ANITA-II "at float"

ANITA-2: Beautiful Flight Path



ANITA-2 Data

Antenna Noise Temperature (includes ice temp)



Temperature (Kelvin)

ANITA-2 Deep Field Pulser Event:



> 200,000 calibration pulser events from deep field for ANITA –II

Summary

• ANITA-1 first analysis

See no neutrino candidates

nor irreducible backgrounds

2nd pass "deep" analyses underway

• ANITA-2

Excellent flight path

Systems worked beautifully

better: flight path, livetime, trigger, amplifiers

100% recovery

Expect factor of order 5-10 more GZK ν sensitivity

Well into GZK territory!

The Start of ANITA-3?