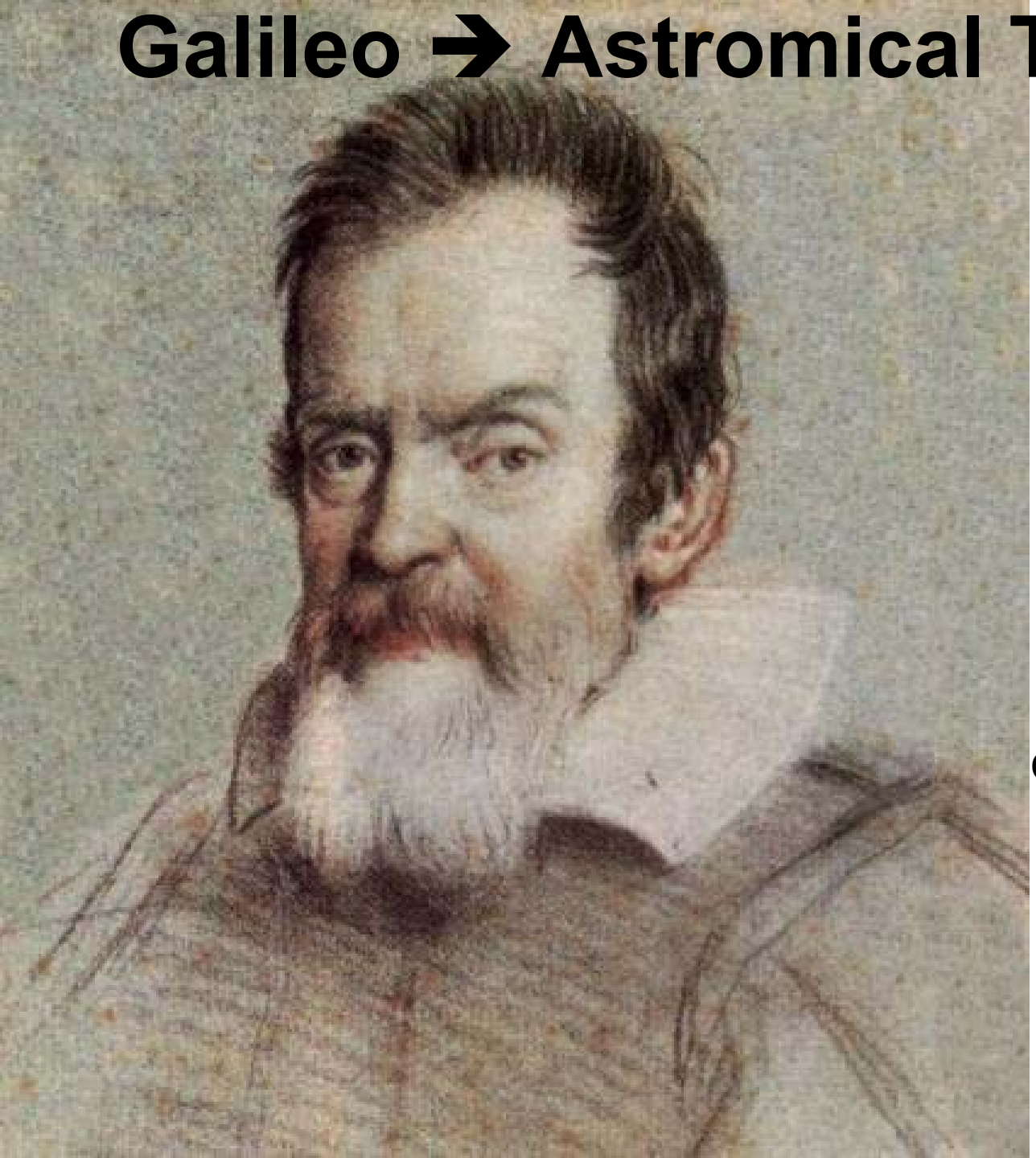
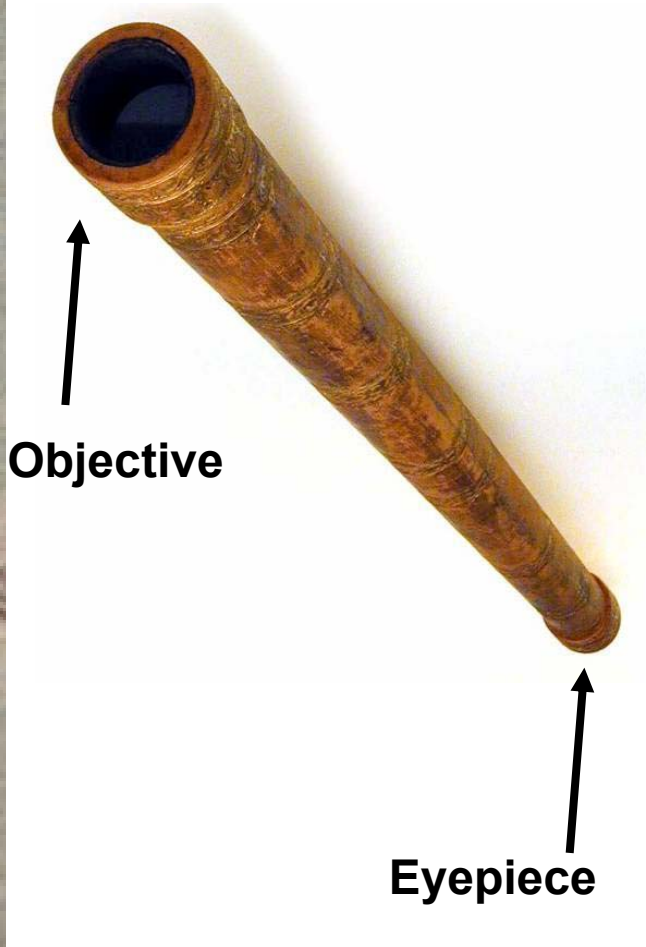
OVERVIEW of the ANITA EXPERIMENT

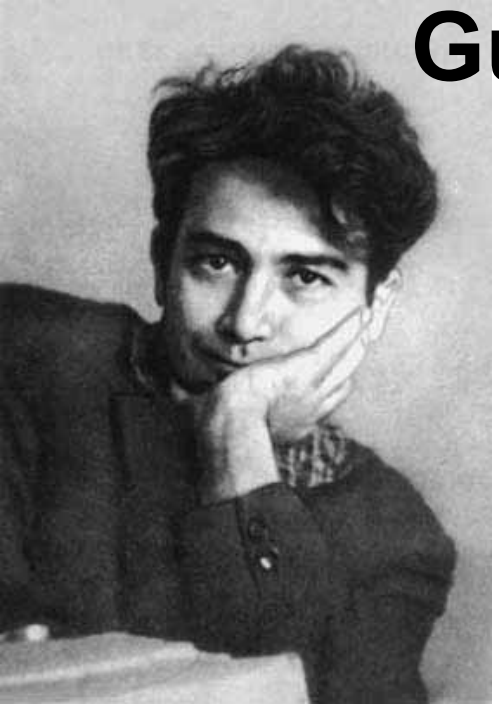
David Saltzberg (UCLA)
Venice ν Telescopes Meeting
March 11, 2009

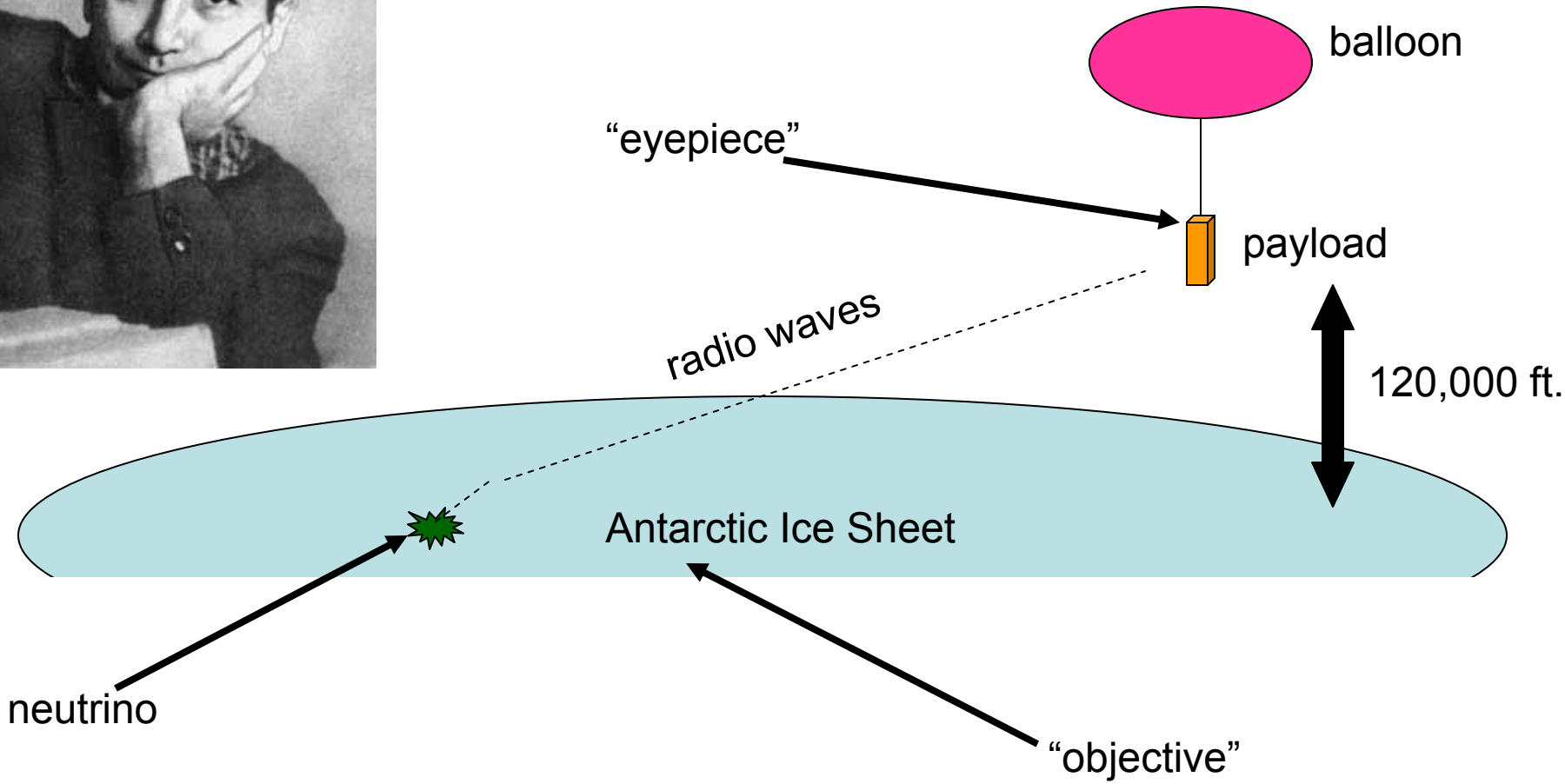
Galileo → Astromical Telescope





Gurgen Askaryan → ν Telescope

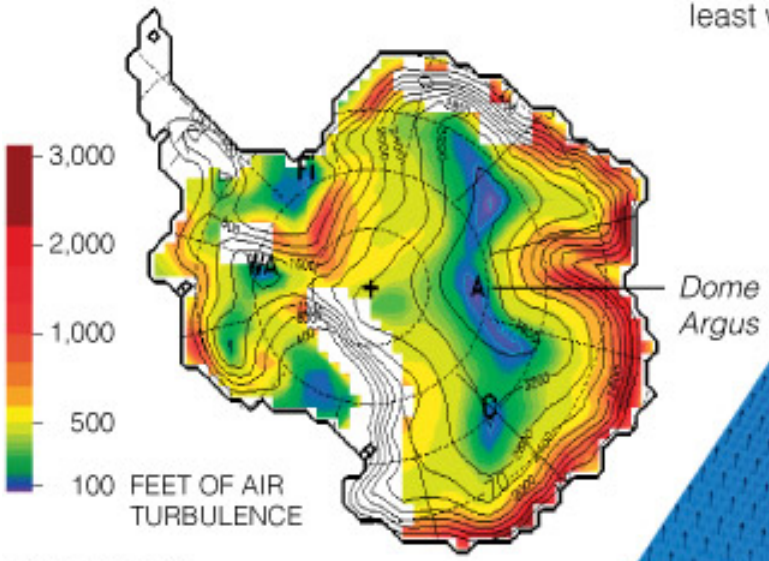




> 1,000,000 km^2, > 1,000,000 km^3 (~20,000 km^3 –sr)

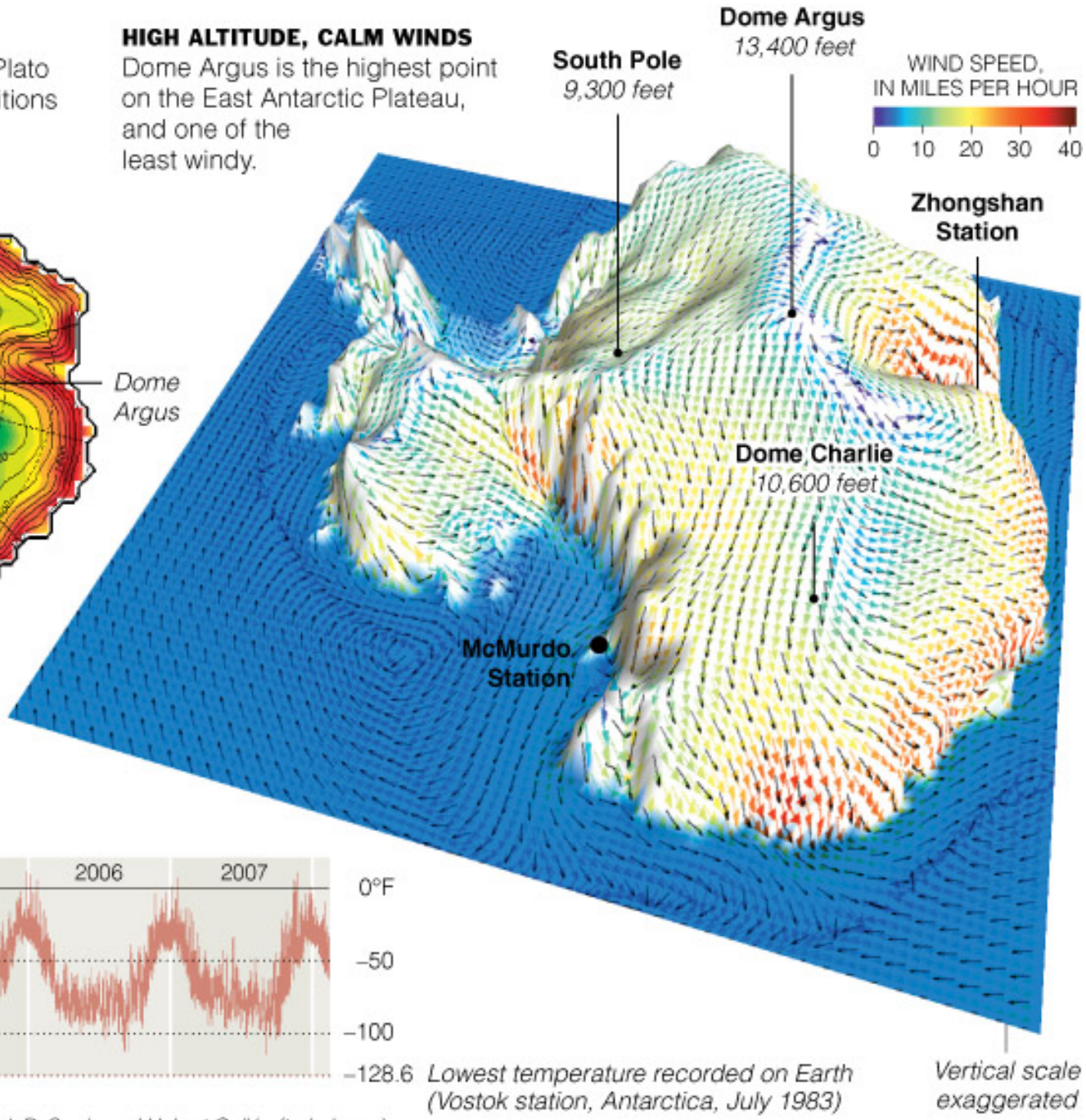
Calm, Clear and Cold

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.

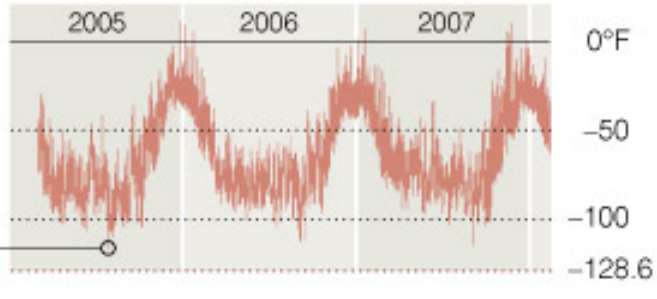


CLEAR SKIES

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.



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

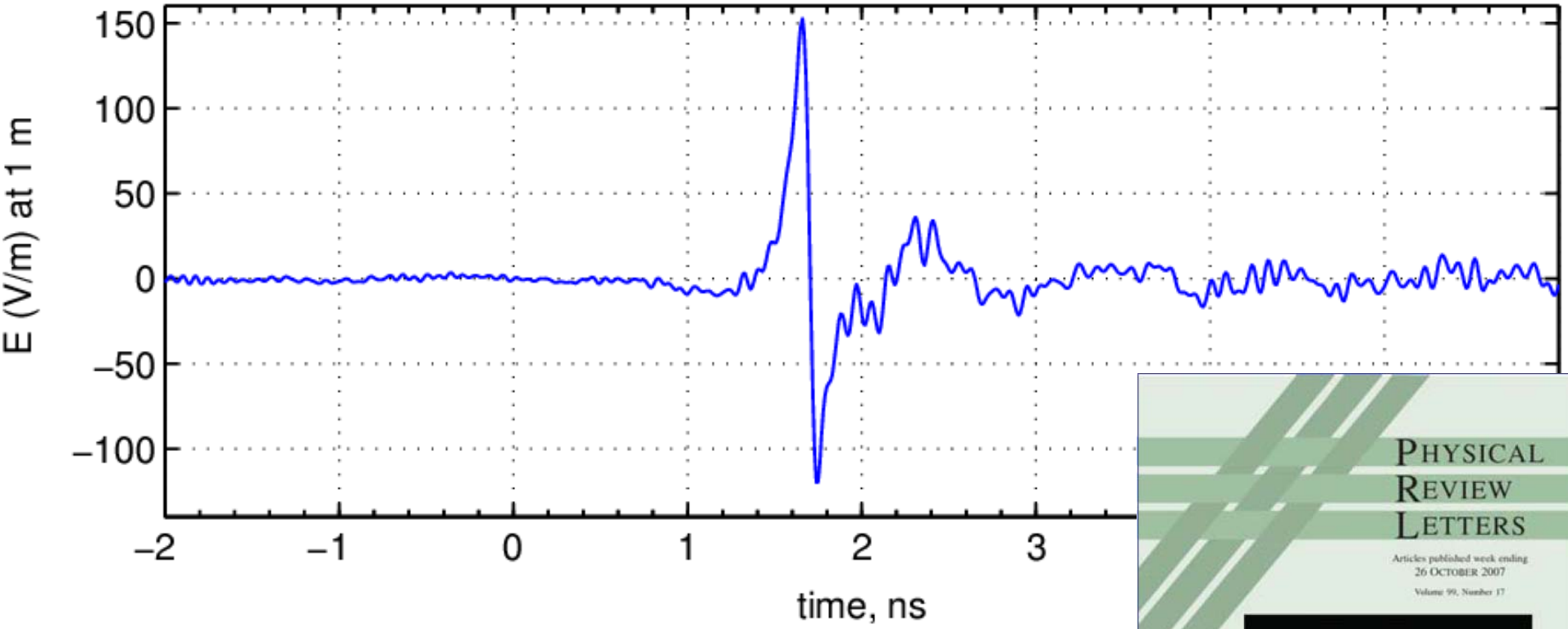
THE NEW YORK TIMES

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

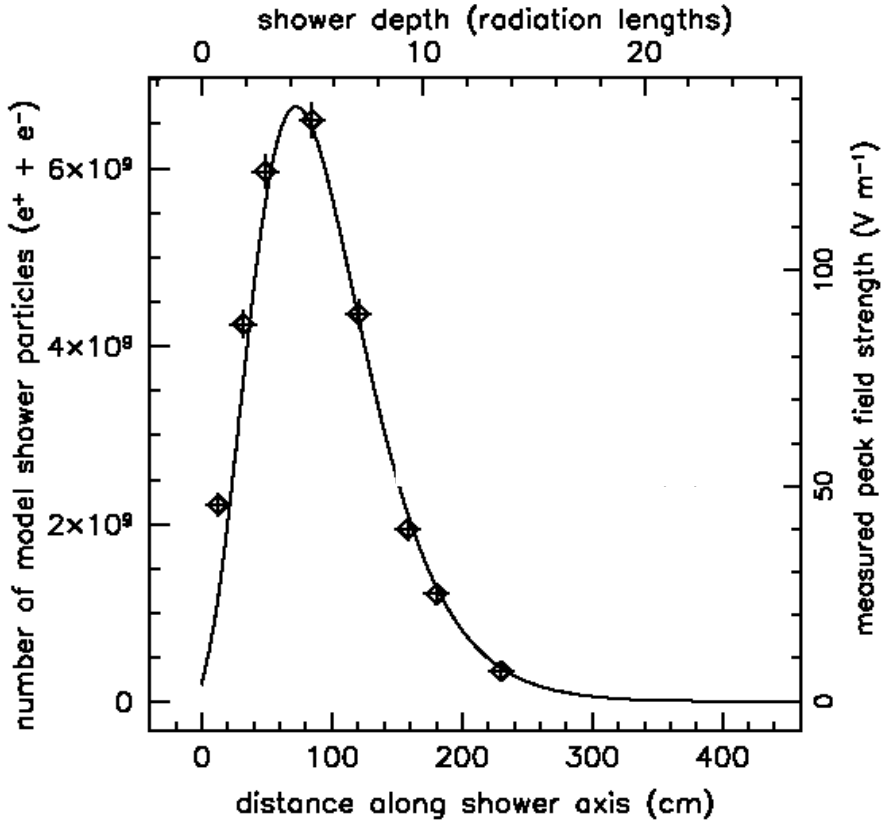


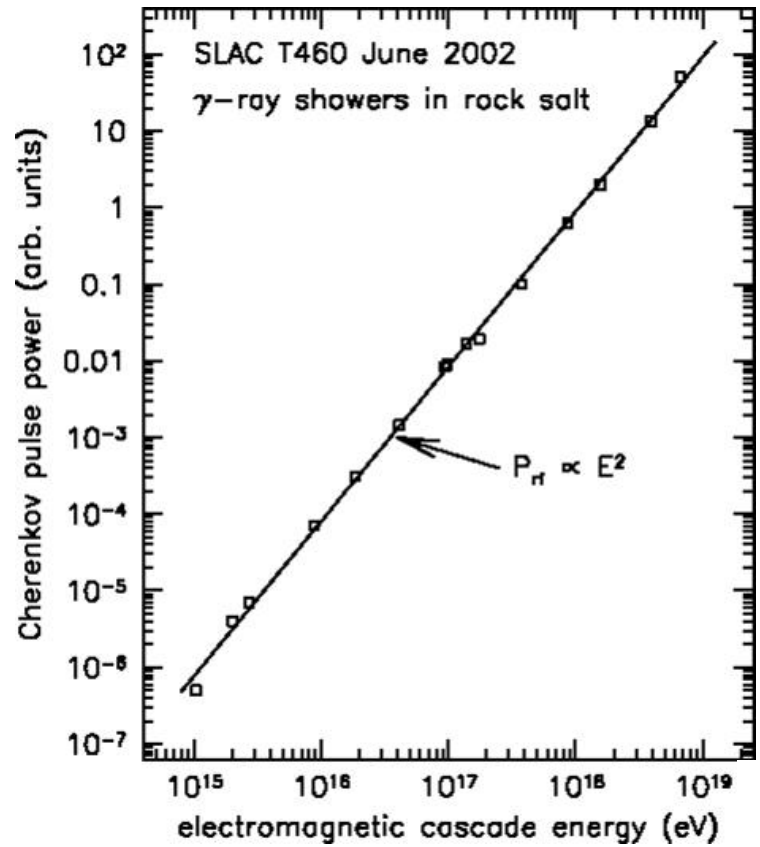
Agrees with modern calculations:

Halzen, Zas, Stanev (1991)

+ Alvarez-Muniz, Ralston, Buniy, Razzaque, McKay, Seckel

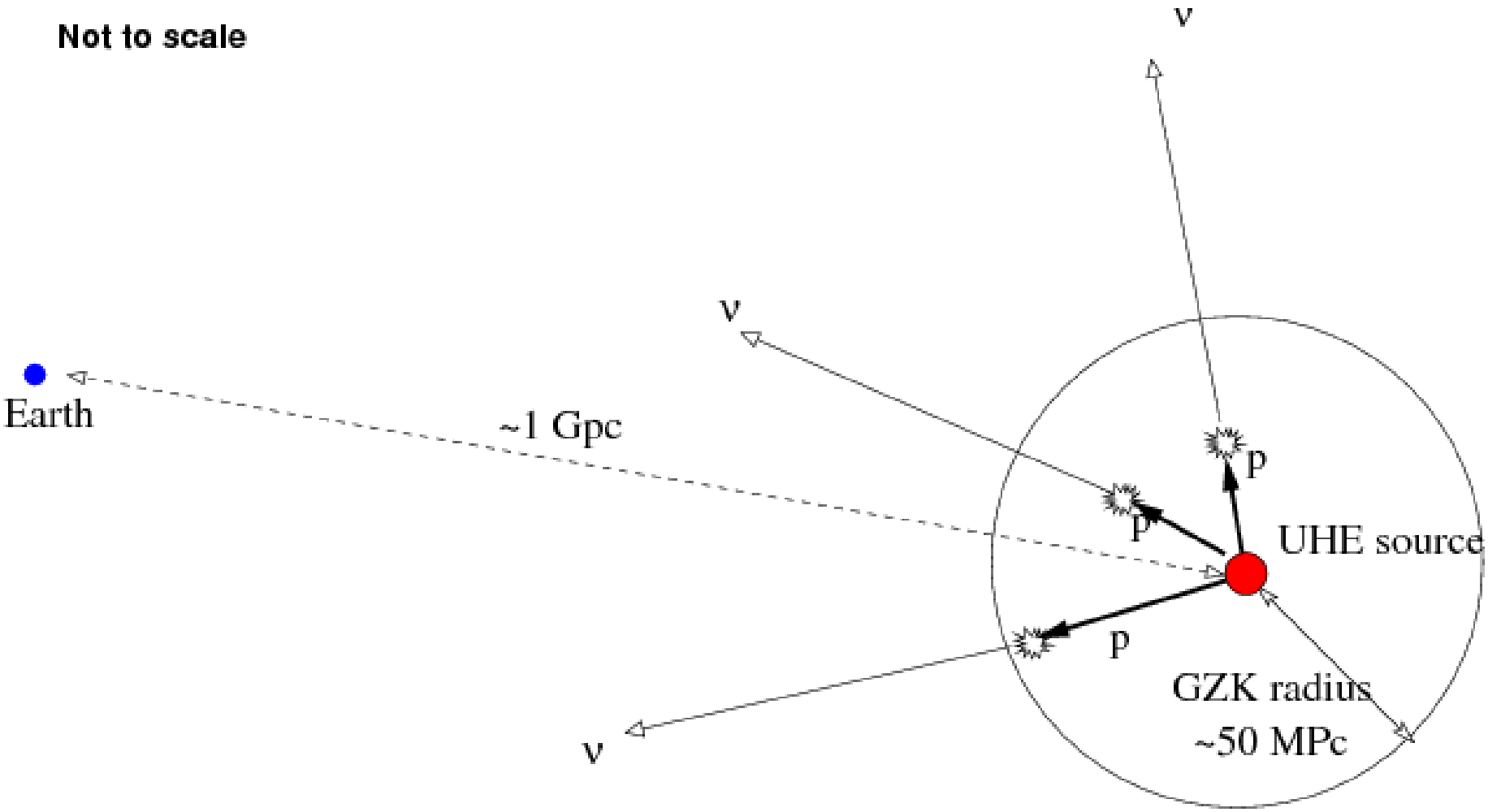
Askaryan Effect at SLAC





- Amplitude expected
- 100% linearly polarized
- Cherenkov angle

GZK-induced Neutrinos



$\delta\theta$ **~ 10Mpc/1000Mpc ~ 30 arcminutes**

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

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

- **Determines (largely) the sensitivity to :**

  Δm^2, <u>decays</u> (eg majoron emission), decoherence …

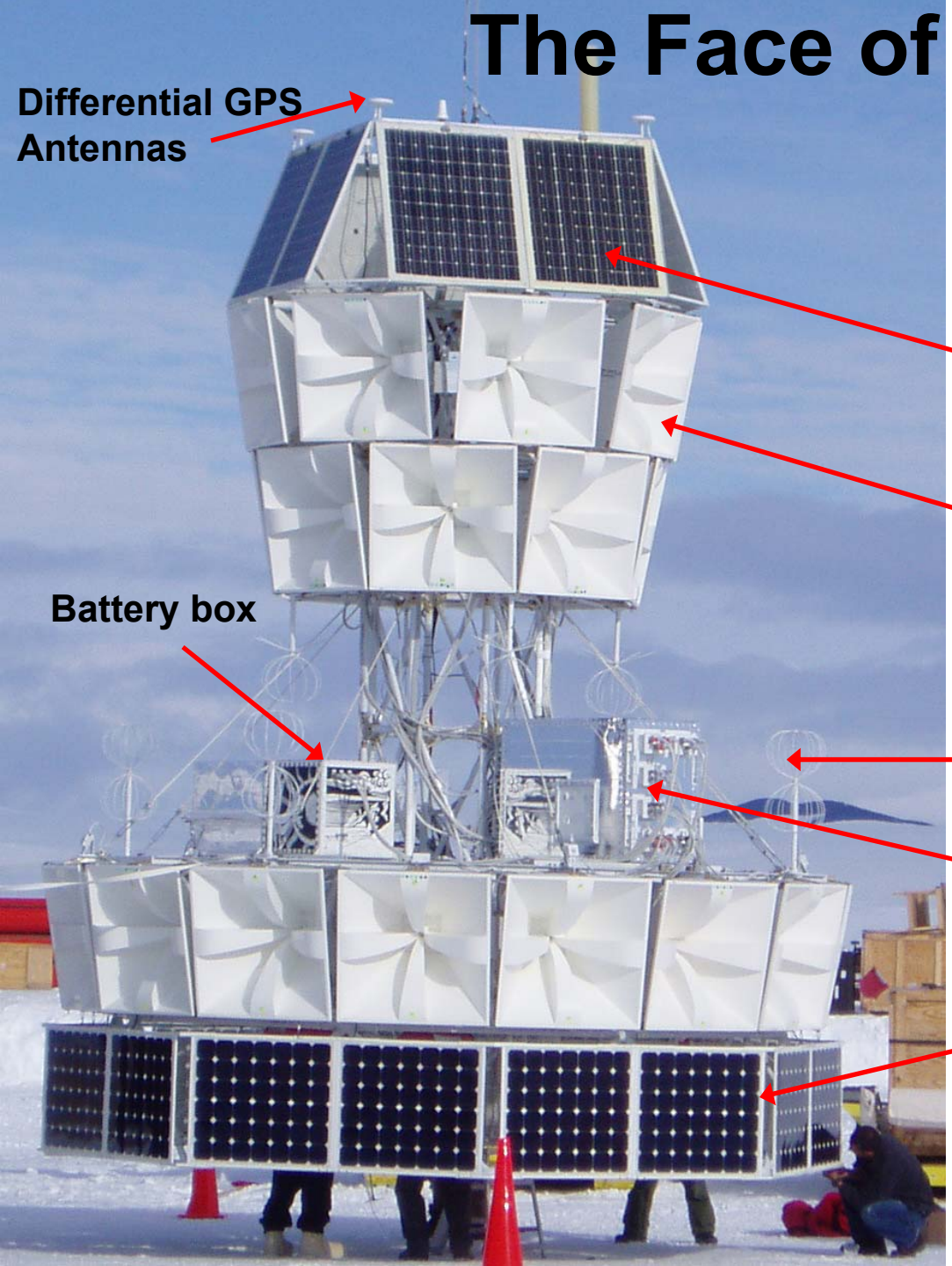
Order of magnitude:

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
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 Face of ANITA-1



Solar cells for NASA equipment

32 Quad-ridge horn antennas
- 200 MHz to 1200 MHz
- 10 degree downward angle

8 low gain antennas to monitor payload-generated noise

ANITA electronics box

Solar panels for science mission

"instrument paper": (50 pp!)
arXiv:0812.1920 [astro-ph]

new

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

University of California, Los Angeles

University of Hawaii at Manoa

National Taiwan University

University College London

Jet Propulsion Laboratory

Stanford Linear Accelerator Center

A Fact of Life in this Business

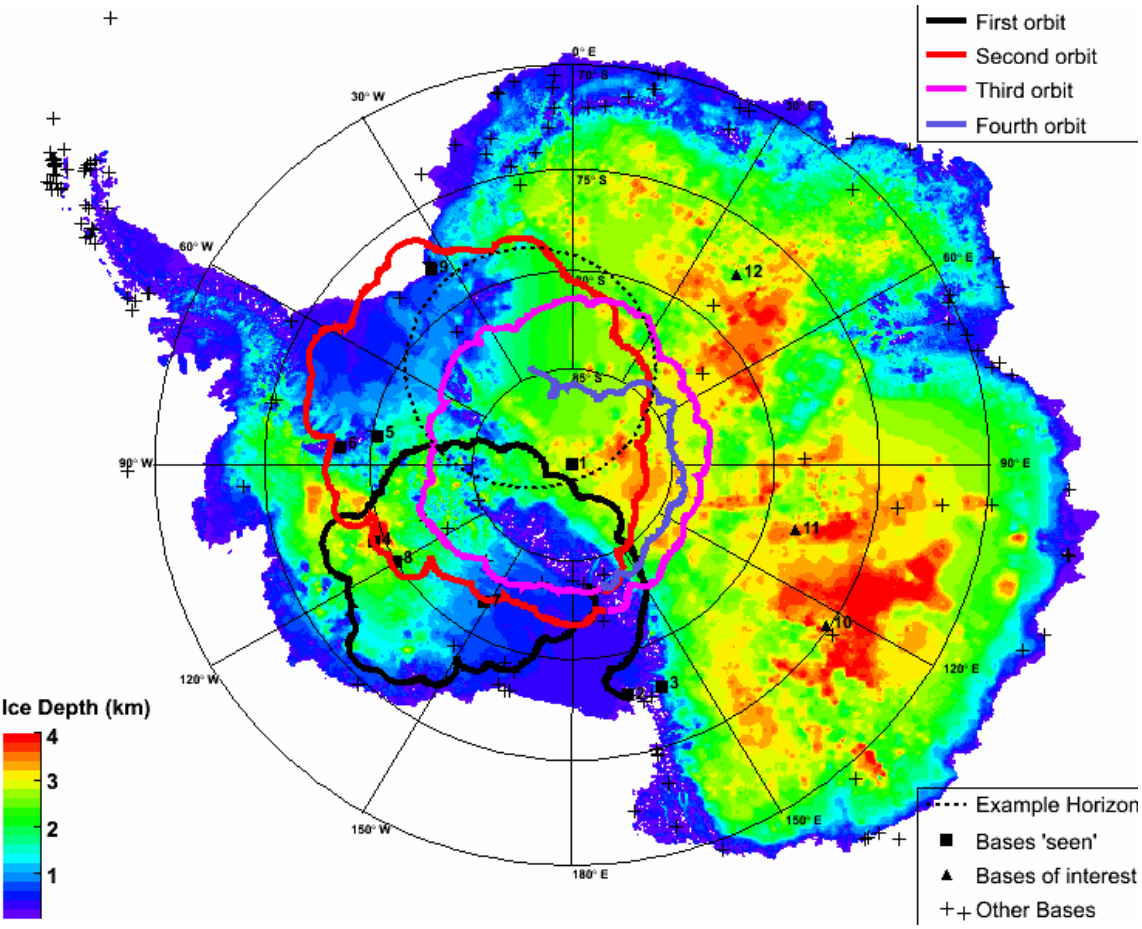
- 2 months in Palestine Texas for Anita-Lite
- 3 months in Antarctica (ANITA-lite)
- UC Irvine prep for Eng. flight
- 2 months in Ft. Sumner NM (Eng flight)
- 2 months at UC Irvine for ANITA-1
- 1 month at SLAC for ANITA-1 cal.
- 3 mo. Anita-1 in Antarctica
- Anita-2 in Hawaii
- 2 mo. Anita-2 in Palestine
- 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 ~ most radio-quiet place on Earth ***

*** = Lucky Coincidence**

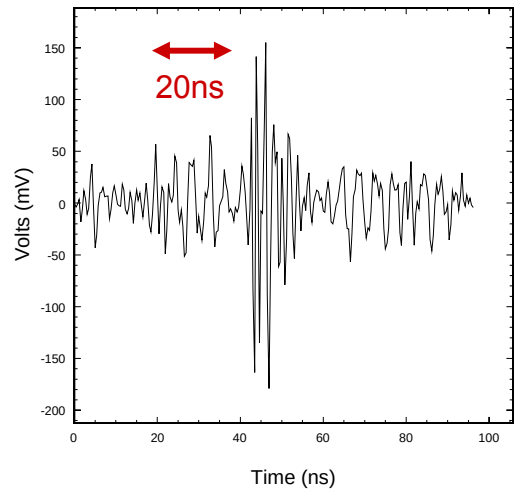
ANITA-1 Flight



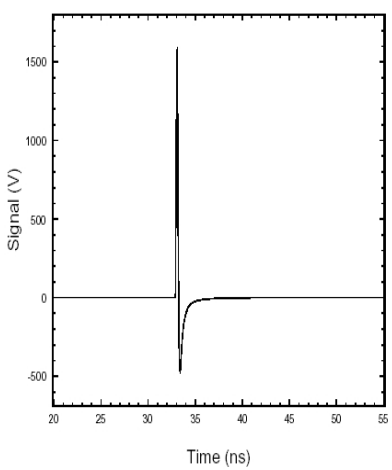
- 35 Days
- Second longest LDB flight ever
- Not much time over deep ice (abnormal)
- Away from bases, saw thermal noise levels.
- 17.3 days livetime

ANITA-1 Data

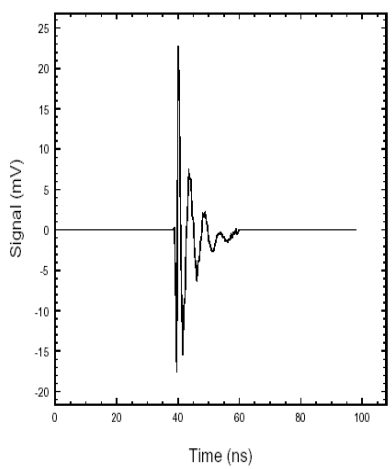
Data (ground pulser)



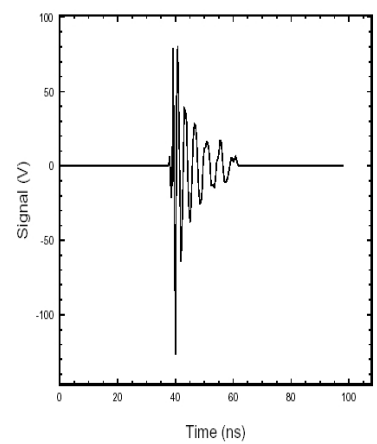
End-to-End Simulation:



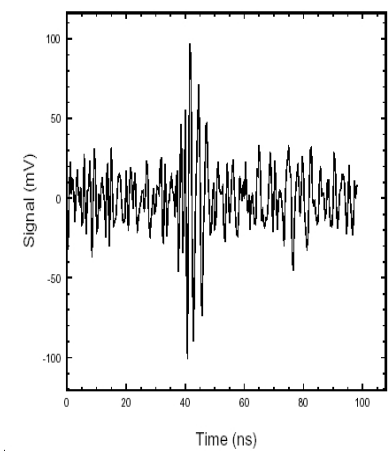
Askaryan



+antenna



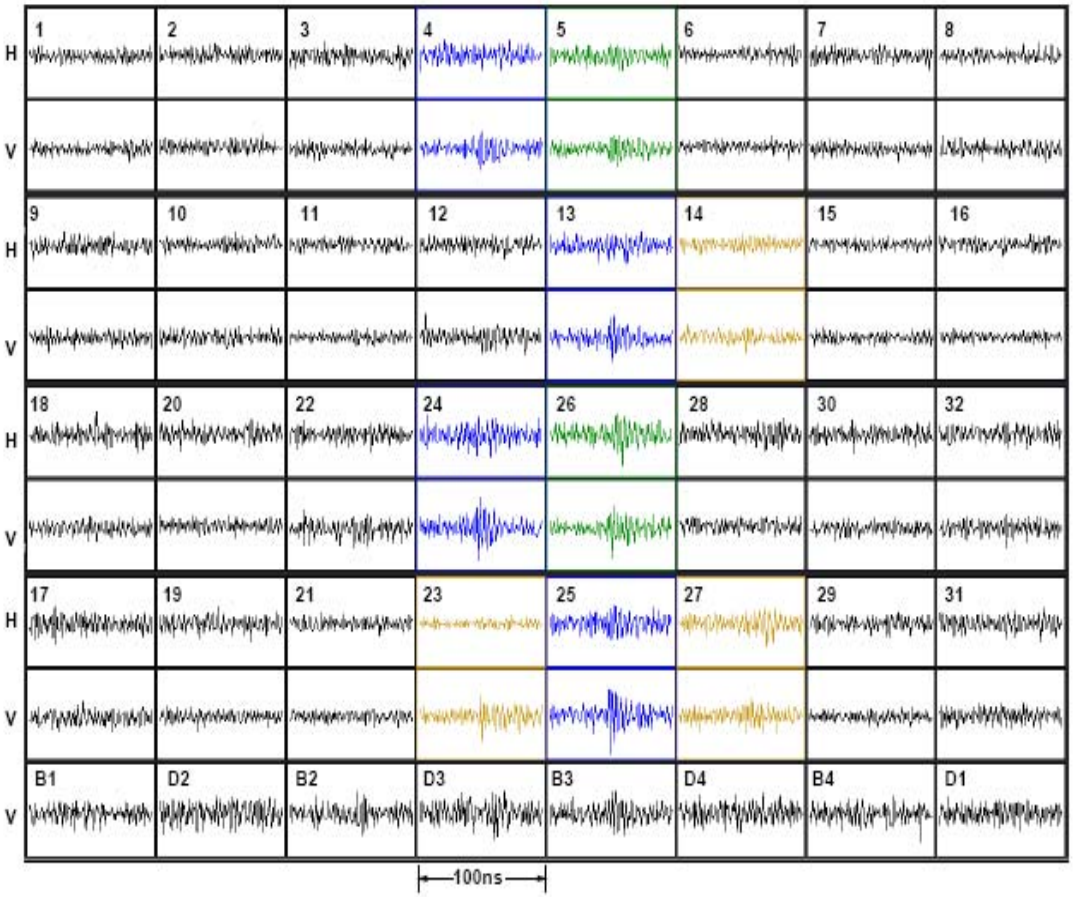
+electronics

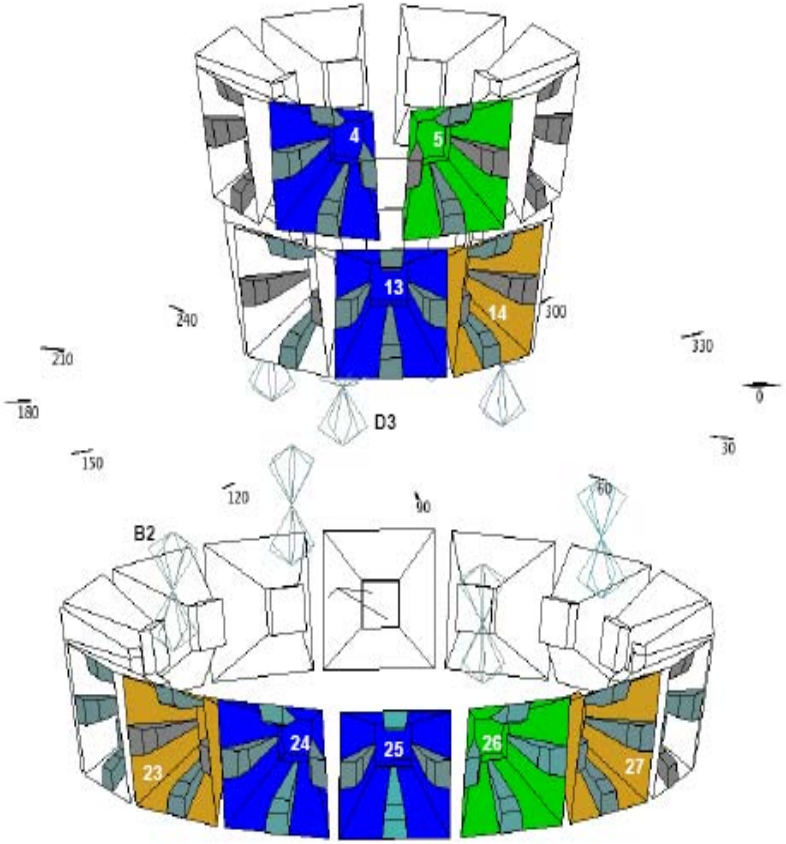


+ thermal noise

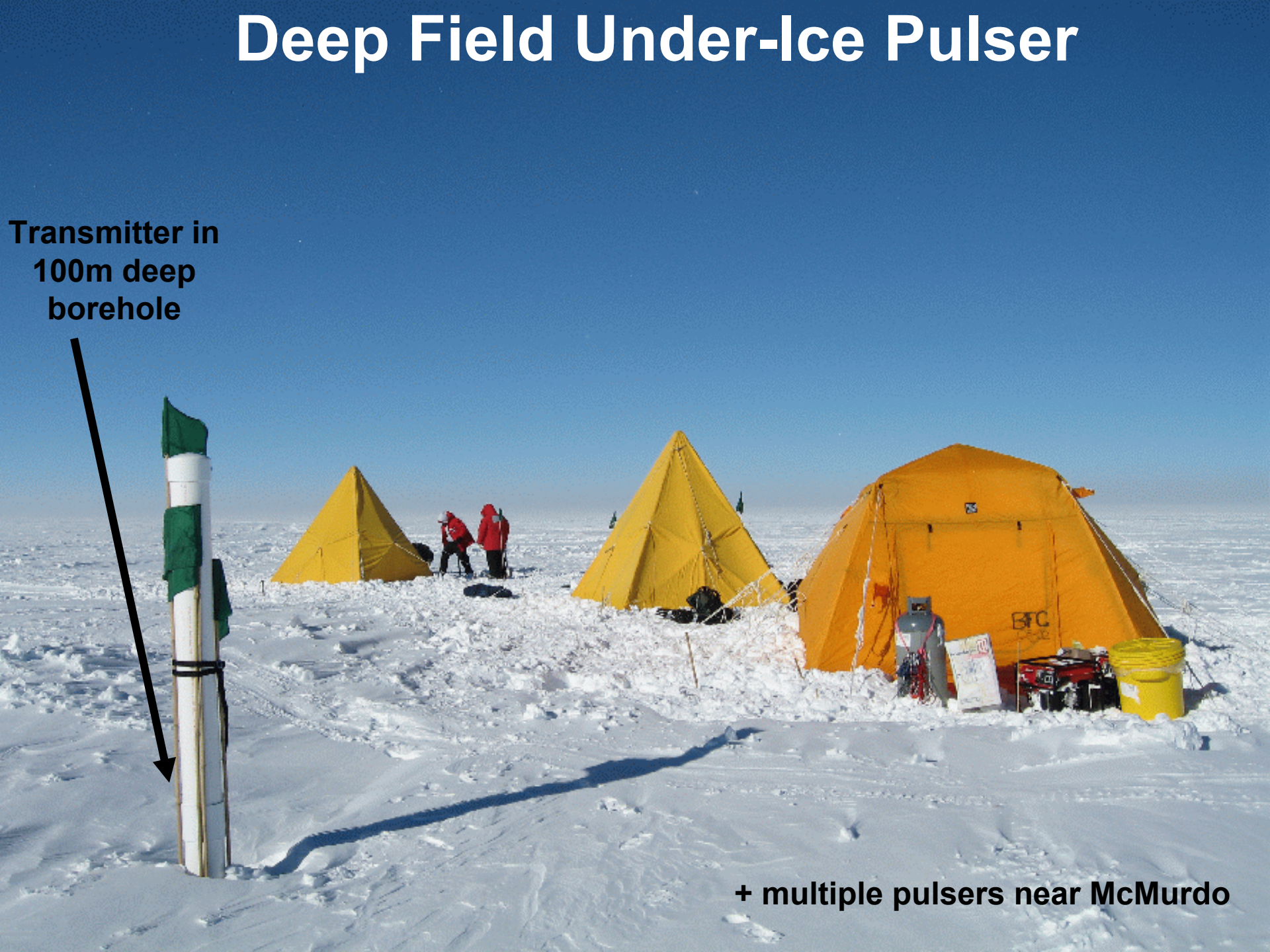
Triggering

- **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

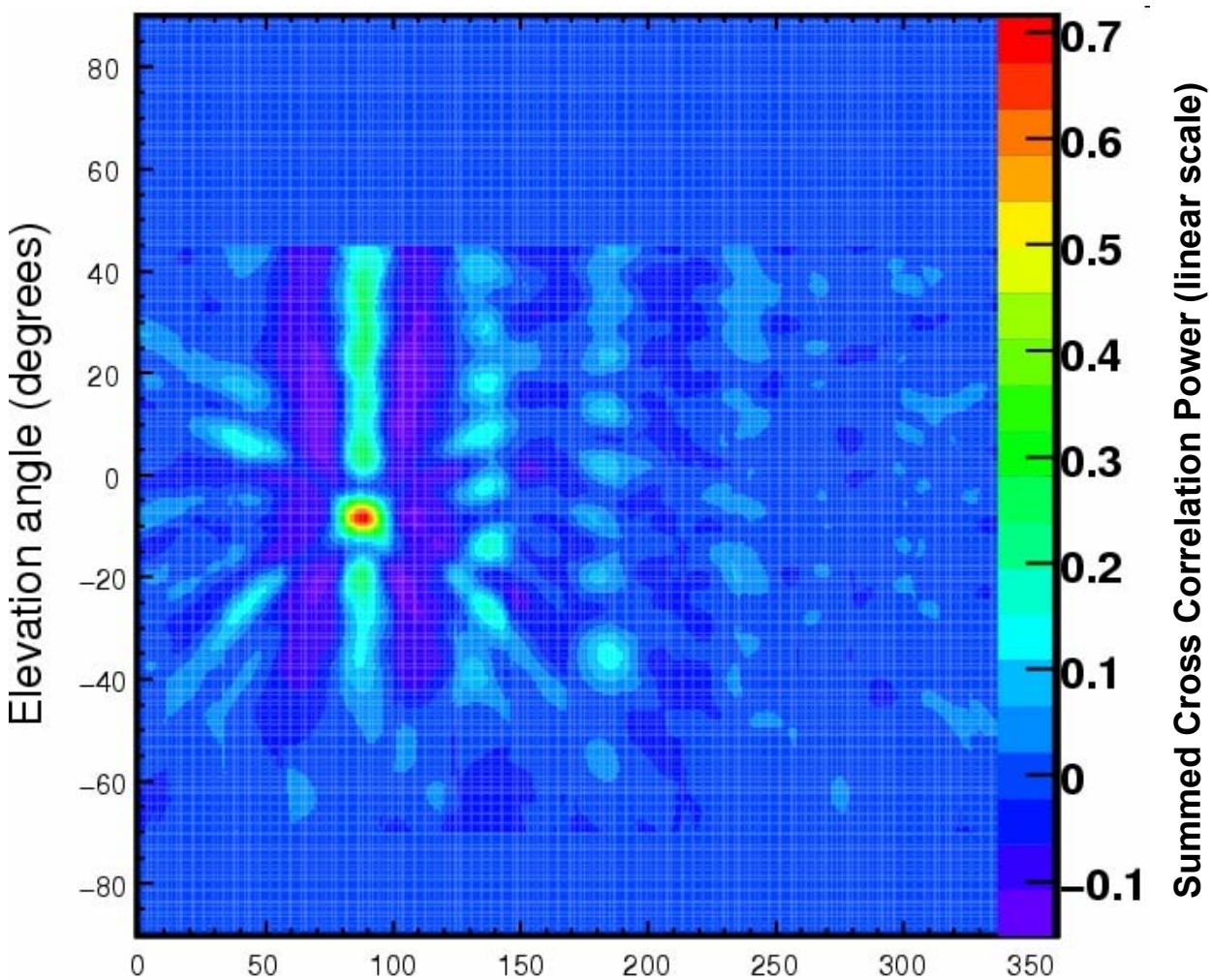




Deep Field Under-Ice Pulser

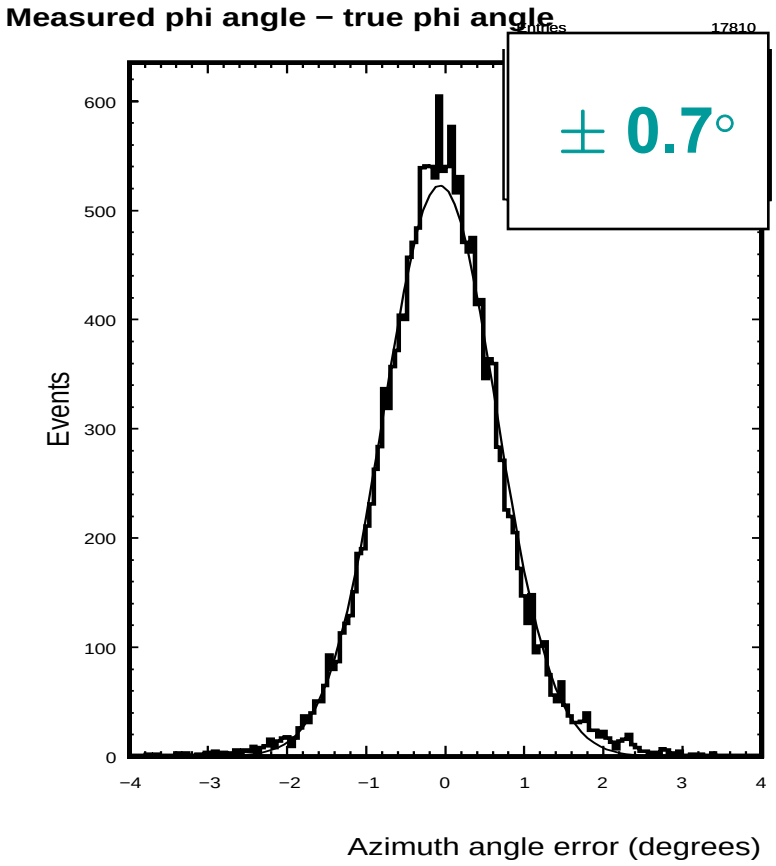


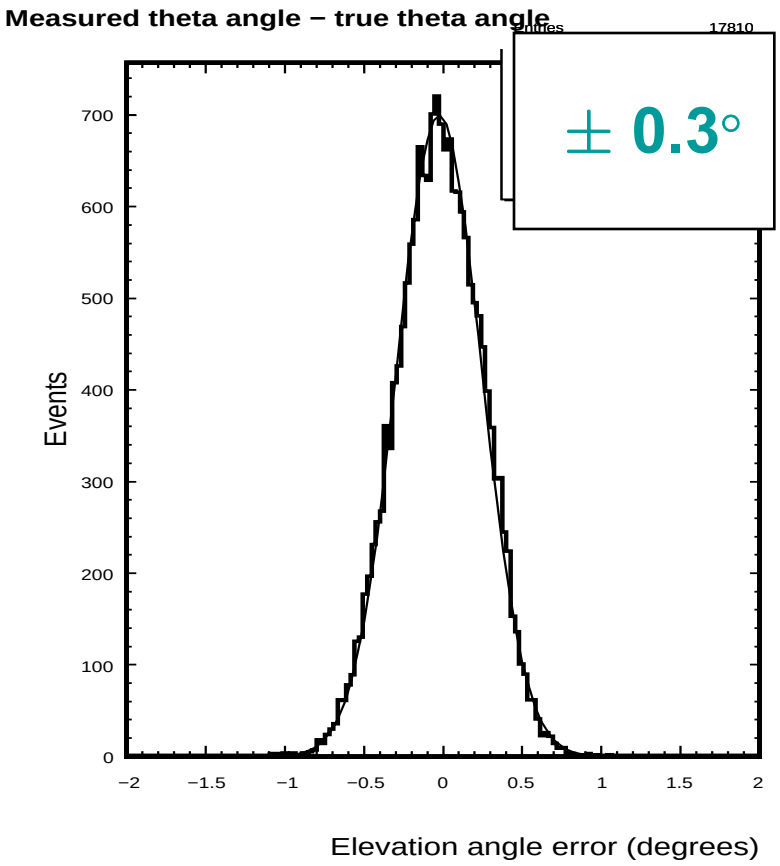
ANITA-I Data:
Particle physicists can do interferometry too



<< degree pointing

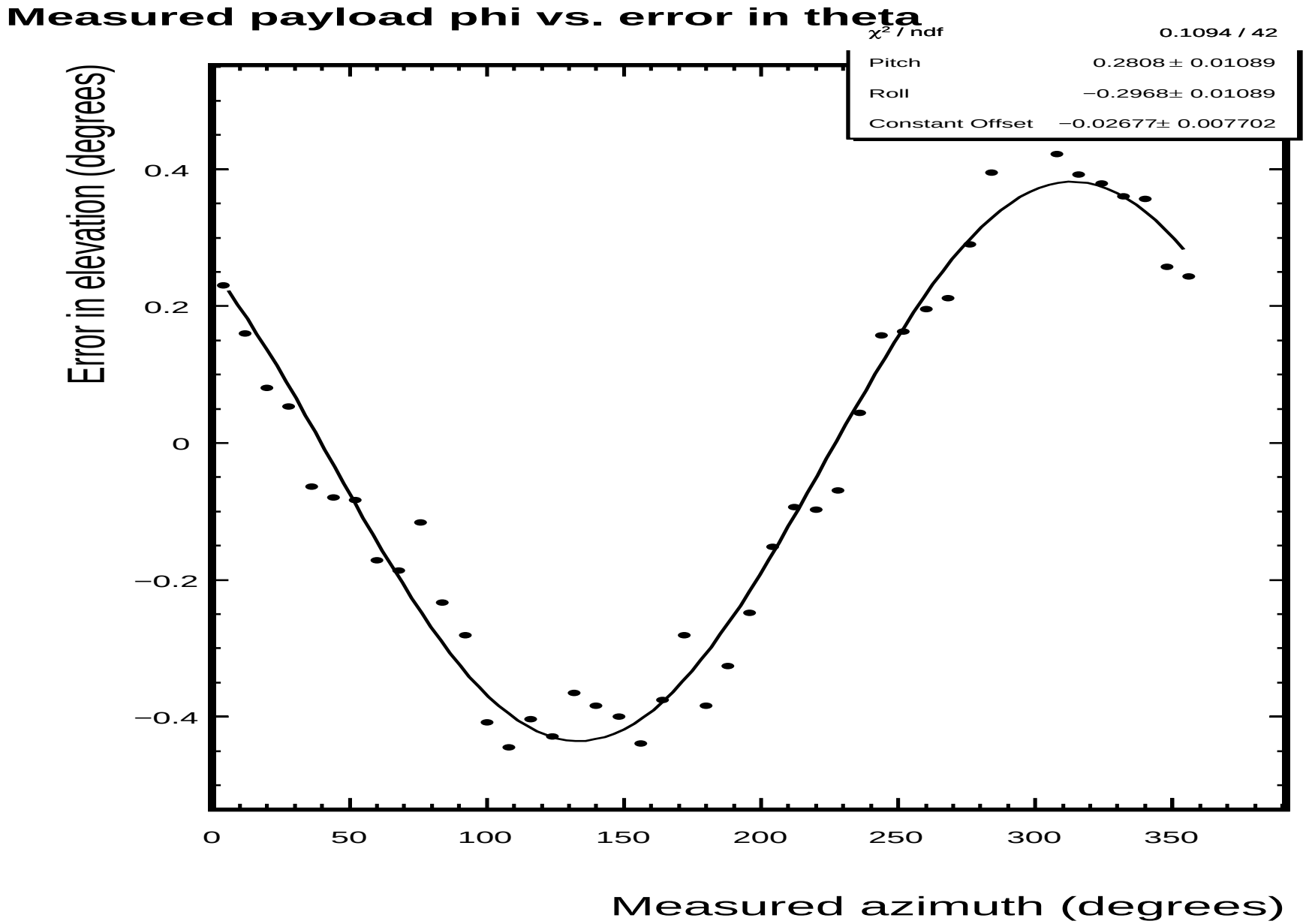
Direction Resolutions





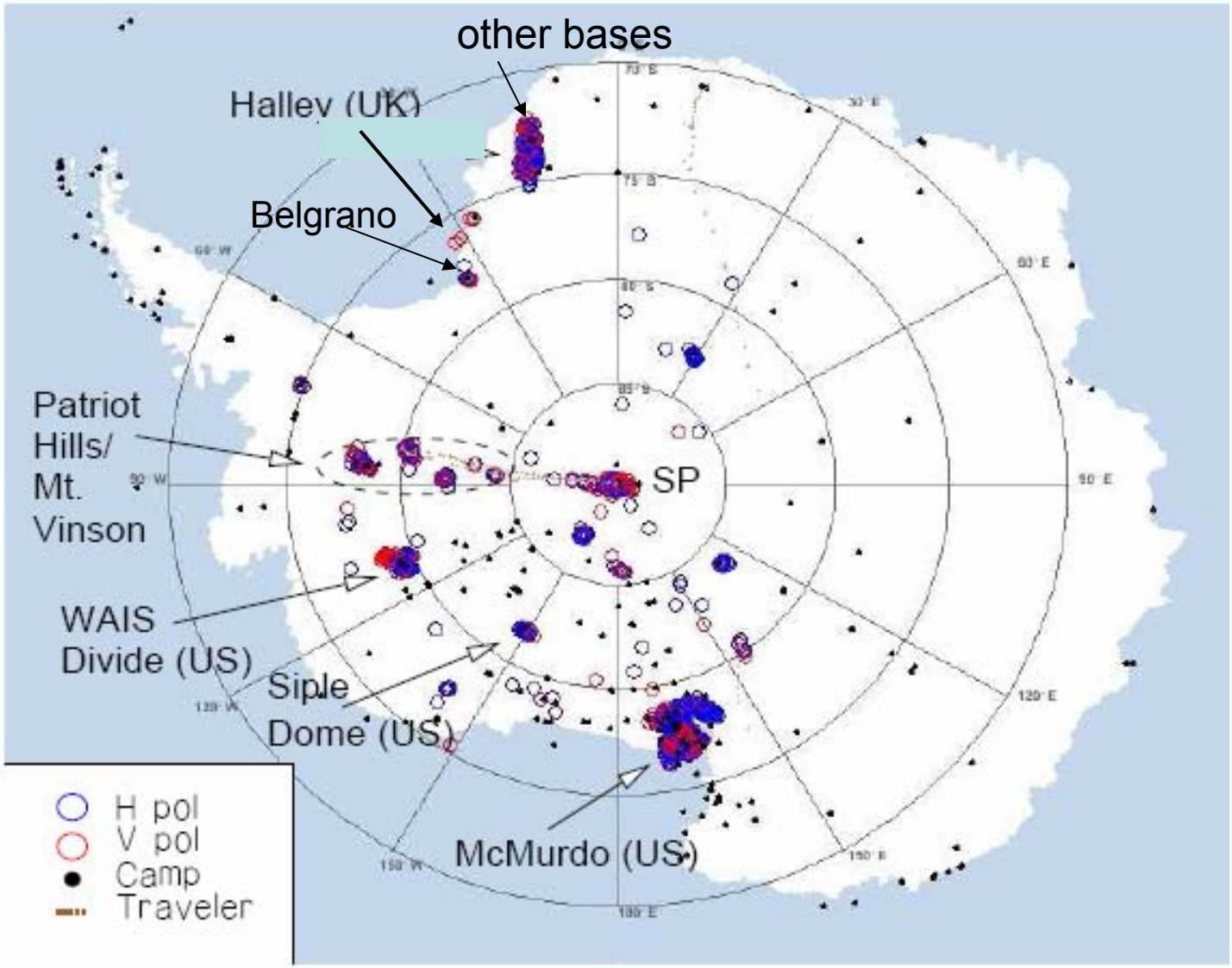
Ground Pulsers

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



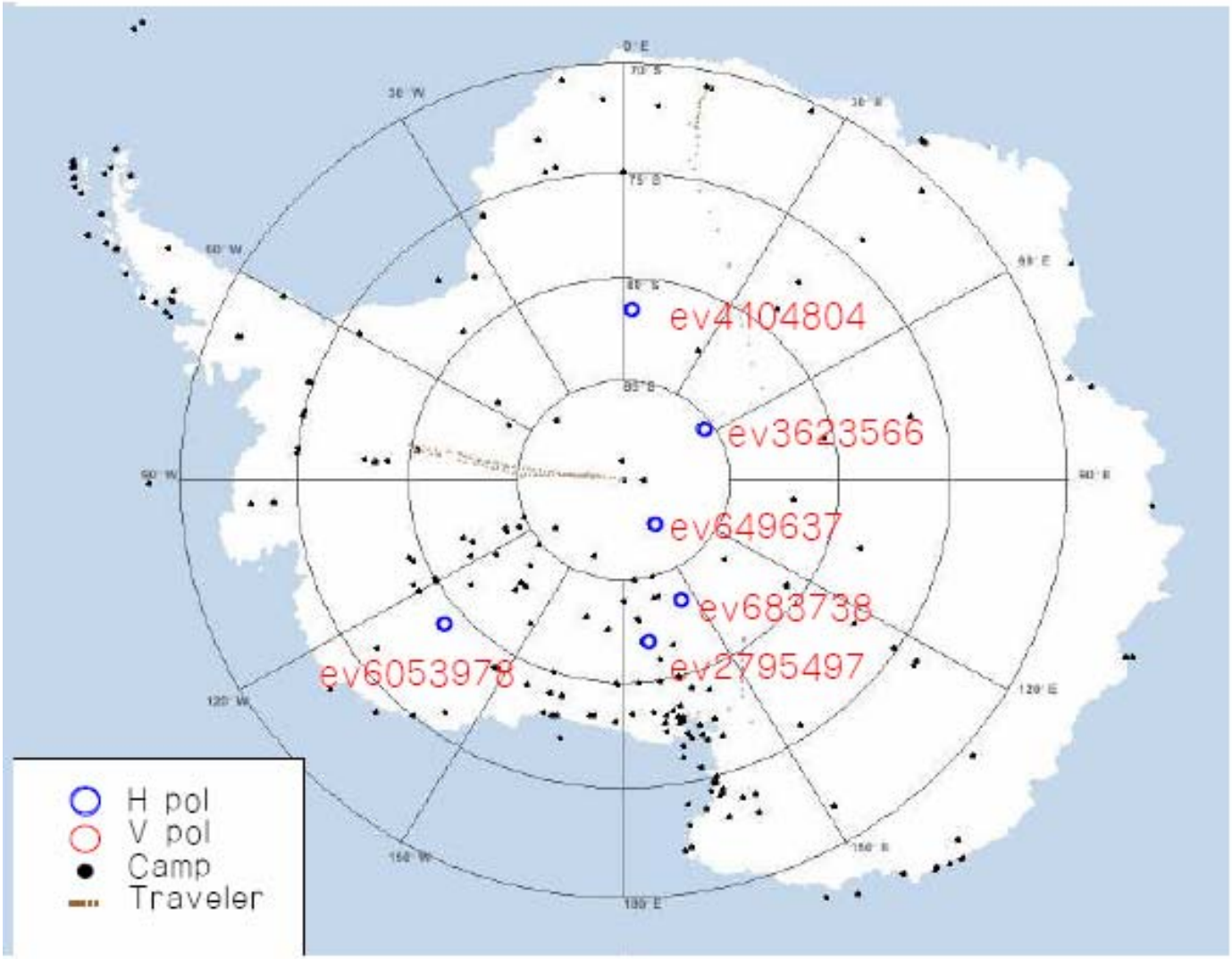
ANITA 1 Data

- **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**

  → **Well simulated**

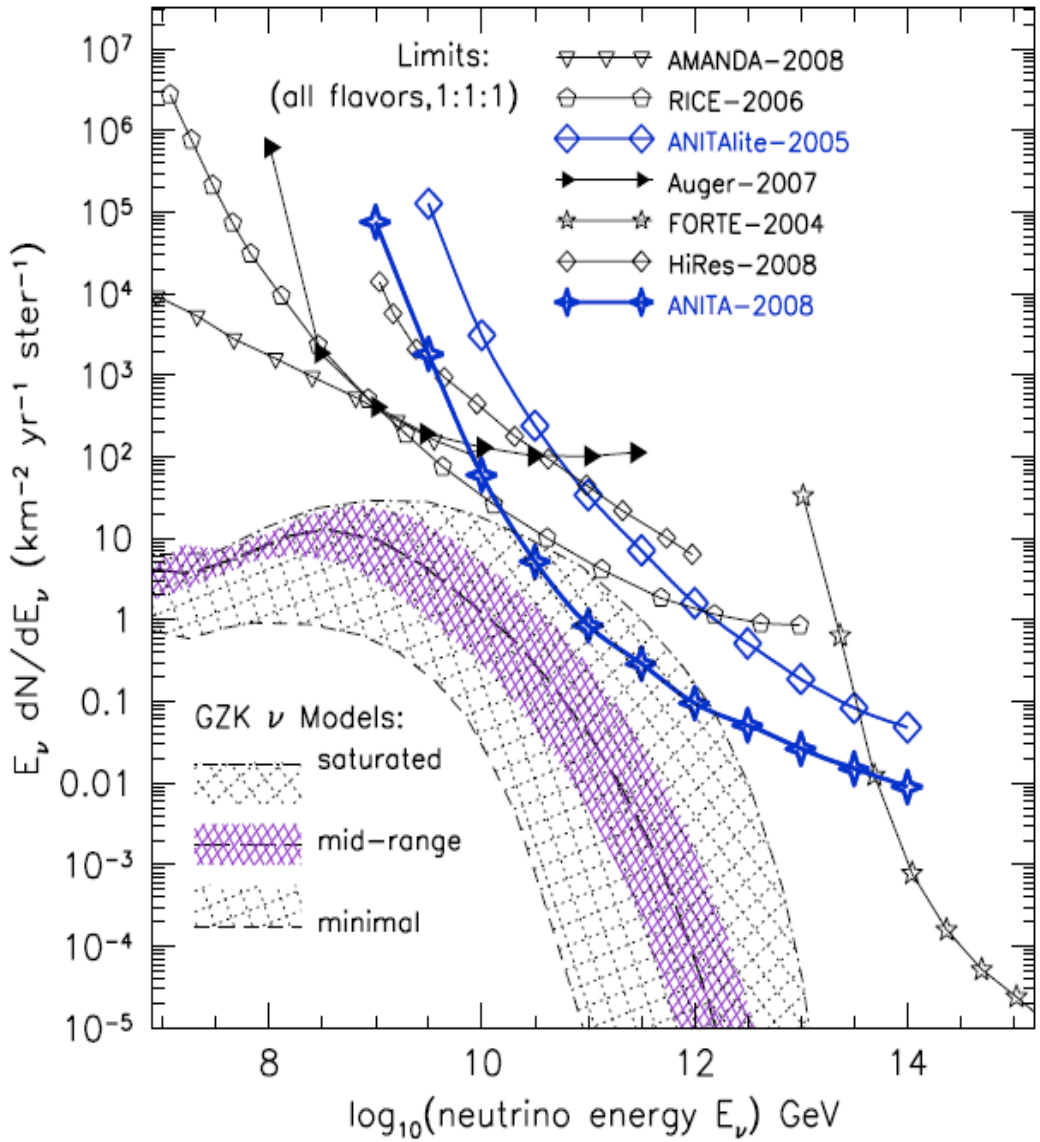
  → **<< 1 event after all cuts**

- **Anthropogenic Impulsive Noise**

  → **E.g., Iridium phones, spark plugs, spark gaps, discharge from structures…**

ANITA-1 Results

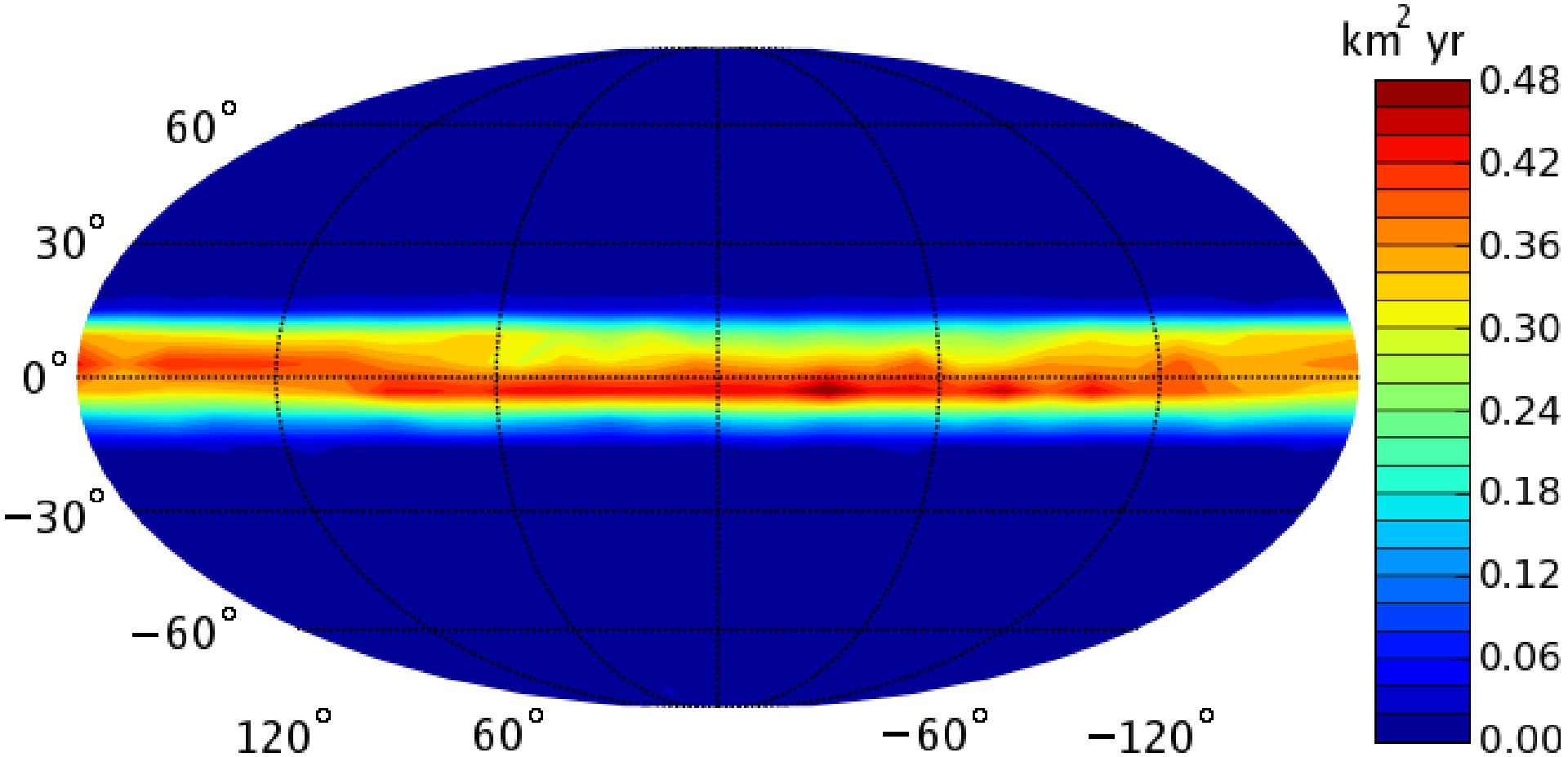
- **6 H-pol, 0 V-pol survive cuts**
  - **H-pol originate above ice sheet (not ν candidates)**
    - **Fresnel transmission**
    - **Askaryan impulse generation**
- **ANITA has first/best constraints GZK ν production models**



Gorham et al., arXiv:0812.2715v1 [astro-ph]

ANITA-1 Sky Map Sensitivity

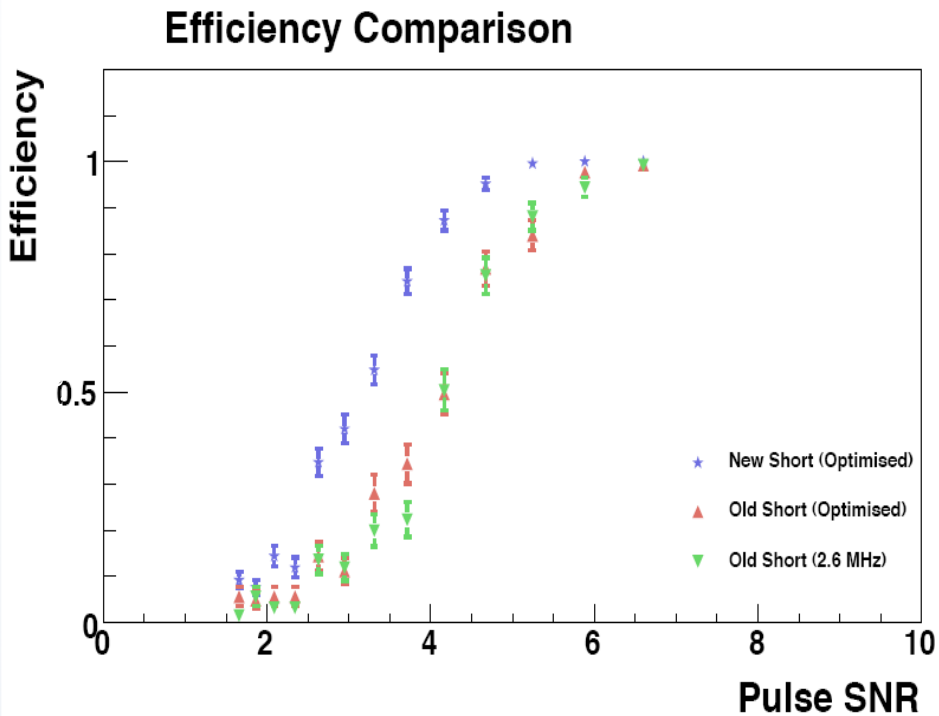
- **Expect GZK ν to be isotropic**
- **(RA, Dec) For 10^{20} eV neutrinos, 17.3 days**



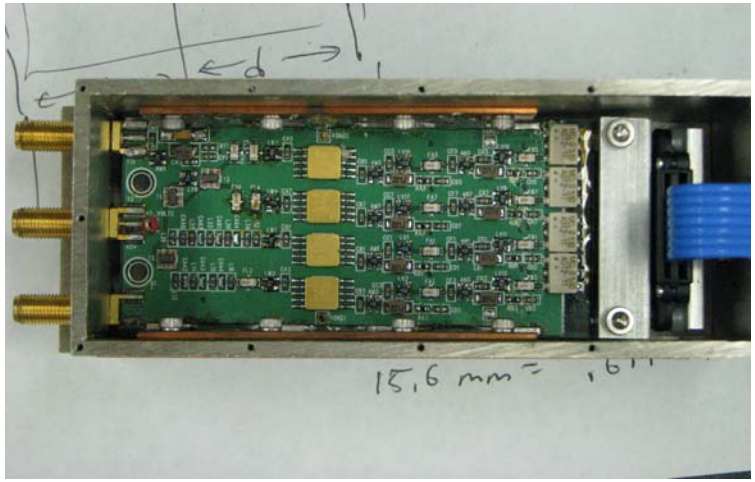
The Start of ANITA-2

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



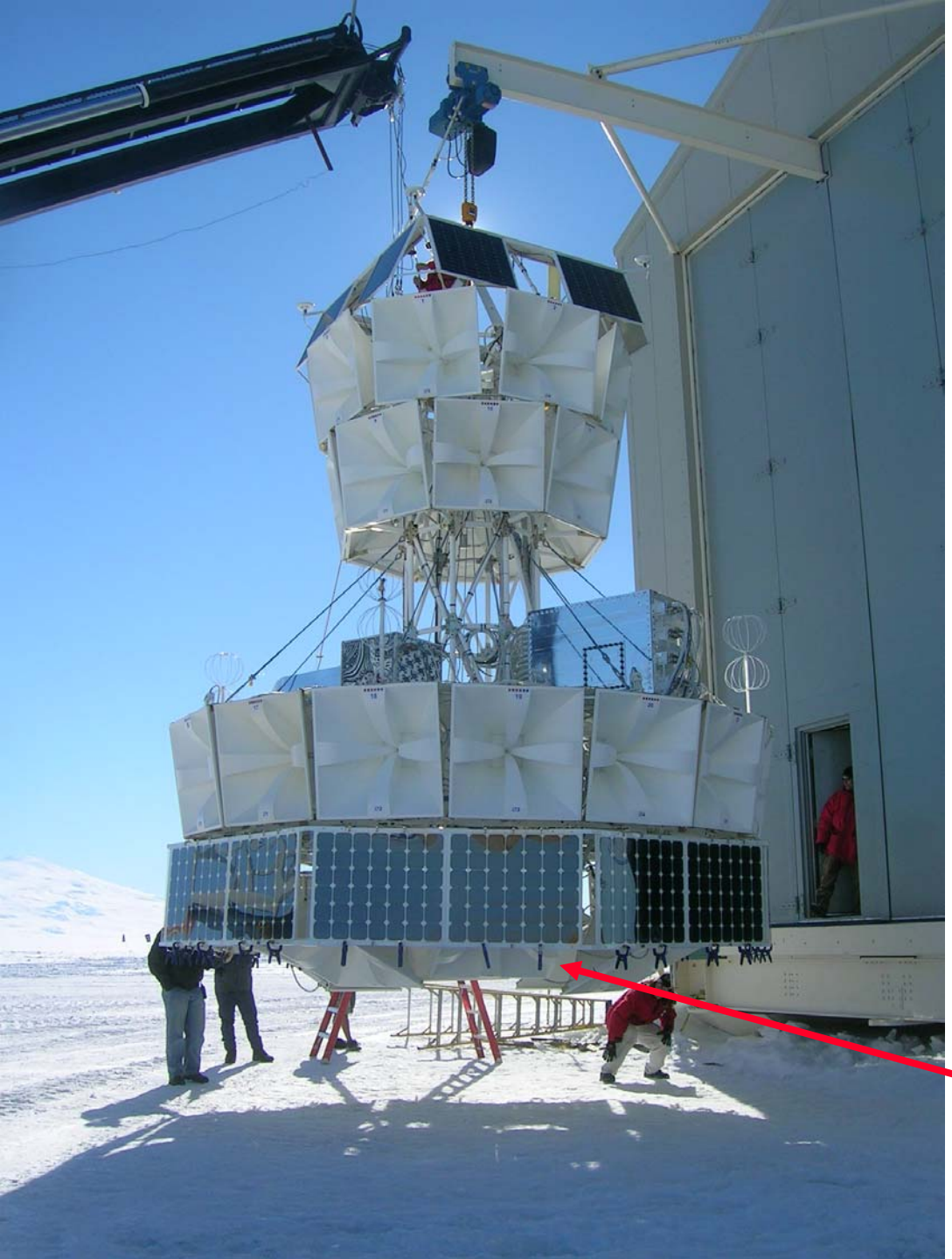
New trigger board



New preamp

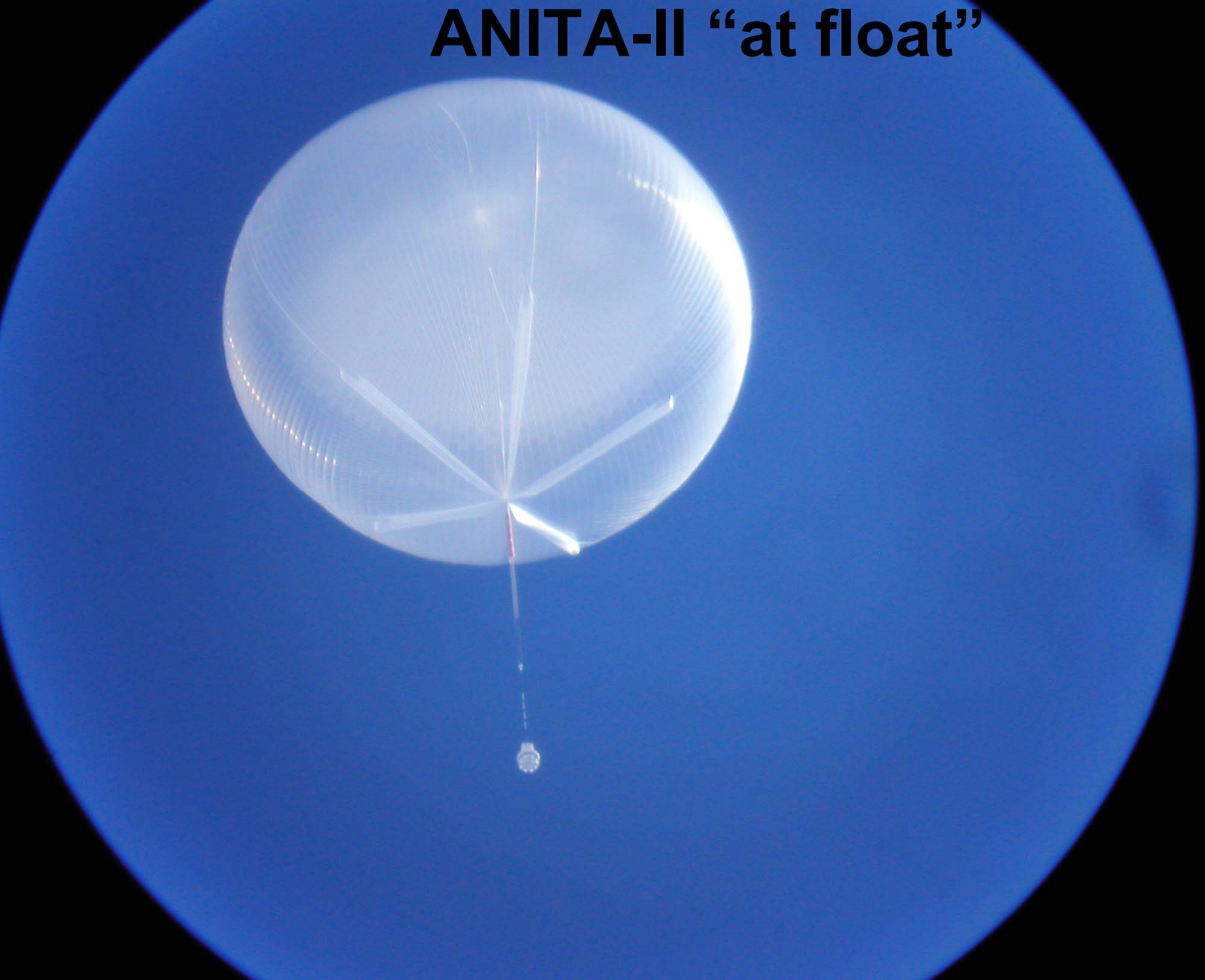
New front end filter

ANITA-2 Ready
Dec. 2008



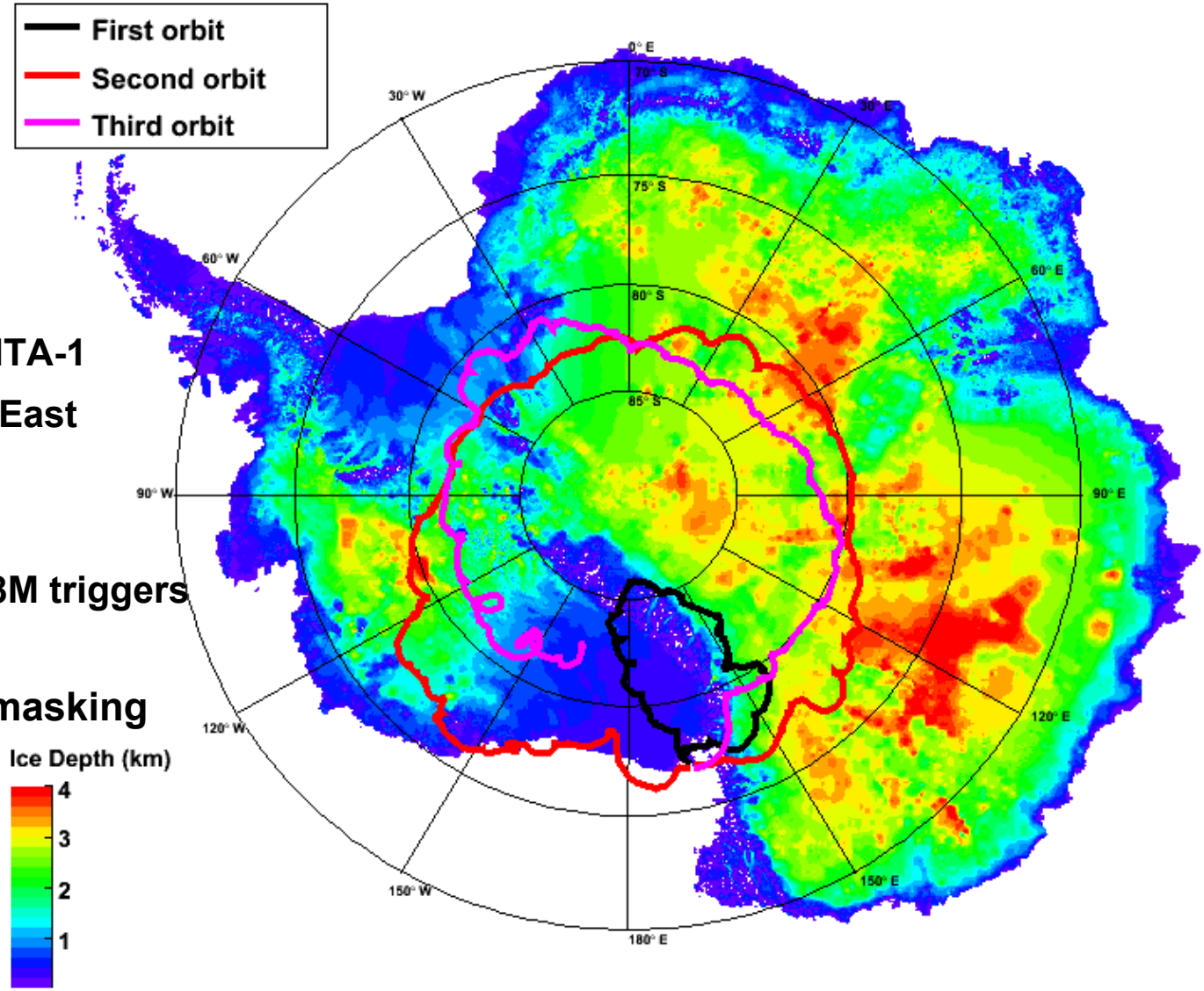
8 “drop down” antennas

ANITA-II “at float”



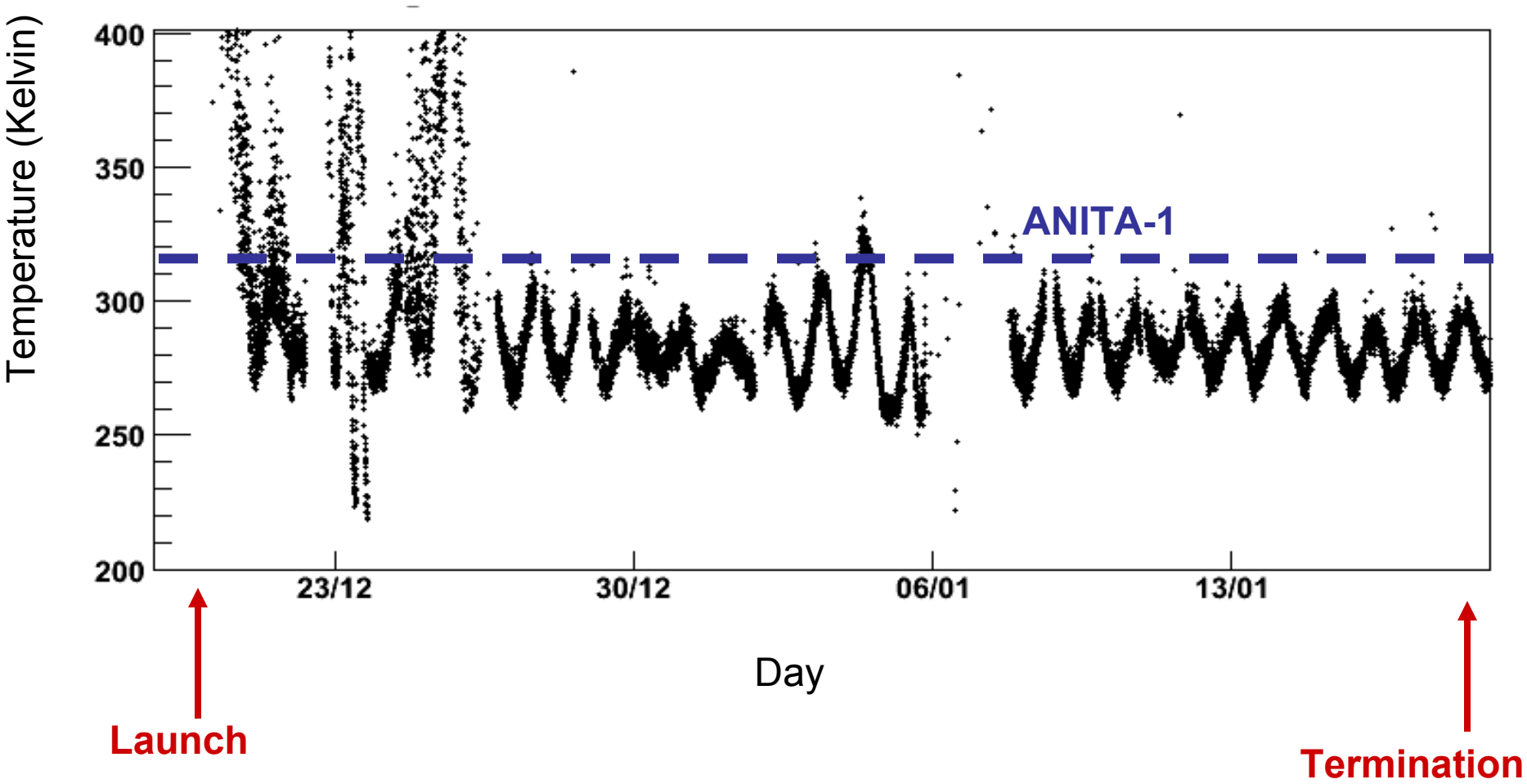
ANITA-2: Beautiful Flight Path

- 2+ Orbits
- Time aloft: 30d
- Compared with ANITA-1
  - More time over East Antarctica
  - Avoided S.P.
  - 27M triggers > 8M triggers
    - (and better!)
- Dynamic azimuth masking worked beautifully

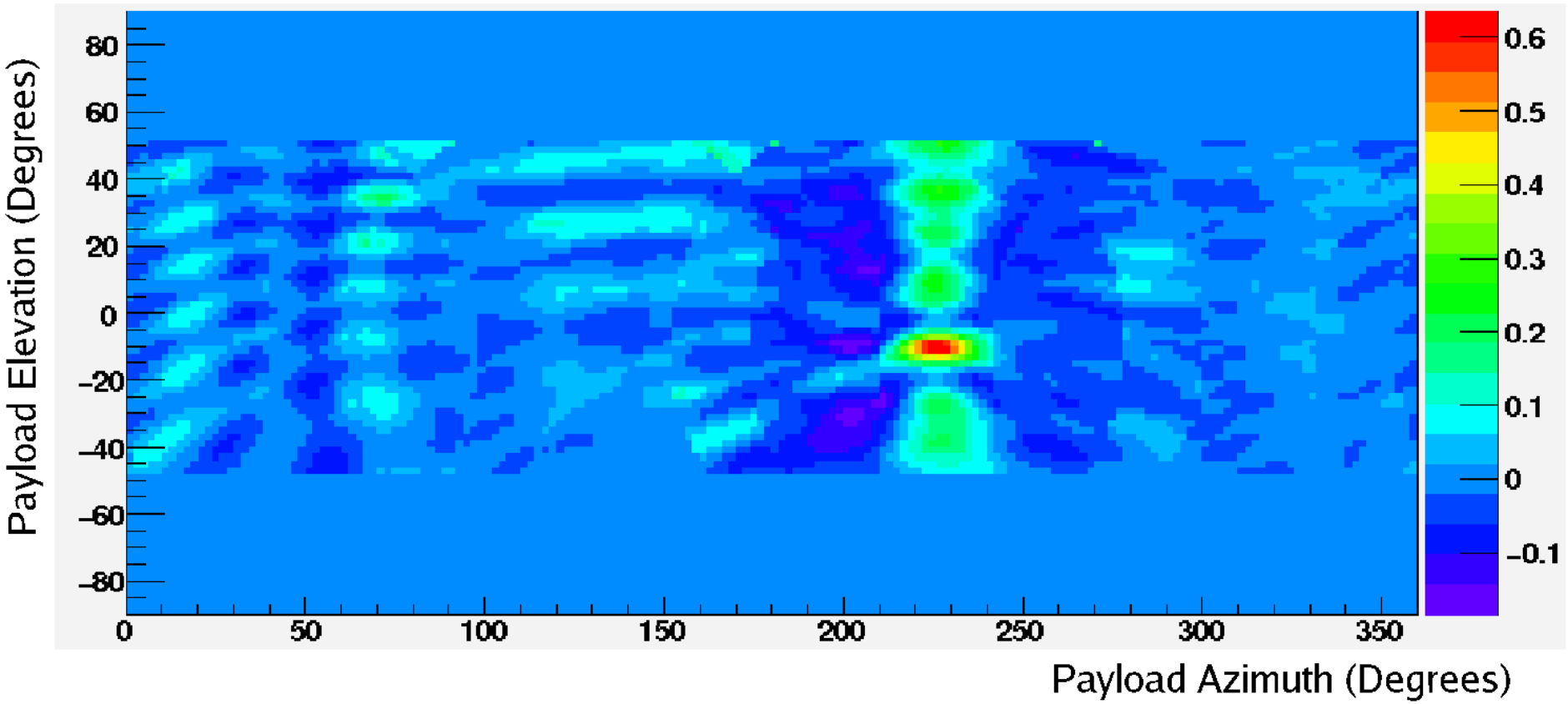


ANITA-2 Data

Antenna Noise Temperature (includes ice temp)



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?