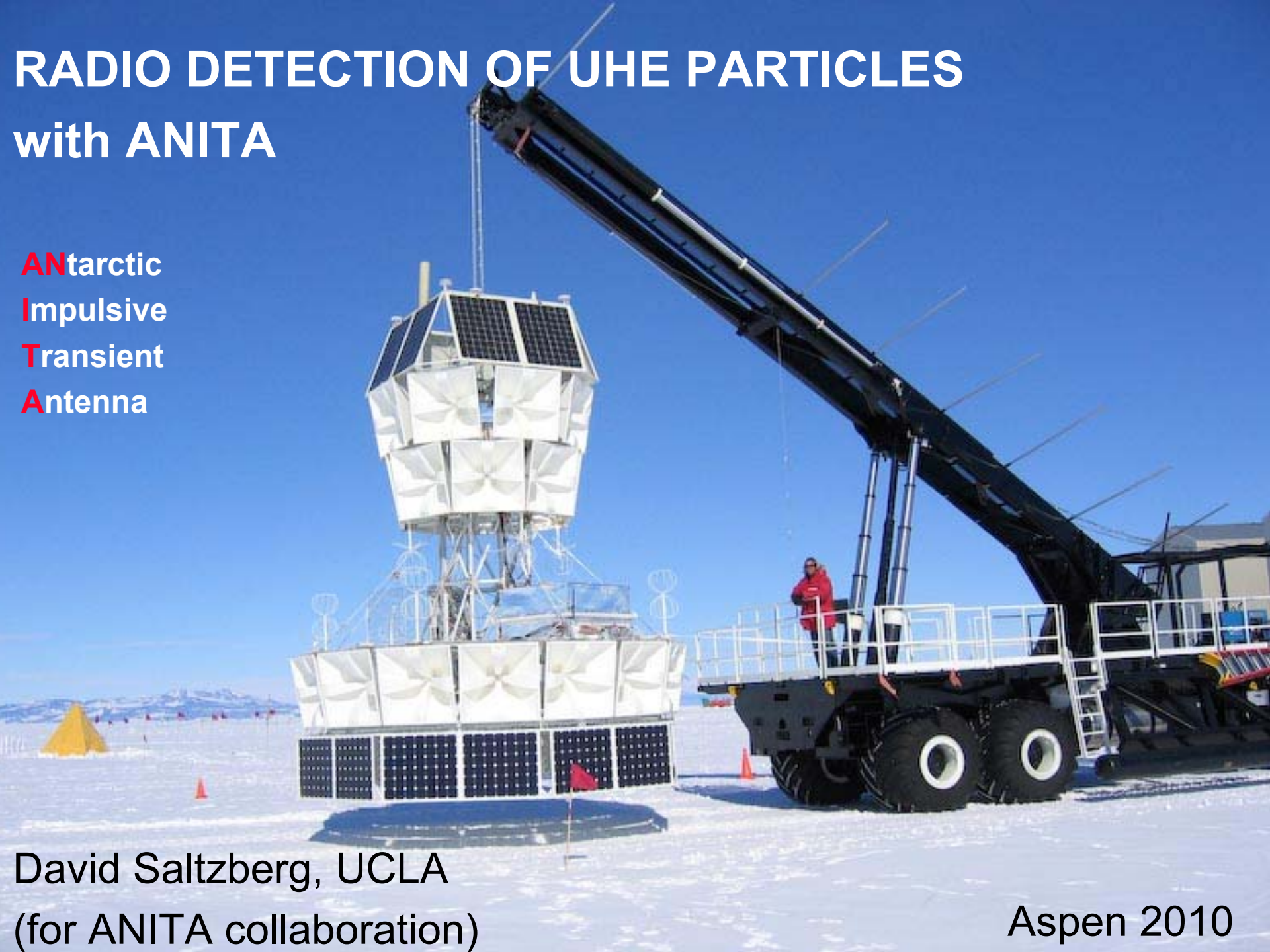


RADIO DETECTION OF UHE PARTICLES with ANITA

ANtarctic
Impulsive
Transient
Antenna



David Saltzberg, UCLA
(for ANITA collaboration)

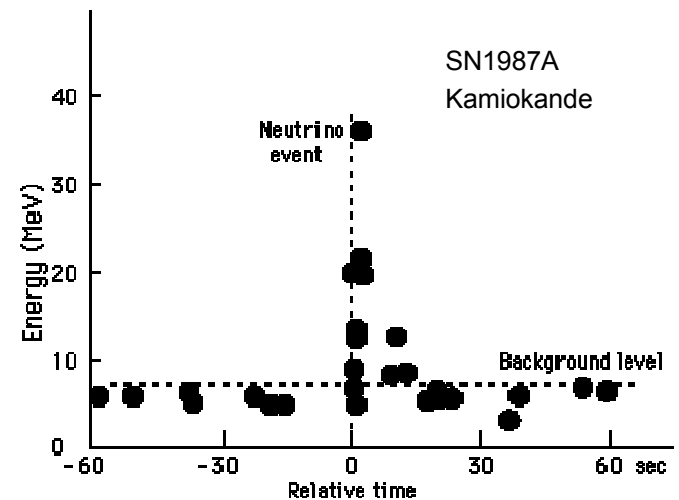
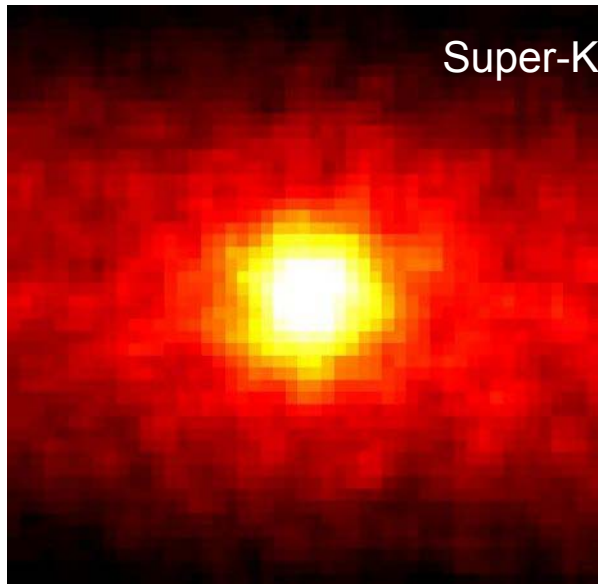
Aspen 2010

Astrophysical Neutrinos

“Batting 1000”

Every source:

1. has had major impact on particle physics
2. Looks deeper into the source than otherwise possible



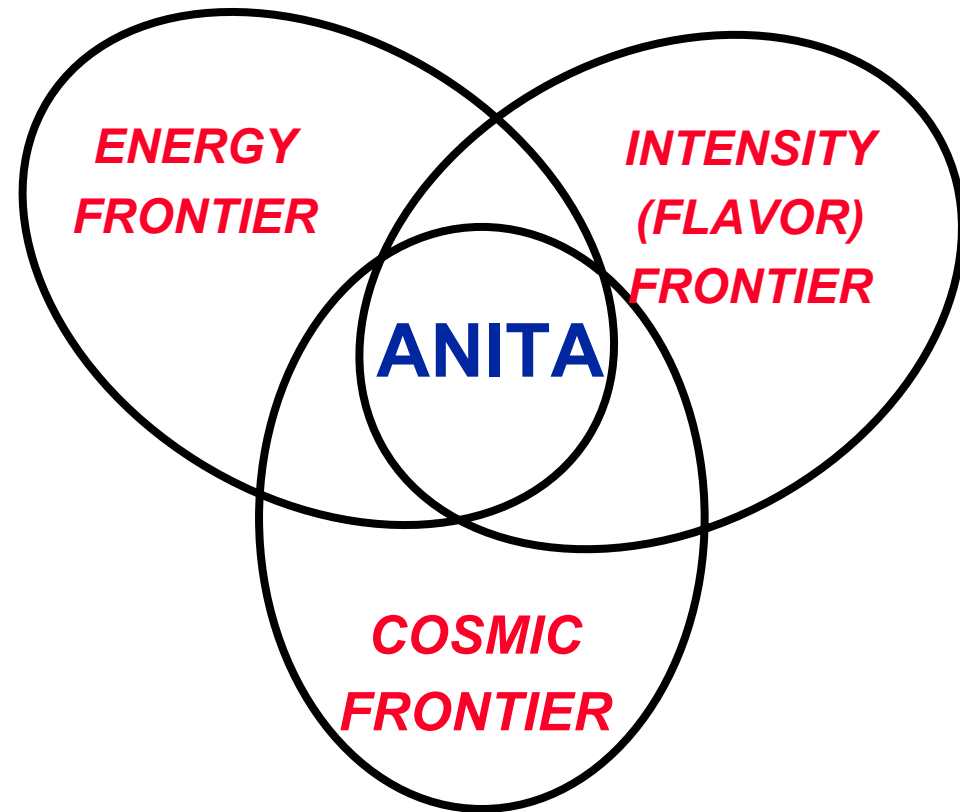
lack of dispersion

- ➔ best mass limits
- ➔ many other constraints

ν weak eigenstates \neq mass eigenstates
& neutrinos have mass



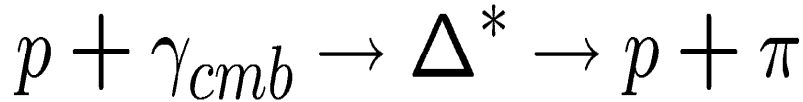
UHE ν for Particle Physicists



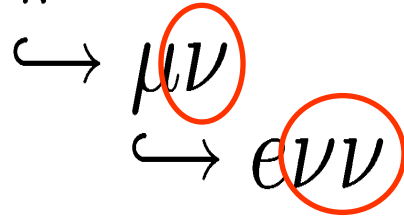
- How can we directly probe the weak scale at $E_{\text{cm}} > 14 \text{ TeV}$?
- How can we probe longer neutrino flavor mixing baselines?
- How can we view the UHE universe beyond 50 MPc?



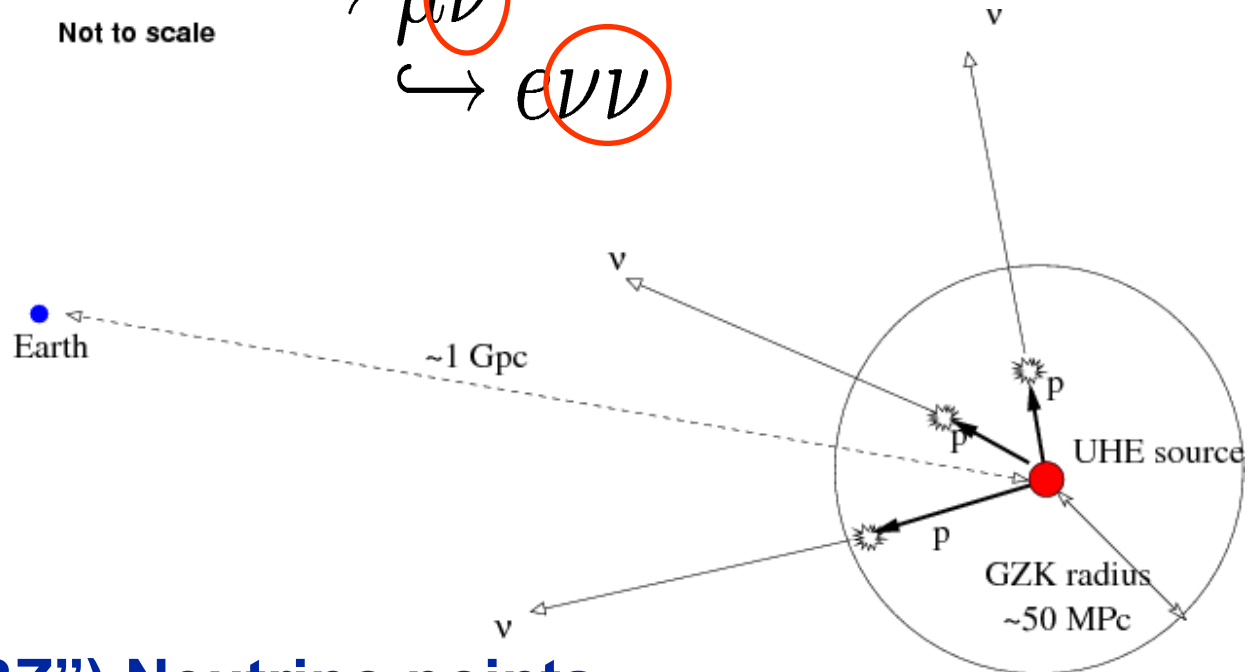
COSMIC FRONTIER



Not to scale



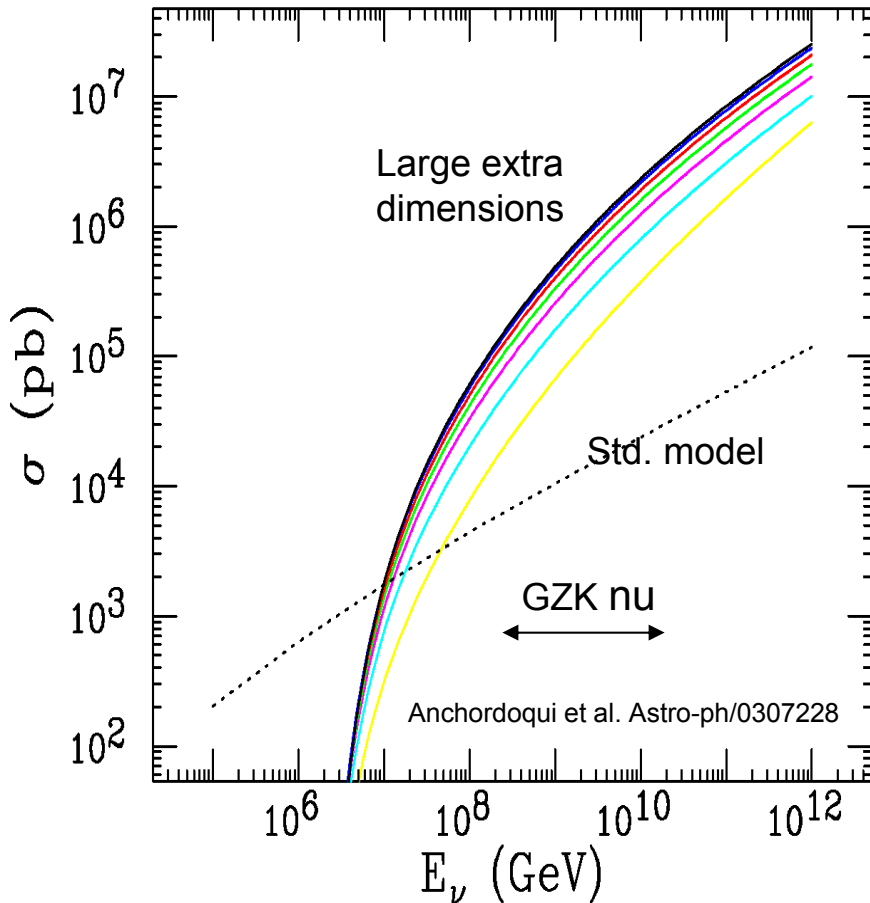
$E_0 \sim 10^{17} - 10^{20} \text{ eV}$



Every “GZK” (“BZ”) Neutrino points back to its source in the visible Universe



Energy Frontier



- The ν cross sections most sensitive to new physics
- Weak interaction at E_{CM} not accessible to LHC: 200 TeV
- $L_{\text{int}} \sim O(250 \text{ km}) \rightarrow$ Use Earth-shielding as cross-section analyzer



INTENSITY (FLAVOR) FRONTIER

Experimental parameter: $(L/E)|_{\text{experiment}} \propto t_{\nu}^{\text{proper}}$

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

Order of magnitude:

type	L/E	$t_{\text{proper}} \sim (L/c)(m_{\nu}/E)$
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



Detecting UHE Neutrinos

By the Numbers:

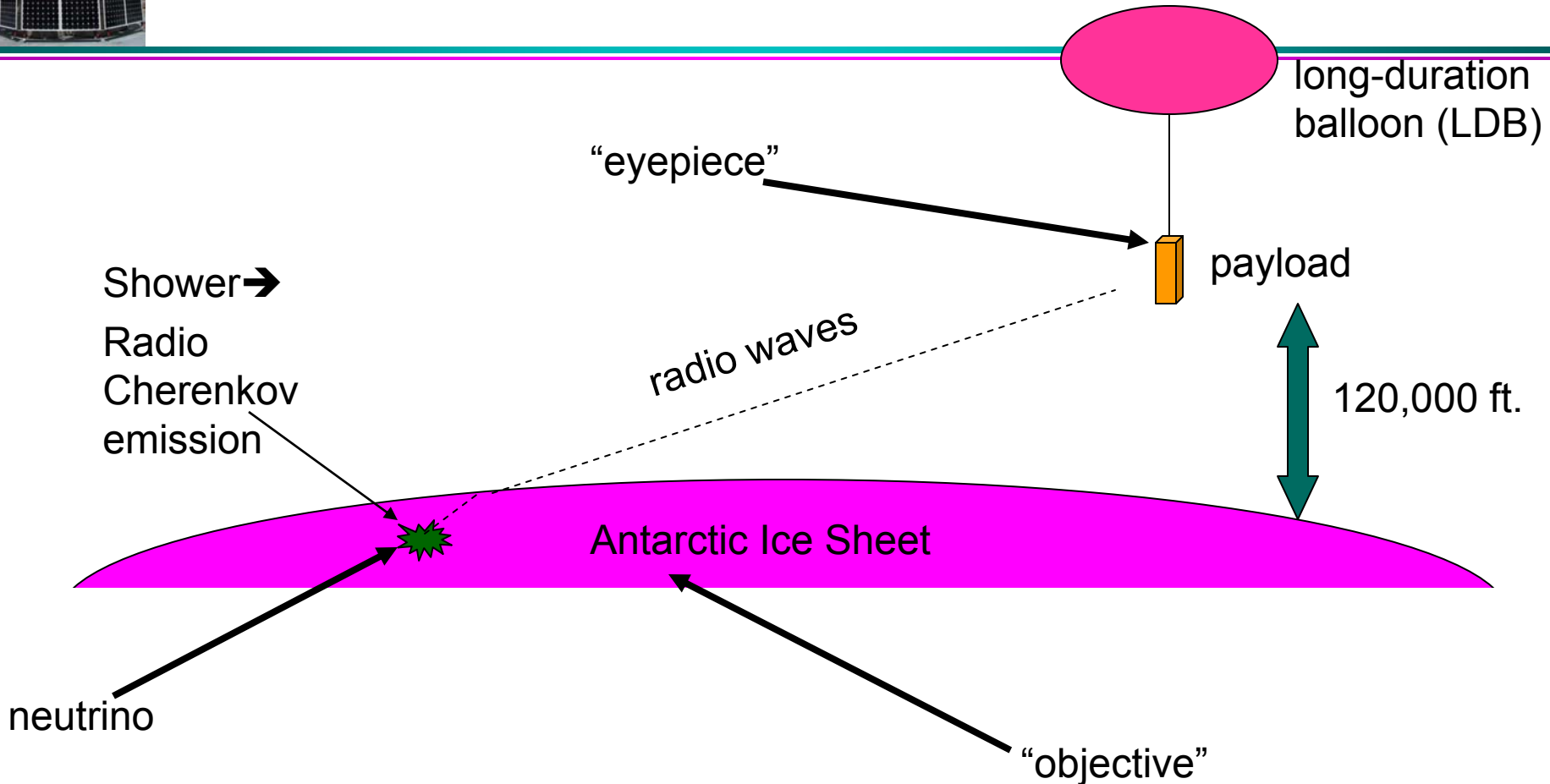
- Flux ~ 1 neutrino / km² / year / str
- $L_{\text{int}, \nu} \sim 500$ km (in ice, $E_{\nu} \approx 10^{19}$ eV)
- Solid angle $\sim 2\pi$ str at best
- ➔ **1 event per 80 km³ per year!**

- × livetime
- × efficiency
- × desire for more than 1 event...

Detector sizes $> 10,000$ km³ needed!

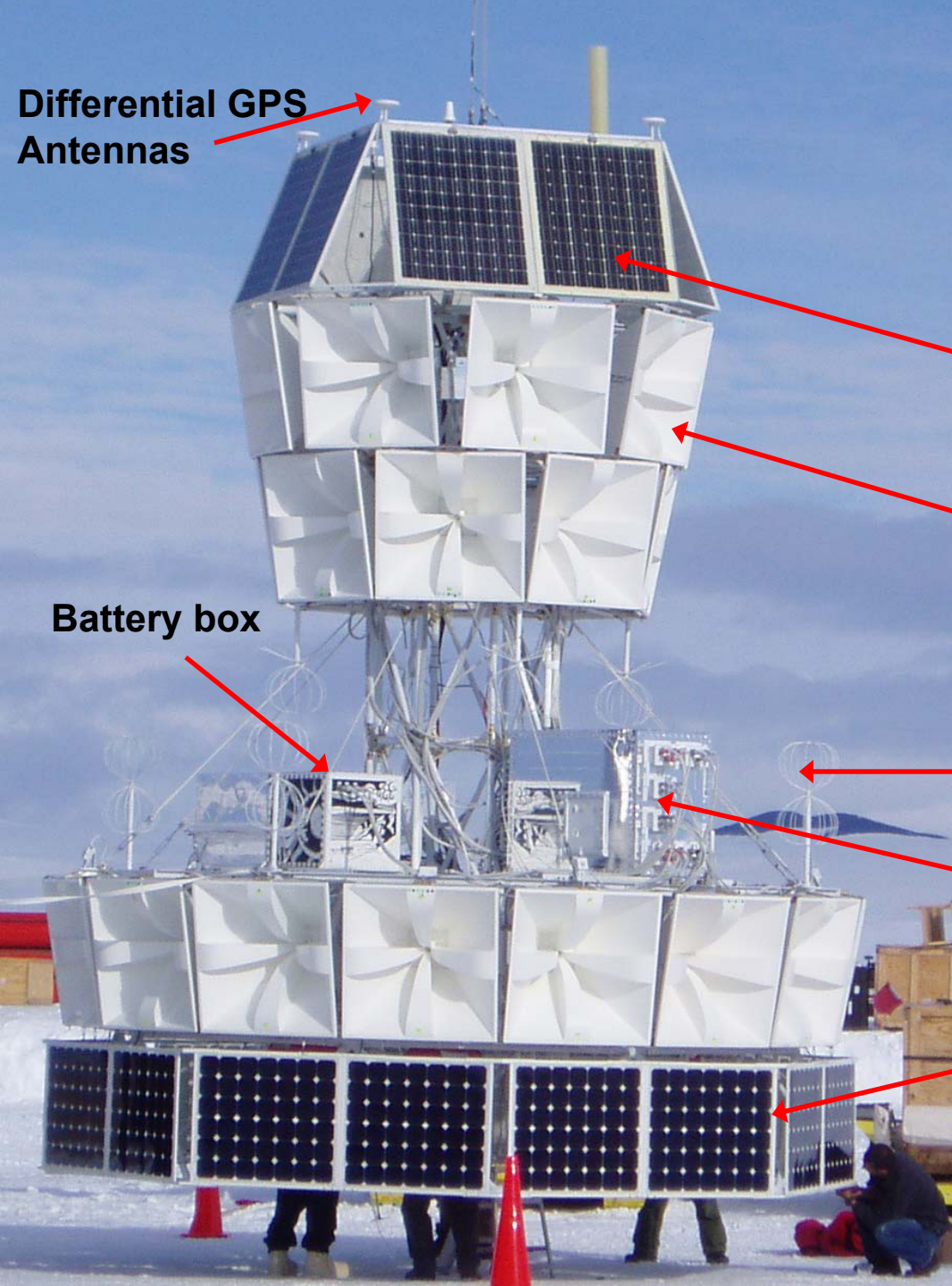


Anita views ~1 Million cubic kilometers of ice



- Top of Cherenkov cone → mostly V-pol E-field

The Face of ANITA-1



Differential GPS
Antennas

Battery box

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 \[astro-ph\]](#)

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



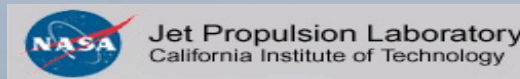
UCIrvine



KU THE UNIVERSITY OF KANSAS



University of Hawai'i
MĀNOA



University of California, Los Angeles

University of Hawaii at Manoa

National Taiwan University

University College London

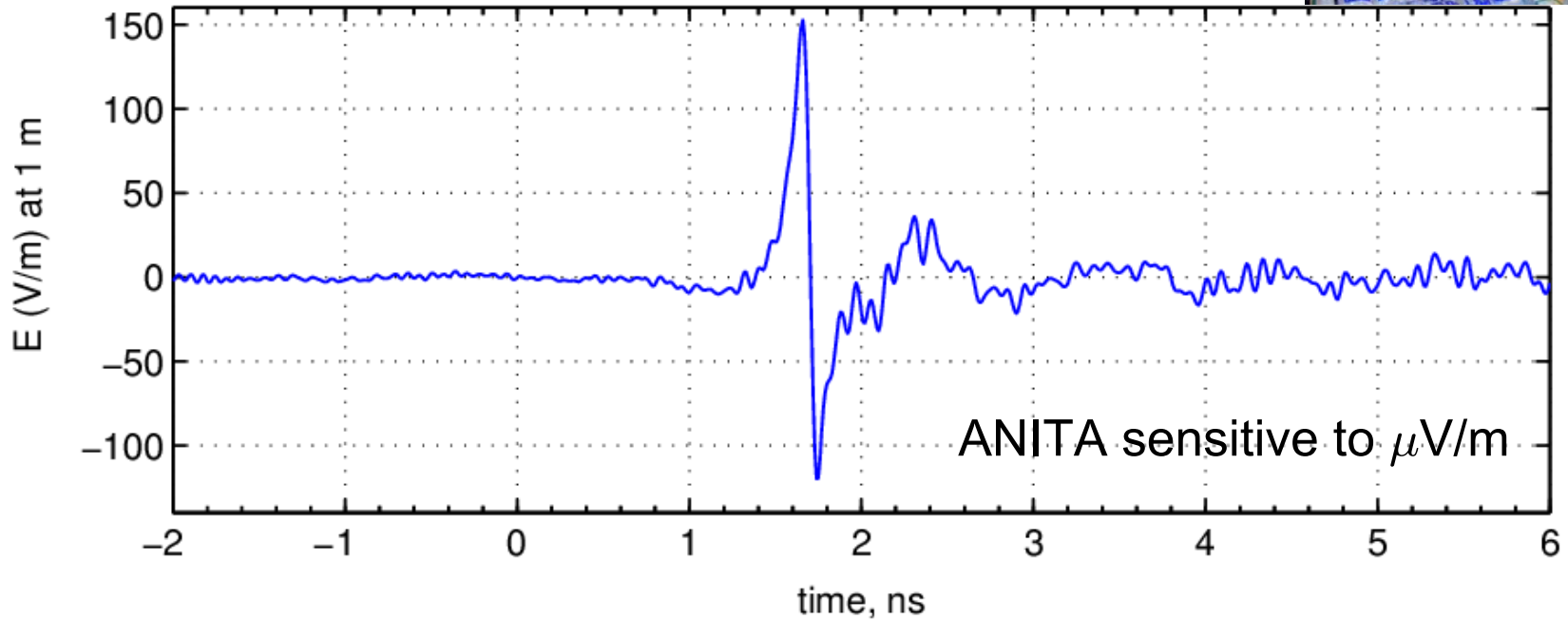
Jet Propulsion Laboratory

Stanford Linear Accelerator Center



UCLA

Proving the Askaryan Effect at SLAC (2000-2006)



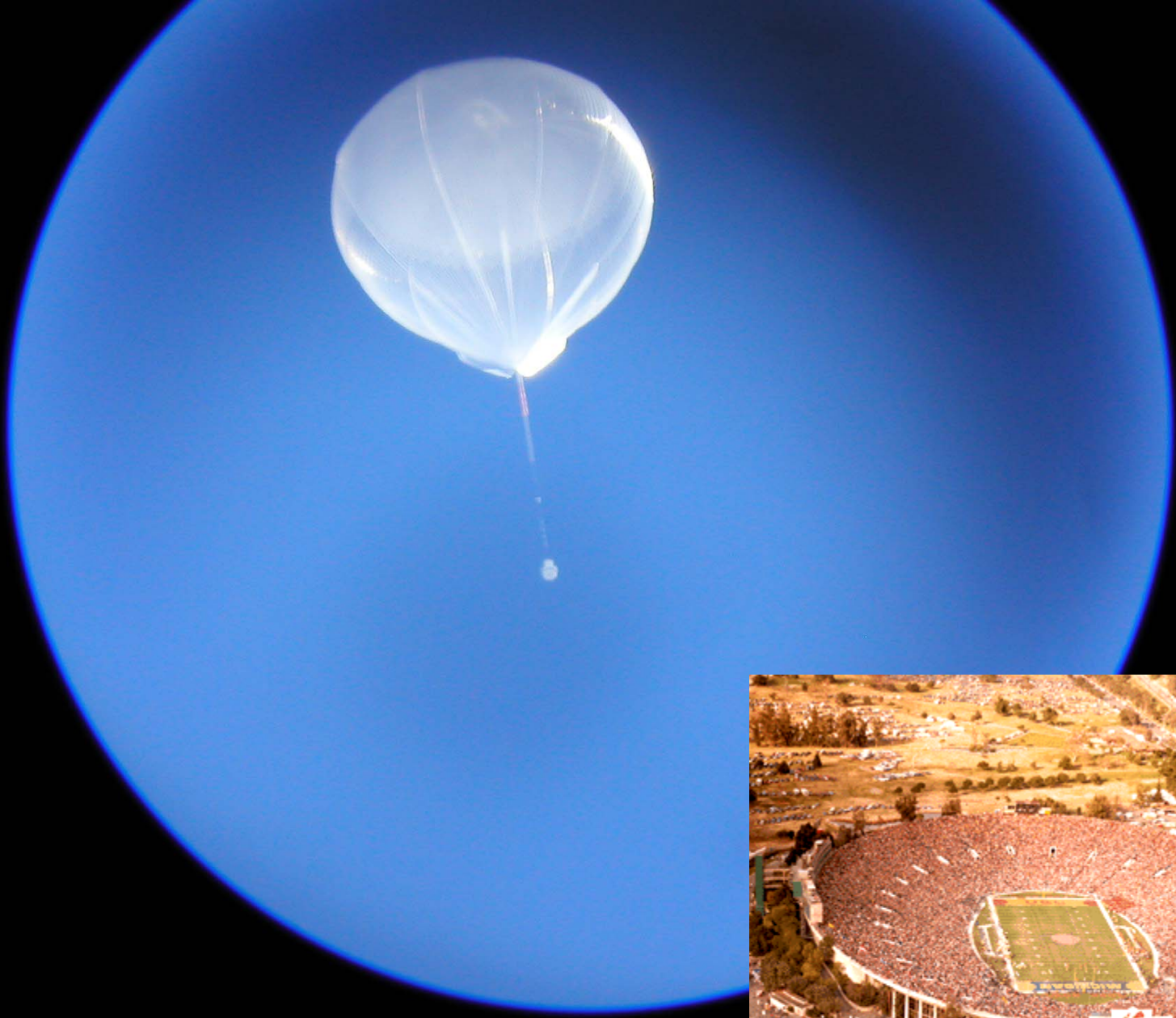
ANITA Assembly



- Major Challenge: Instrument is RF tight to 10^{-12} of power

- i.e., typical electronics noise 100mV/m. We need $<1 \mu\text{V/m}$



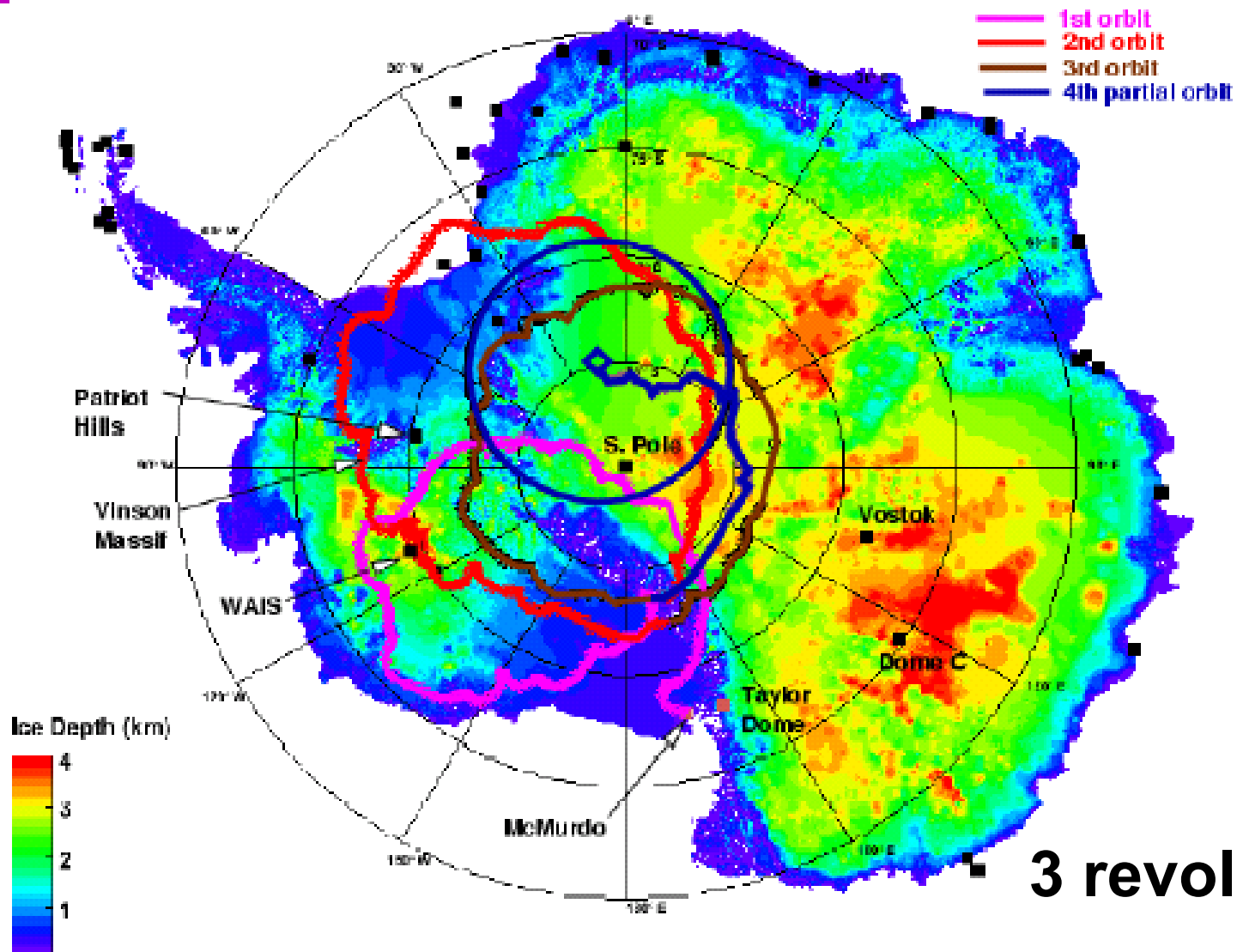


ANITA at 120,000 feet (37km)



ANITA-1 (06-07) 35-day Flight

2nd longest LDB flight at the time

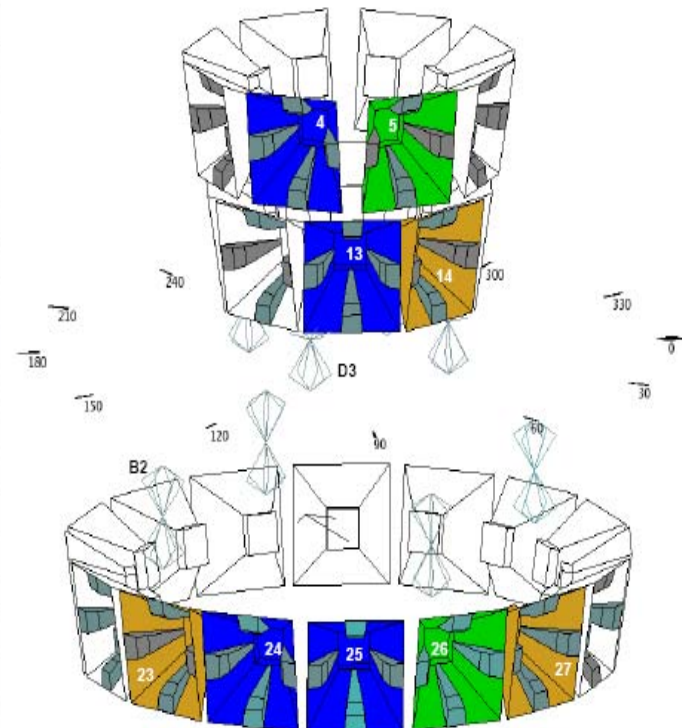
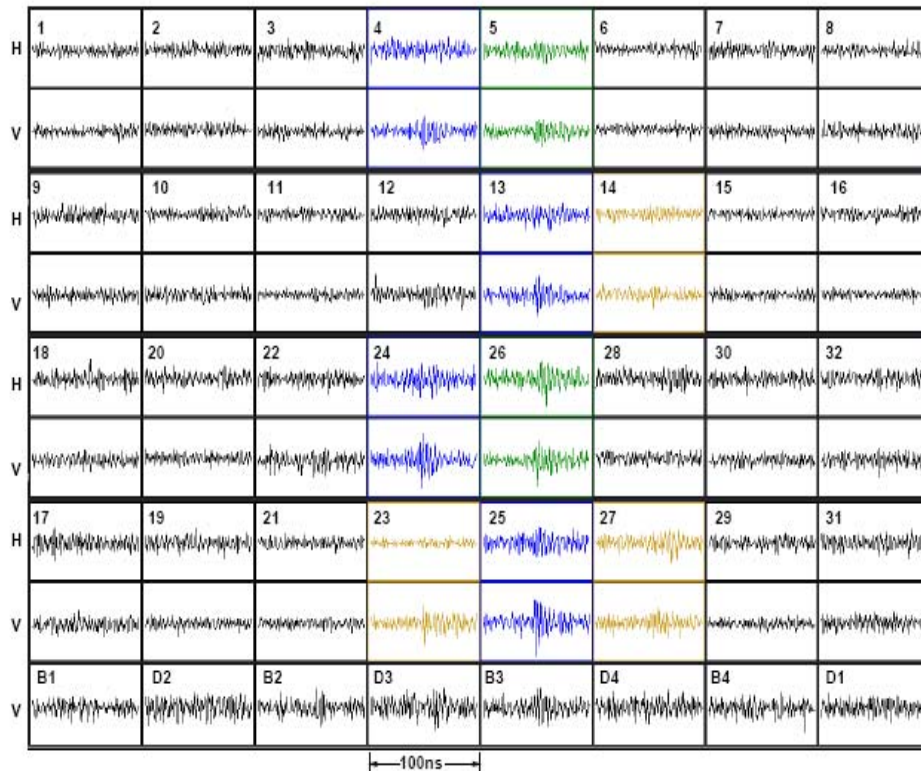


3 revolutions!



Three-Level Trigger

- 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; ~ 40 kHz
 - Blue, L3: coincidence between L2 triggers in same phi sector; ~ 5 Hz



**Just like HEP:
Need Known Calibration Pulses
→ “Deep Field” Camp**



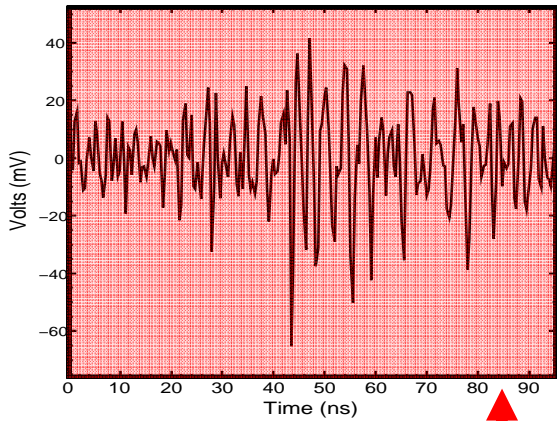
Taylor Dome Camp, 100m borehole pulser



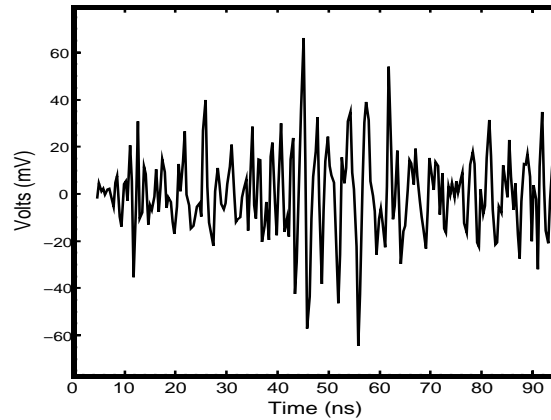


Event Reconstruction: Cross-Correlation

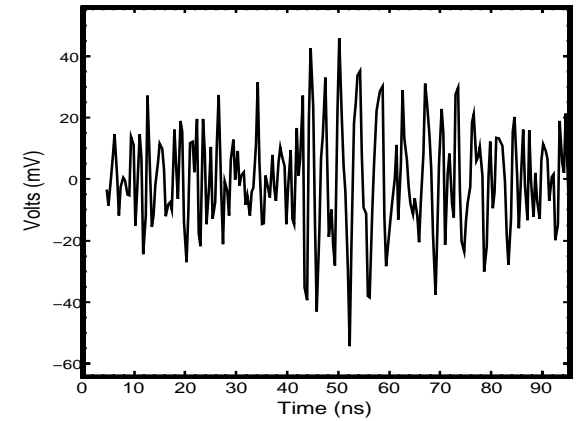
Event# 4338830 : Antenna 10H



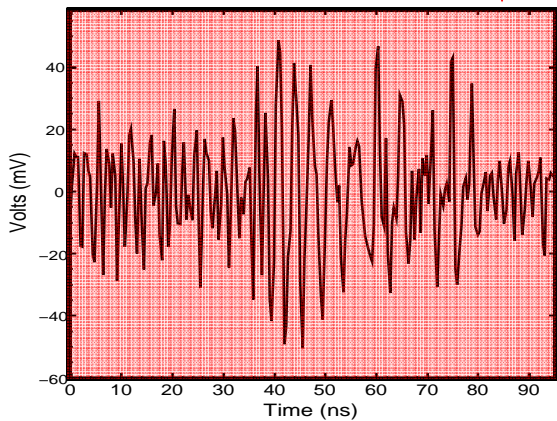
Event# 4338830 : Antenna 2H



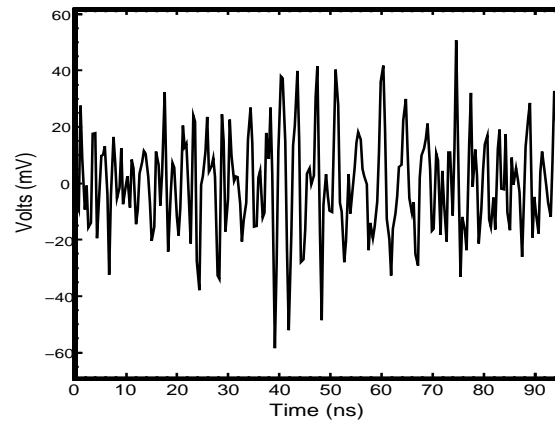
Event# 4338830 : Antenna 11H



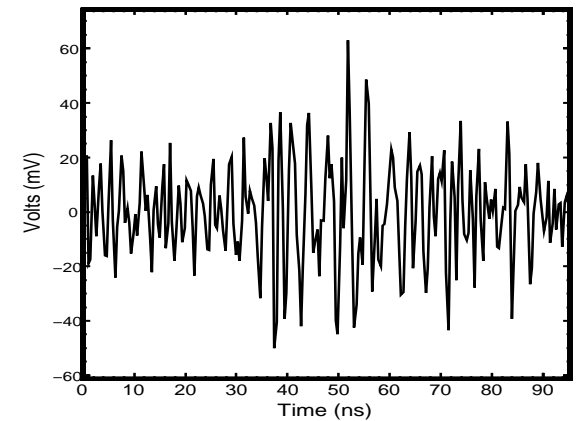
Event# 4338830 : Antenna 19H

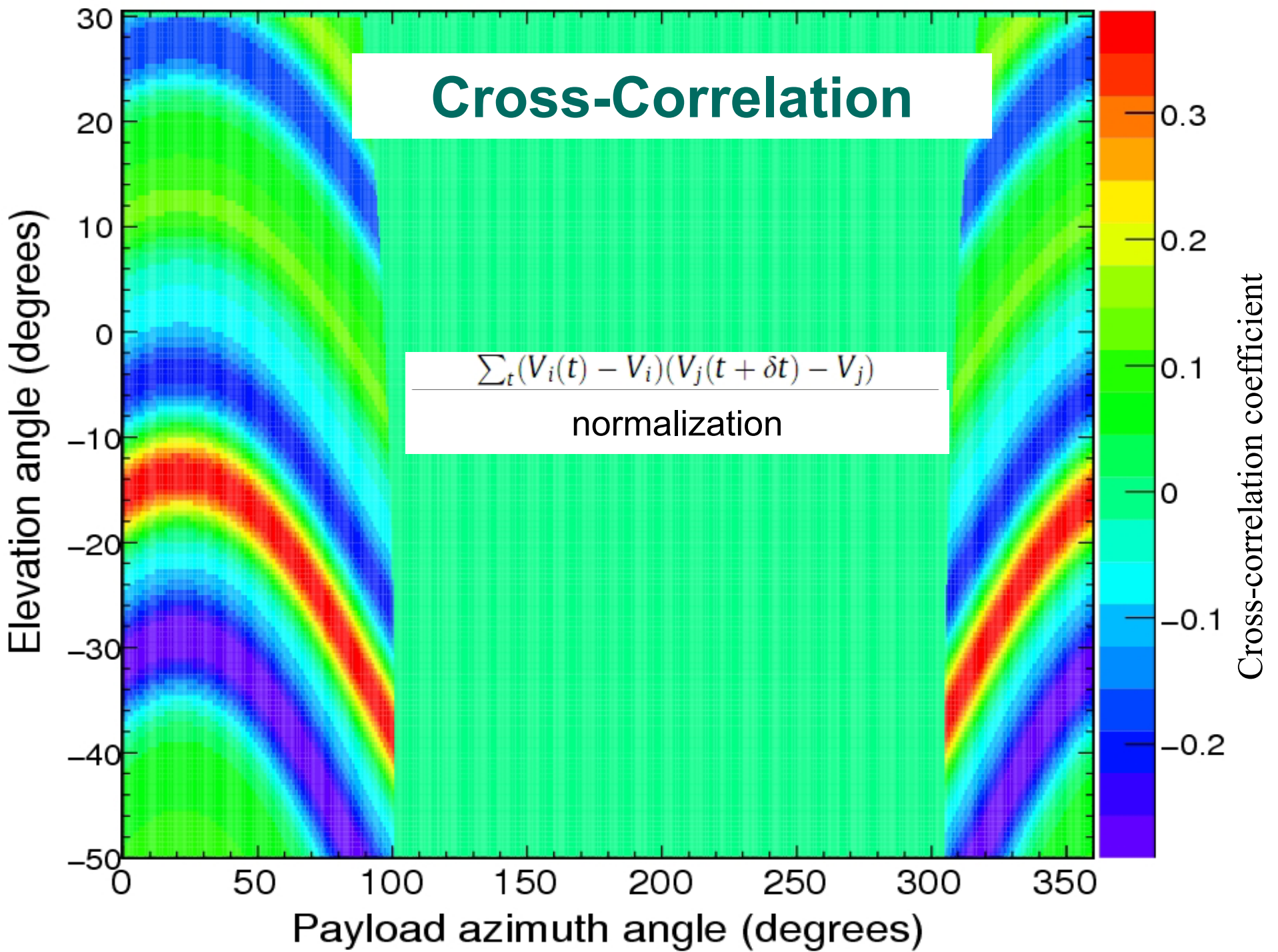


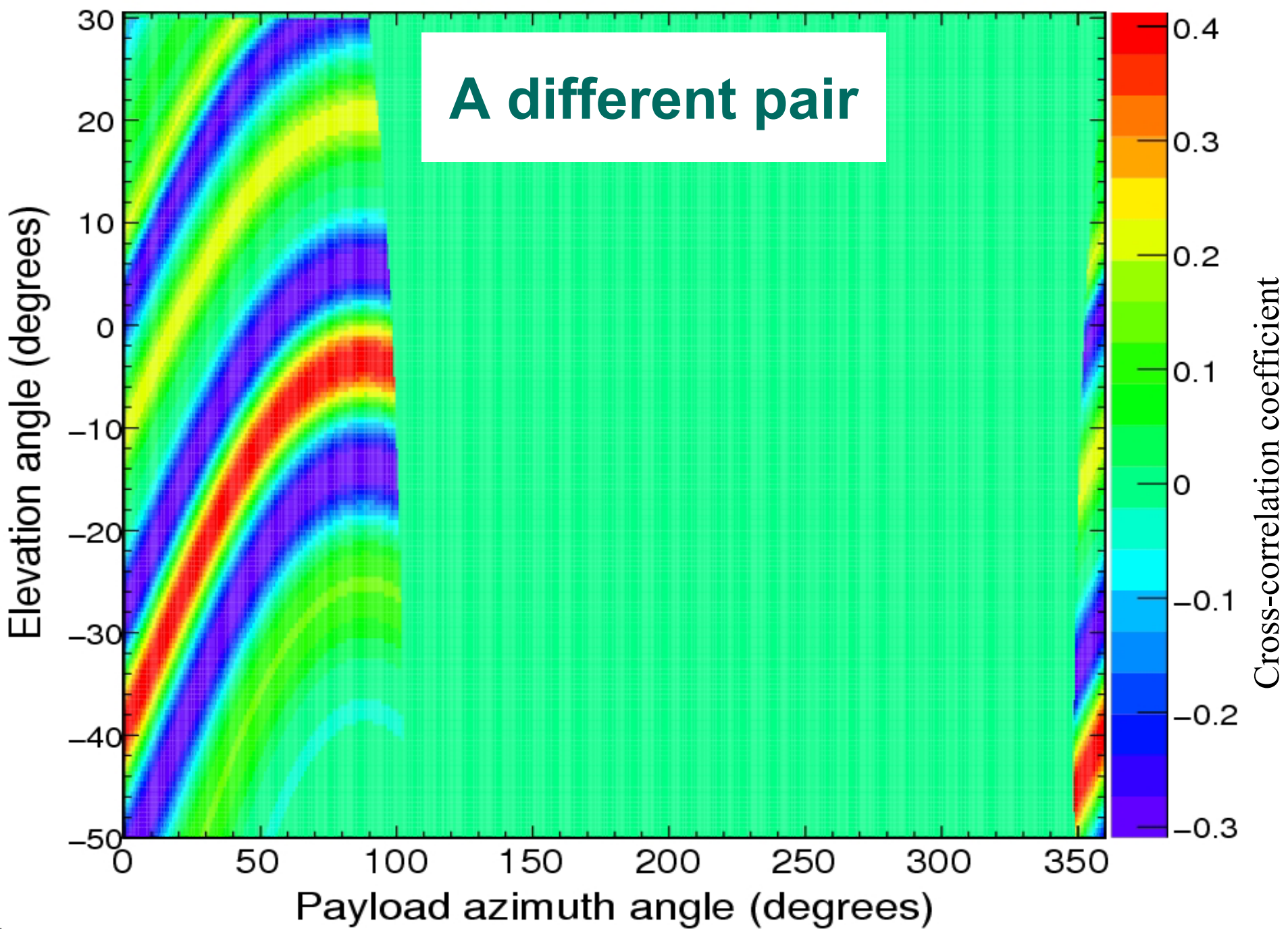
Event# 4338830 : Antenna 20H

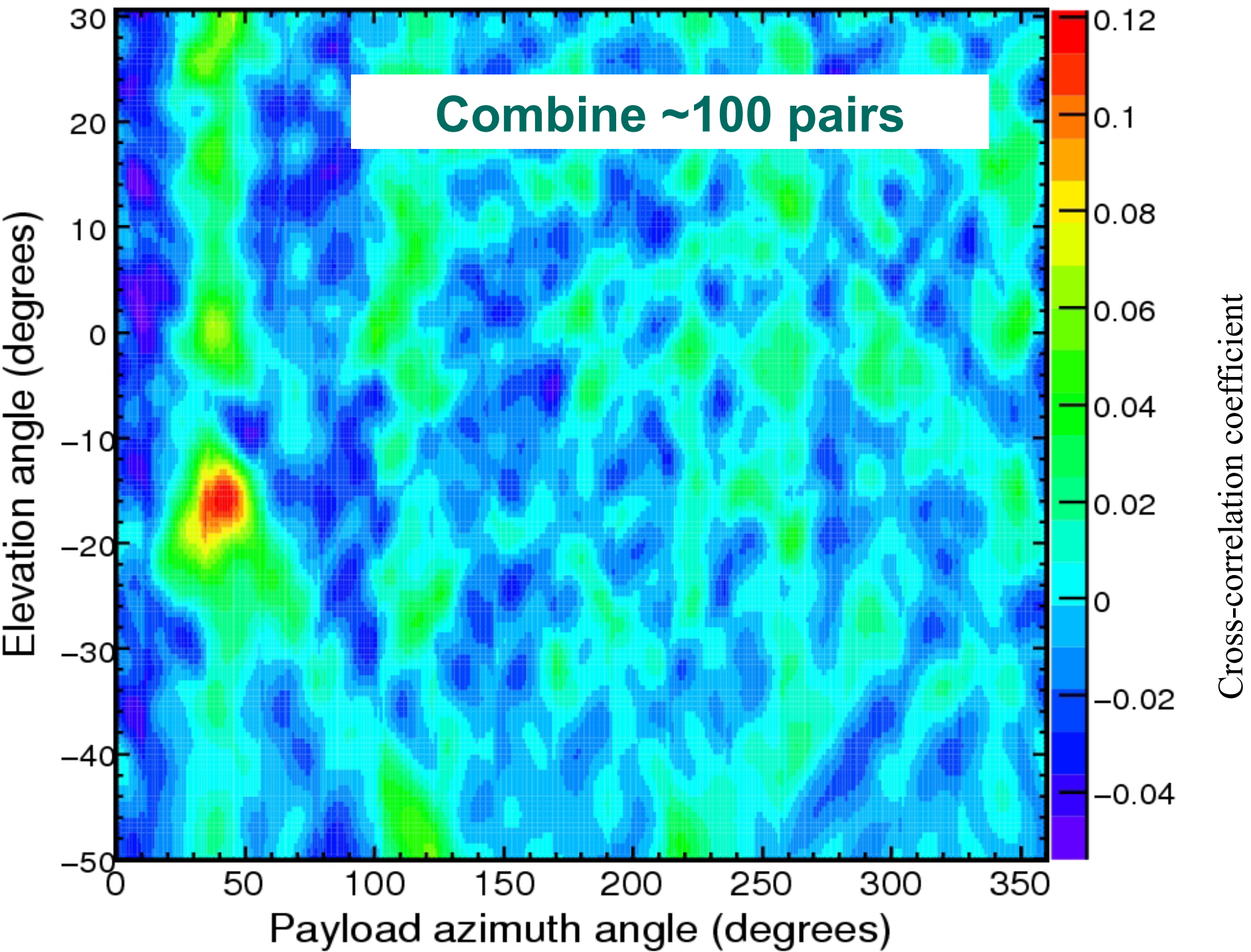


Event# 4338830 : Antenna 21H





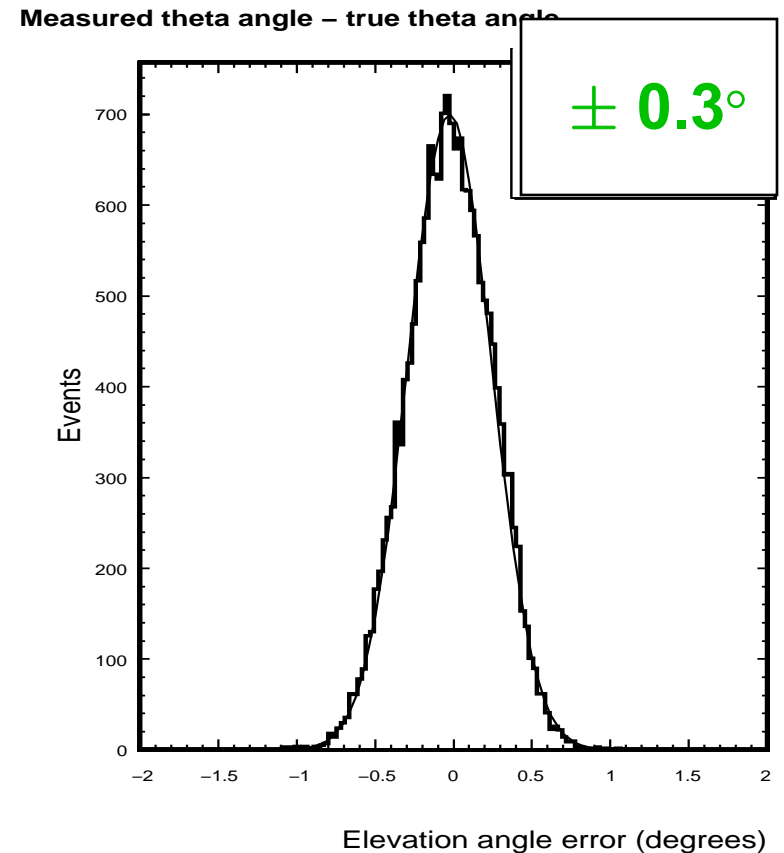
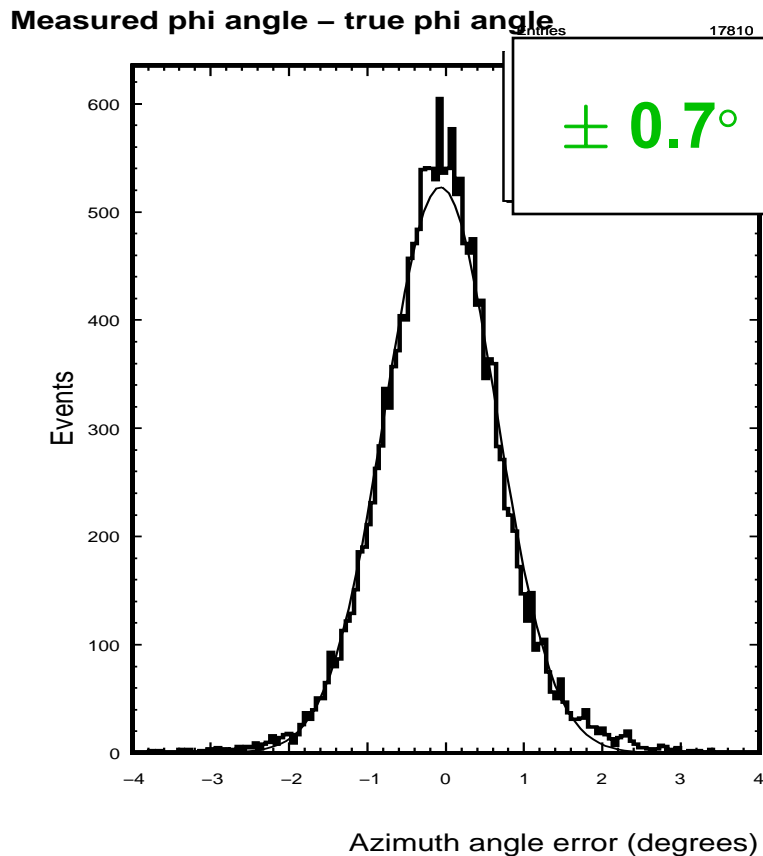






Pointing Calibration

Known location of pulsar proves pointing to 0.3 x 0.7 degree

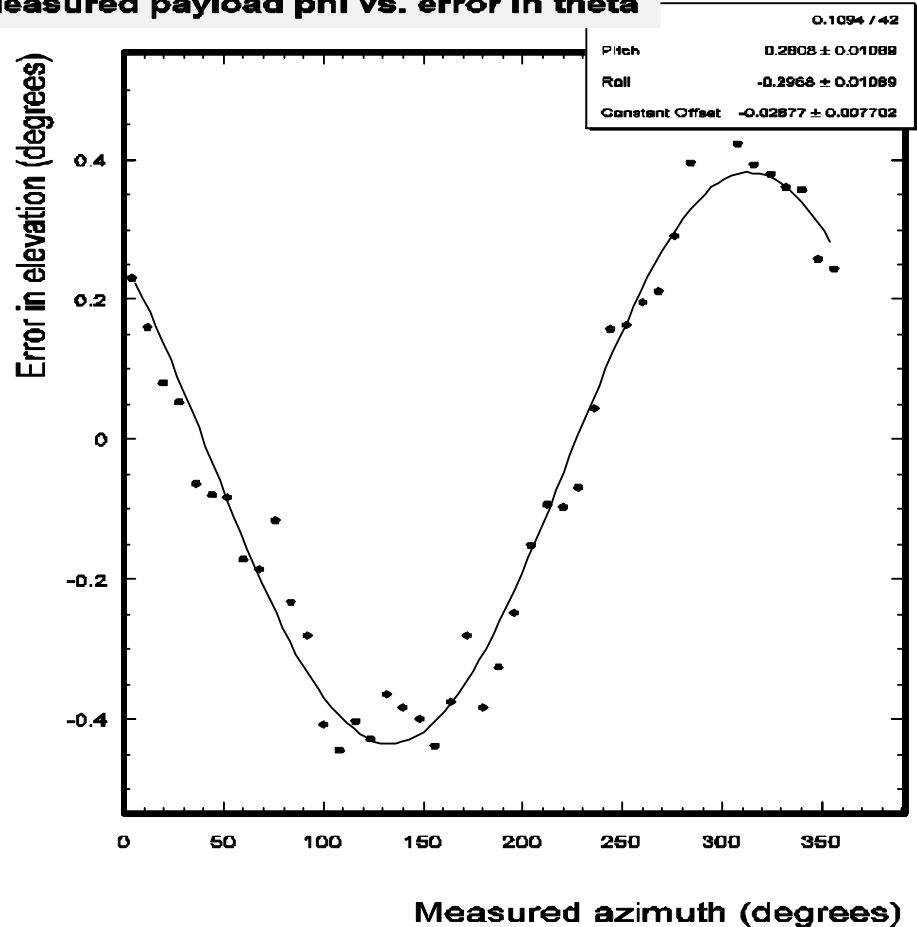




Calibration & Alignment

- Can find 2nd order effects such as payload tilt.
- Even ~1cm asymmetry in antenna phase location can be found and fixed.

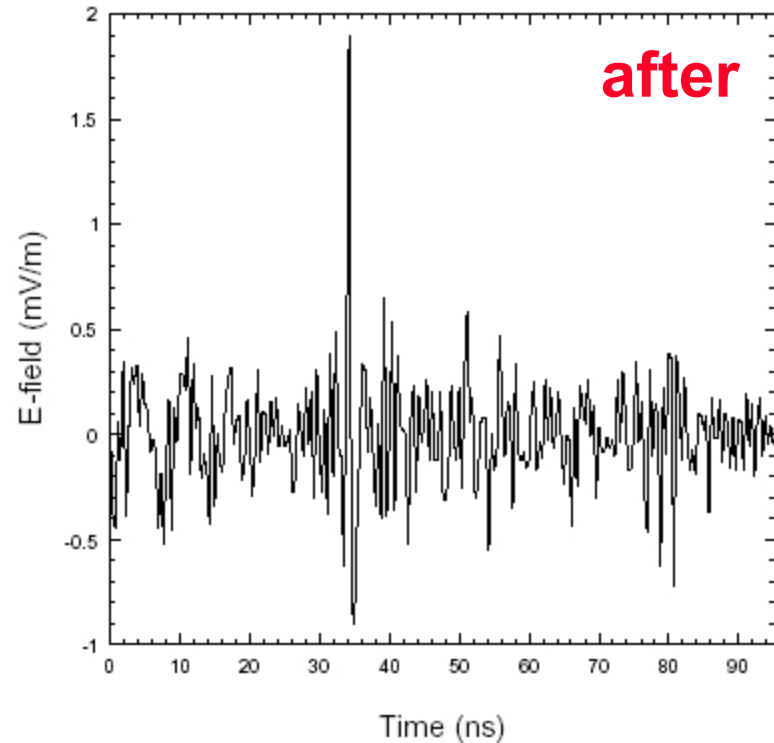
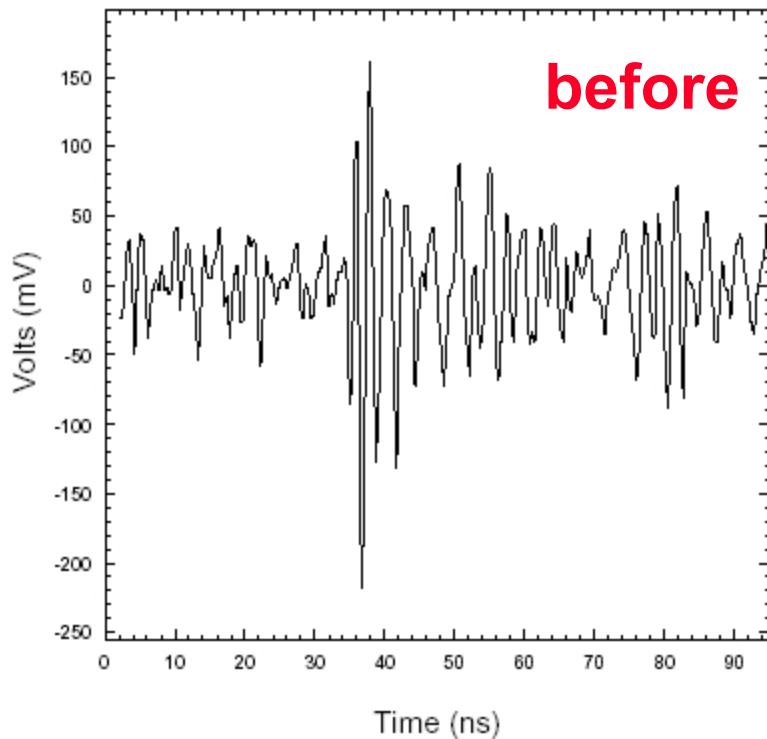
Measured payload phi vs. error in theta



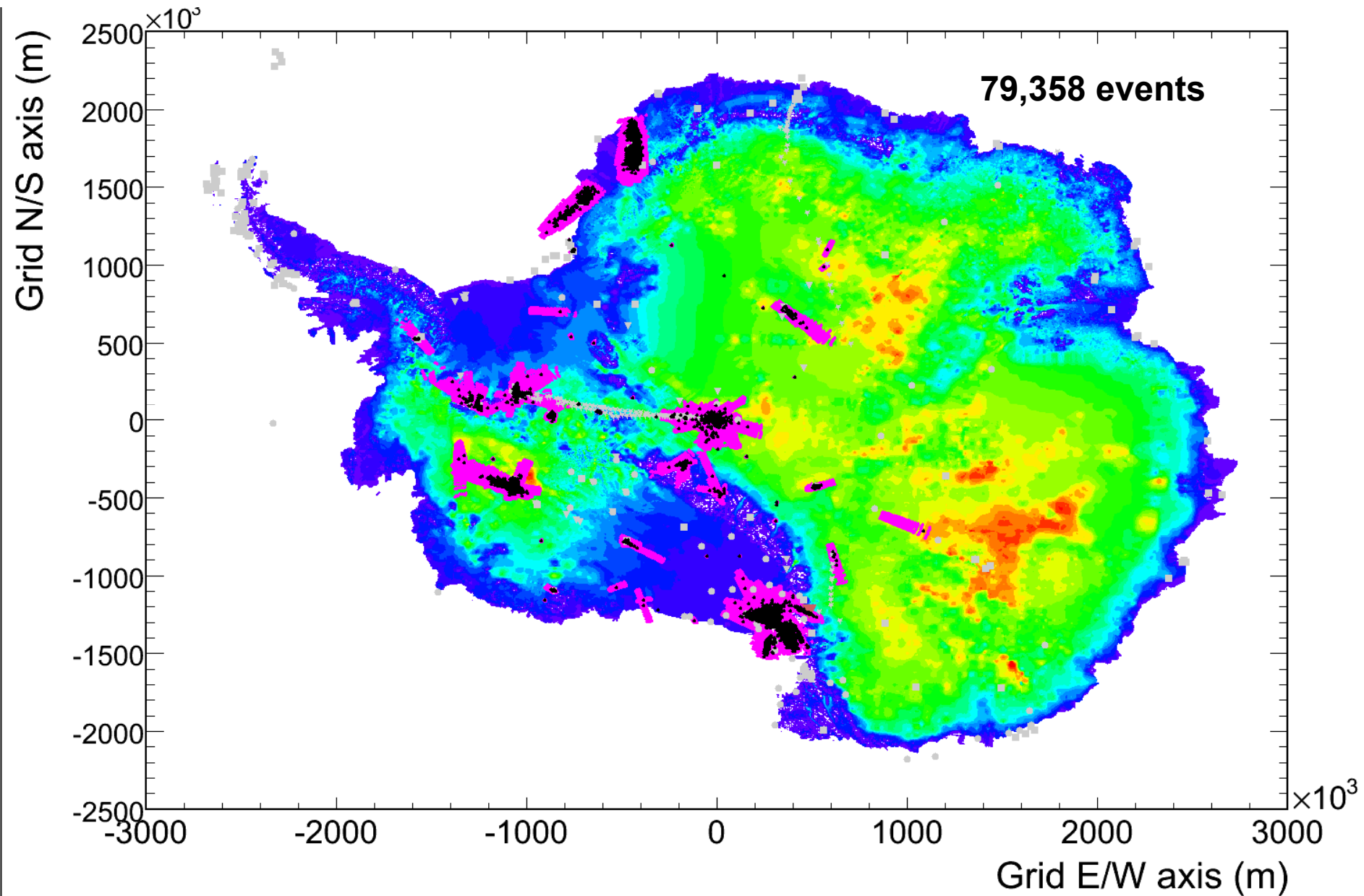


De-convolution of Instrument Response

Unlike most HEP detectors, since we record phase, we can use the calibration data to remove instrument response



ANITA-1 : Reconstructed Events in Second-Pass “Deep” Analysis





Second Pass “Deep” analysis

(First pass published: PRL 103:051103,2009)

Vertical/Mixed Polarization (neutrino search)

Expected Background

1

Observed Events

1

Horizontal/Mixed Polarization (cosmic rays?)

Expected Background

2

Observed Events

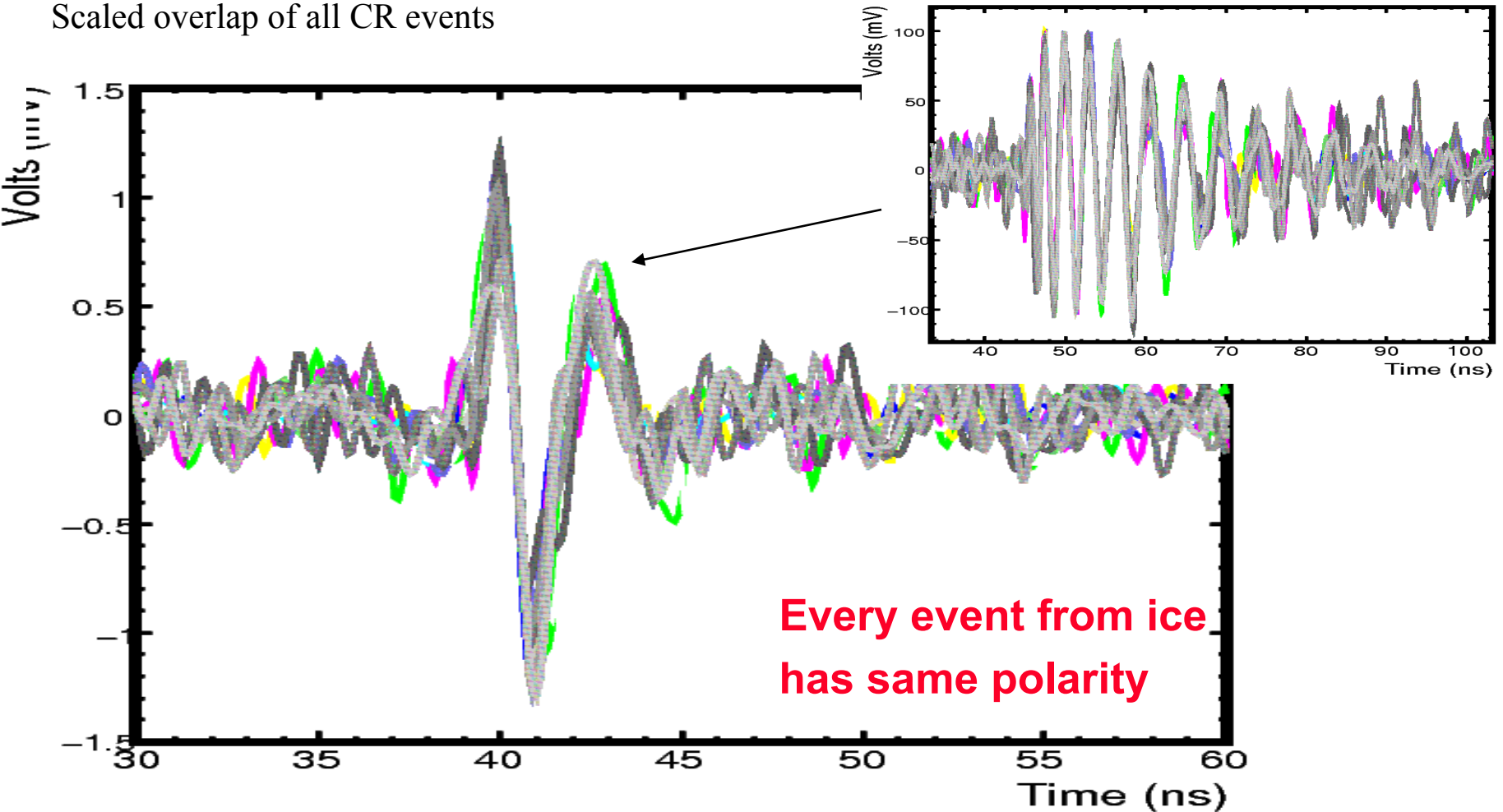
16

- N.B. backgrounds can actually decrease with exposure



Horizontal Polarization (H-pol) Events

Scaled overlap of all CR events





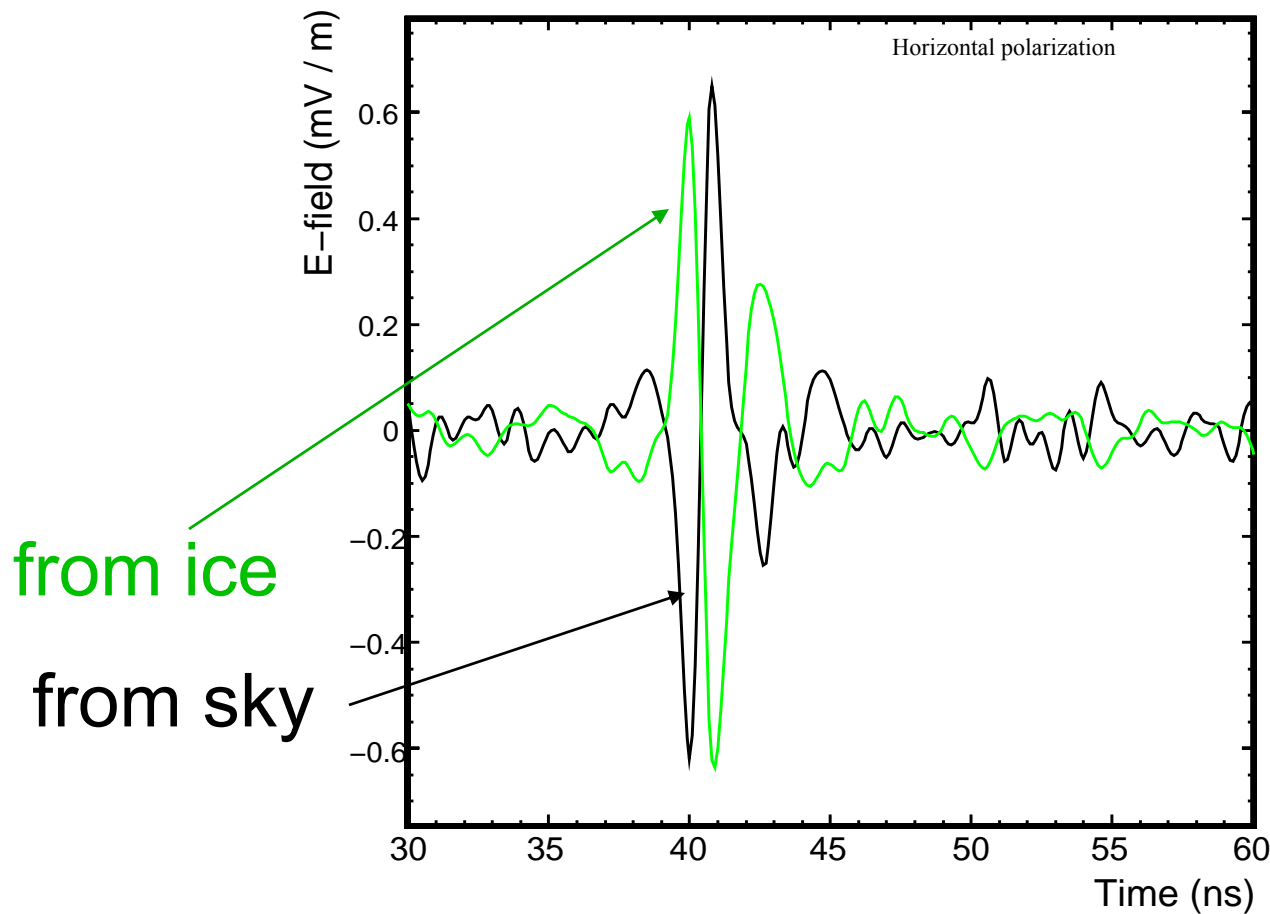
Polarity of Geosynchrotron Emission

- Vicinity of South magnetic pole, so vertical component dominates and points everywhere up
- $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$
 - e^- *always* seen moving right, e^+ *always* moving left!
 - Creates H-pol emission
 - always same polarity pulse!



+2 Above-Horizon H-pol Events

Inverted relative to others!!



reflection
→ × -1



Proof they are Geomagnetic?

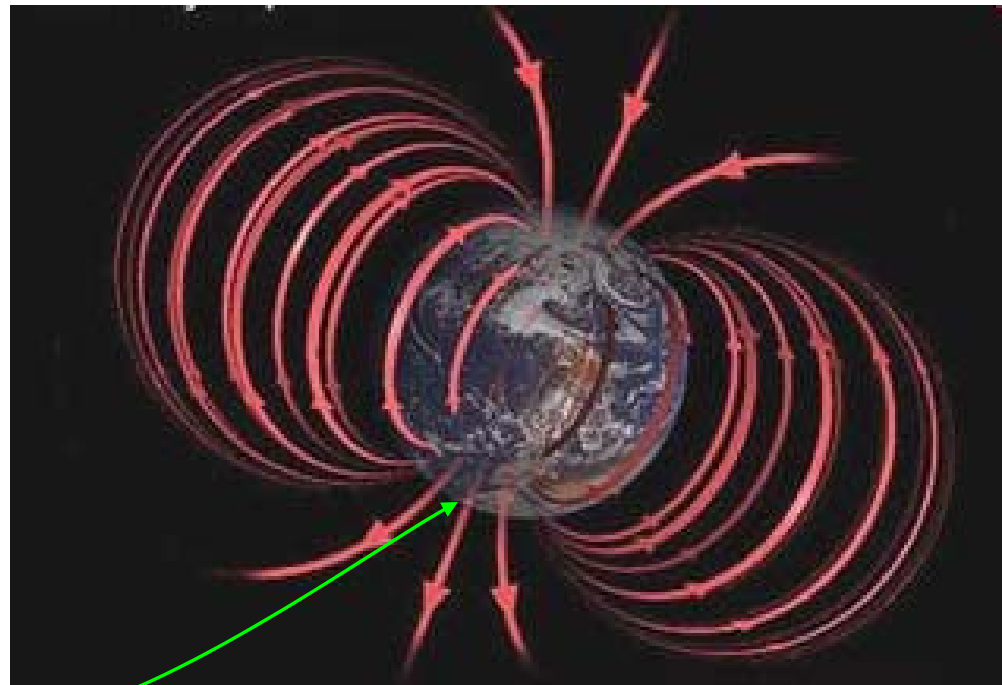
There is information in the vertical polarization recorded in the “H-pol events”



Why always the same polarity?

- Vicinity of magnetic pole, so vertical component dominates and points everywhere up
- $B_{\text{vertical}} : 30 - 60 \mu\text{T}$
- $B_{\text{horizontal}} : \pm (0 - 20 \mu\text{T})$

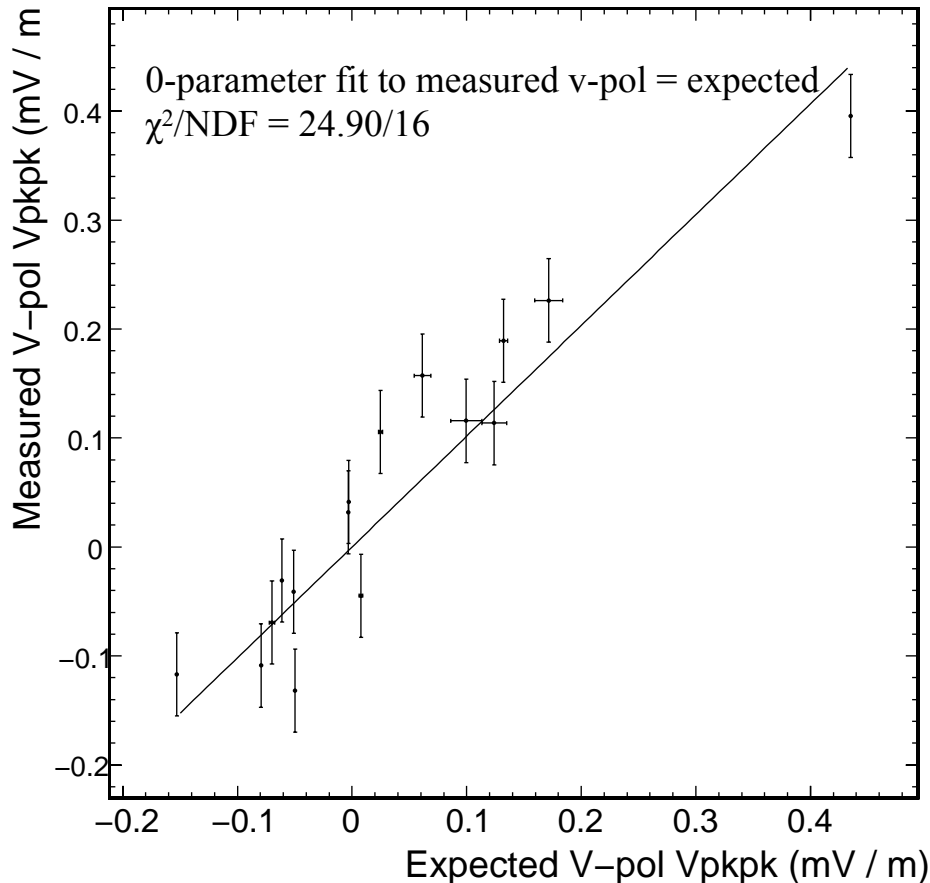
ANITA flew here





Geo-Magnetic Analysis

Measured vs. Expected V-pol content

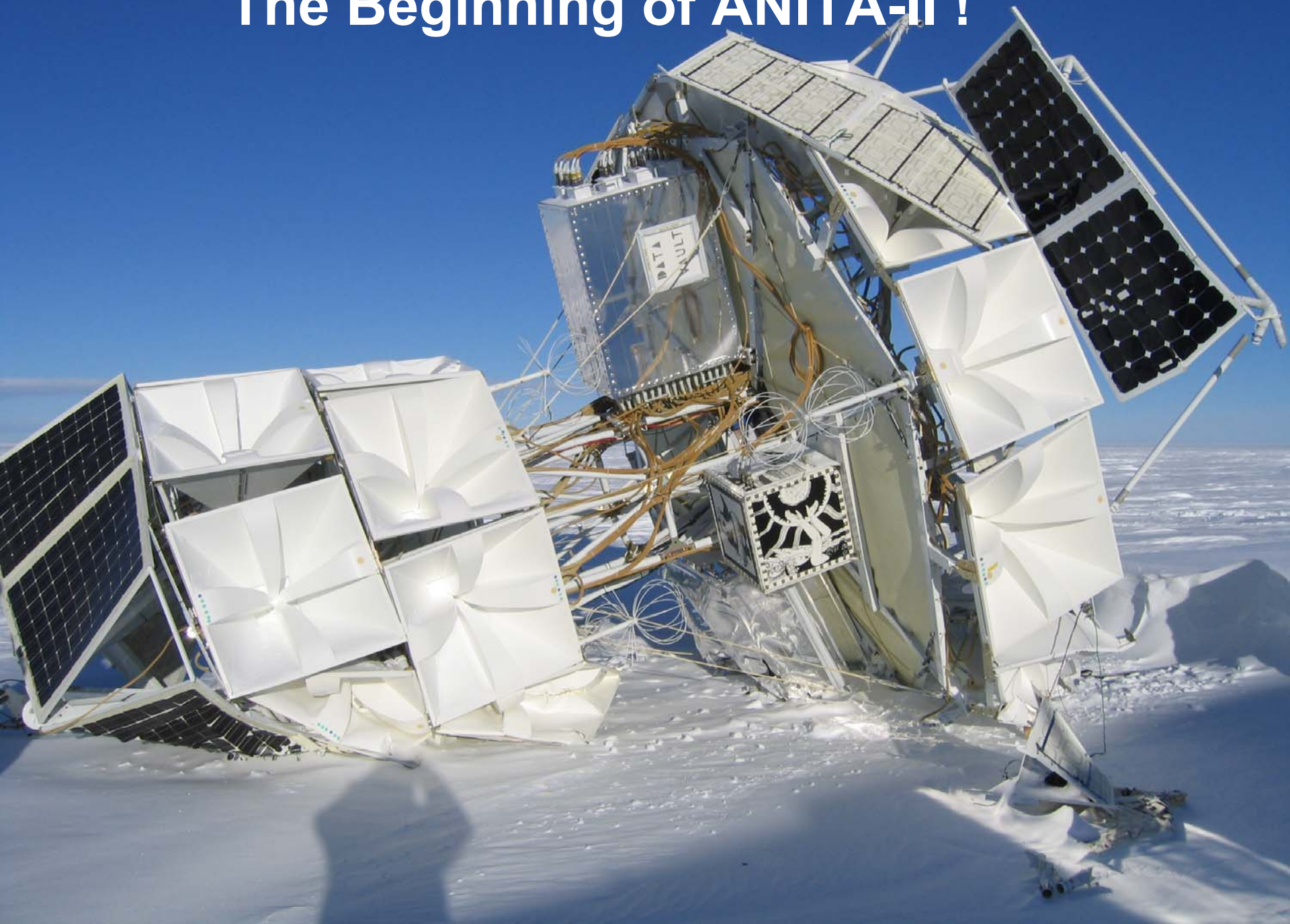


● $\langle E_{\text{CR}} \rangle \sim O(10^{19} \text{ eV})$

● Best measured radio cosmic ray sample

● 17 live days → significant UHECR statistics

The Beginning of ANITA-II !

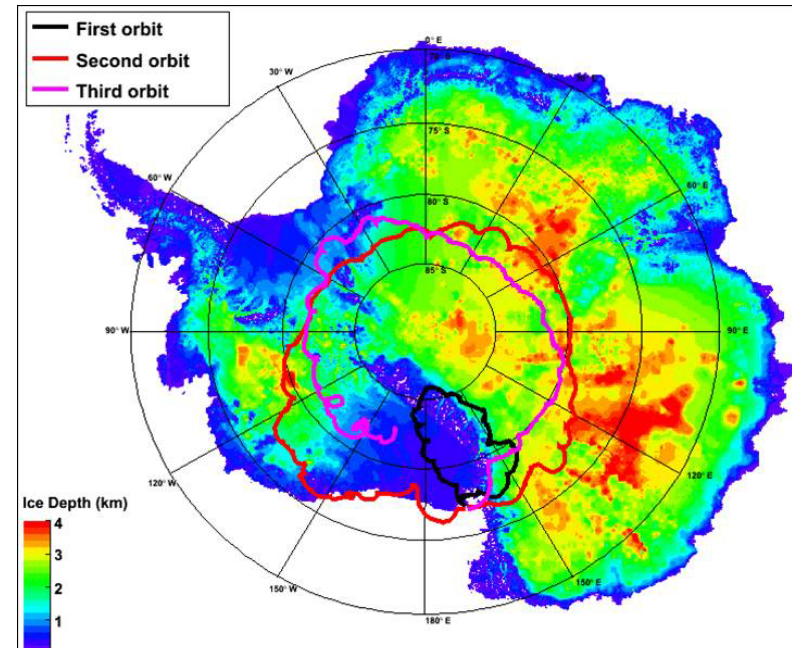




Improvements for ANITA-II (2008-09 flight, 30 days)

- More typical flight path (→ better)
- Drop-Down Antennas
- Updated computer + software + firmware
- Optimized trigger configuration
- Lower Noise amplification
- Experience

~ factor 5 improvement





ANITA-II Neutrino Search

- 80k → 250k reconstructed events & lower threshold
- in the Box...



Stay tuned for Feb 2010 APS!

Start of ANITA-III



- **Proposal due March 2010**
 - **Want to improve 18 \rightarrow \sim 100 UHECR events**
 - **Reaching into heart of predicted fluxes \rightarrow Neutrino Events!**



Conclusions

- **ANITA successful: flights & detector. Low background**
- **ANITA-I did not see neutrinos, but found ~18 UHECR**
- **ANITA-II neutrino search public on Valentine's Day**
- **ANITA-III proposal: improved UHE ν and CR detection**