EHE Physics and ARIANNA

http://arianna.ps.uci.edu

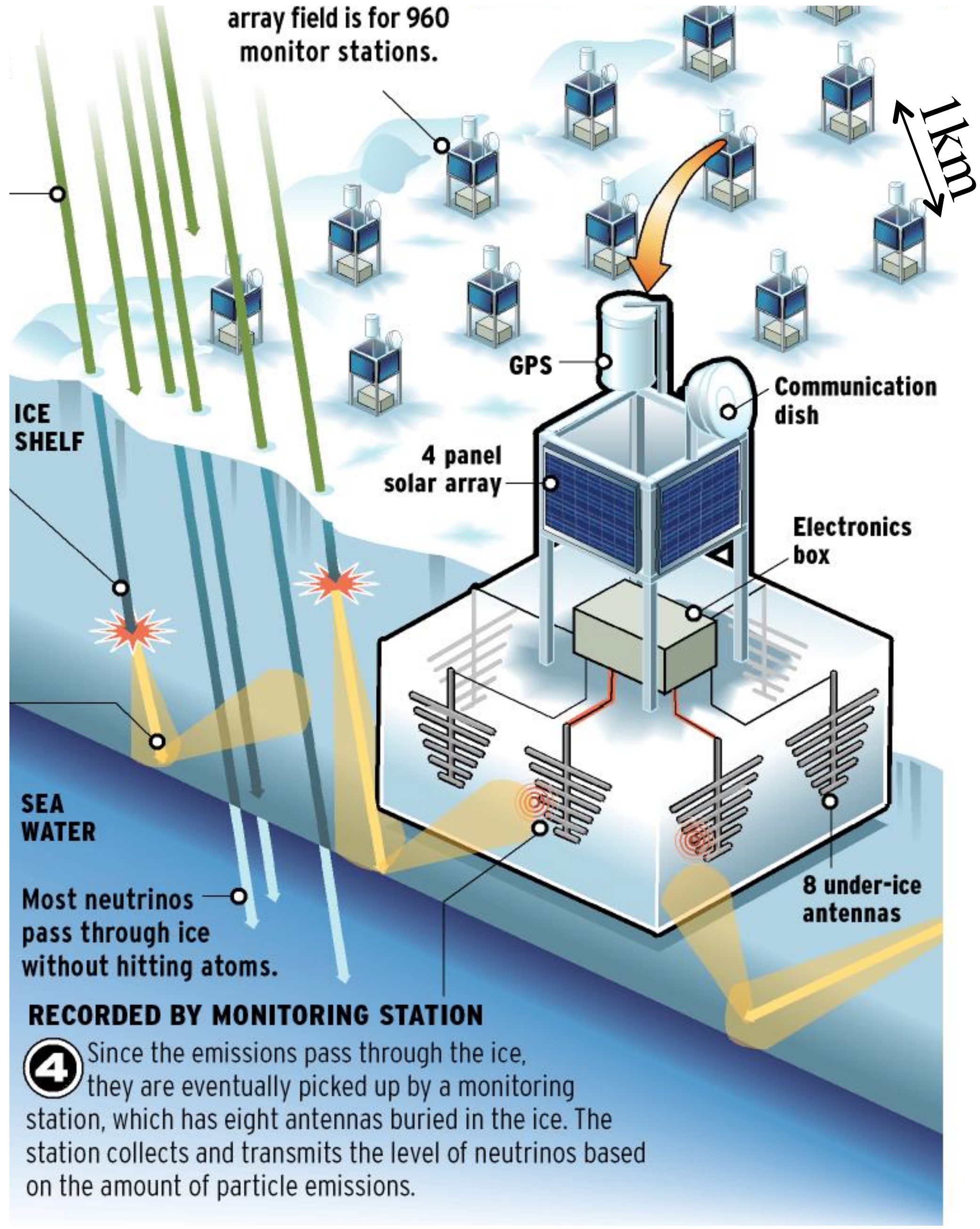
Steve Barwick, UCI

for the ARIANNA collaboration

US

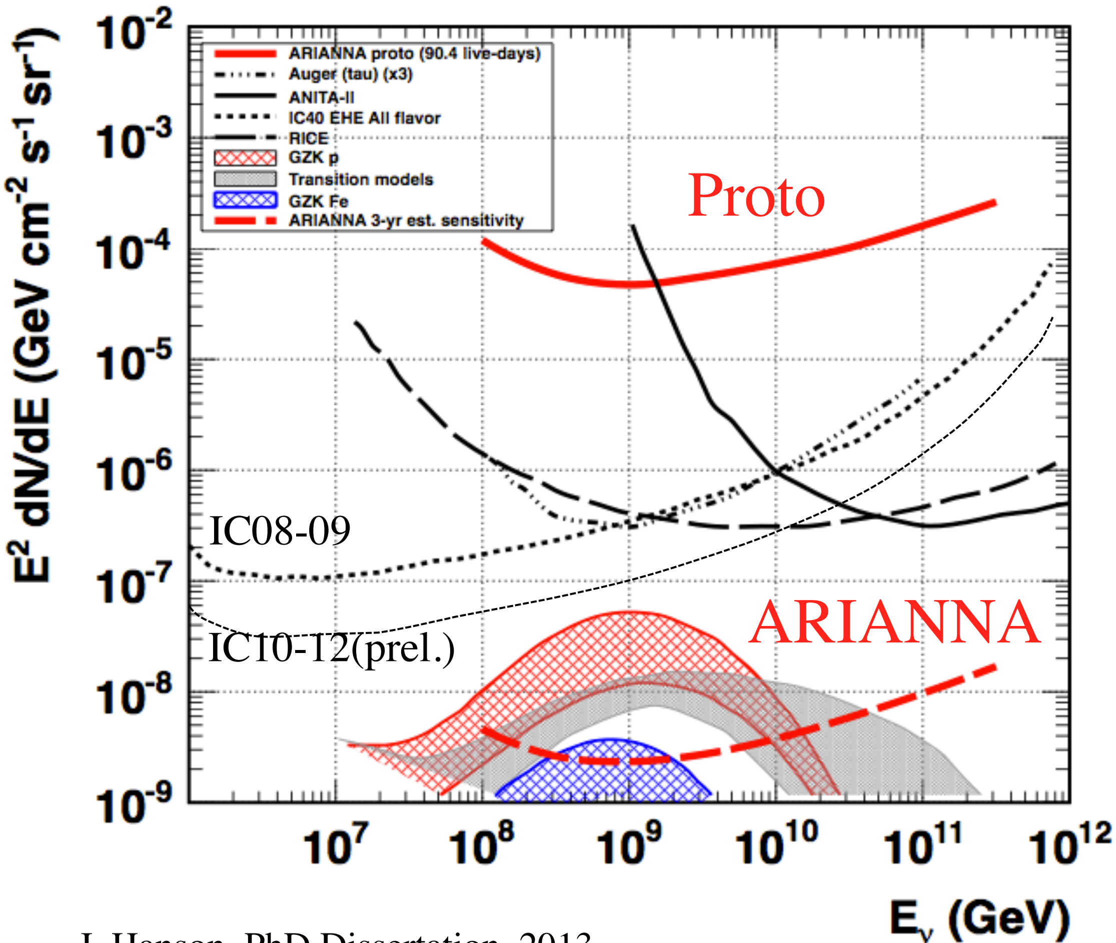
Sweden

New Zealand



From OC Register 2012

Cosmogenic neutrino flux



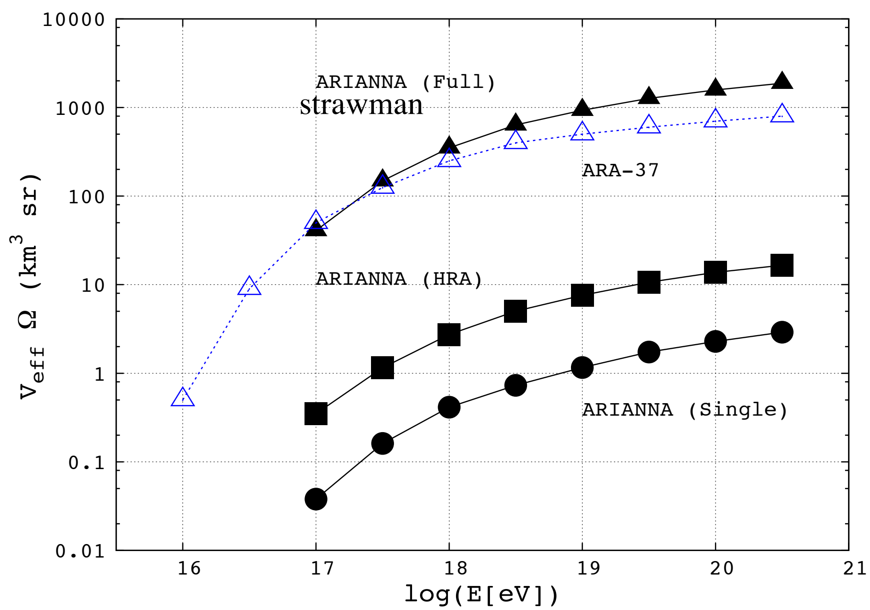
J. Hanson, PhD Dissertation, 2013
Fig. adapted from Kampert&Unger

Calculations depend on:

1. Composition [p, mix]
2. Evolution of sources
3. Highest energy, E_{max}
4. Injection Spectrum
5. End of Gal. CR

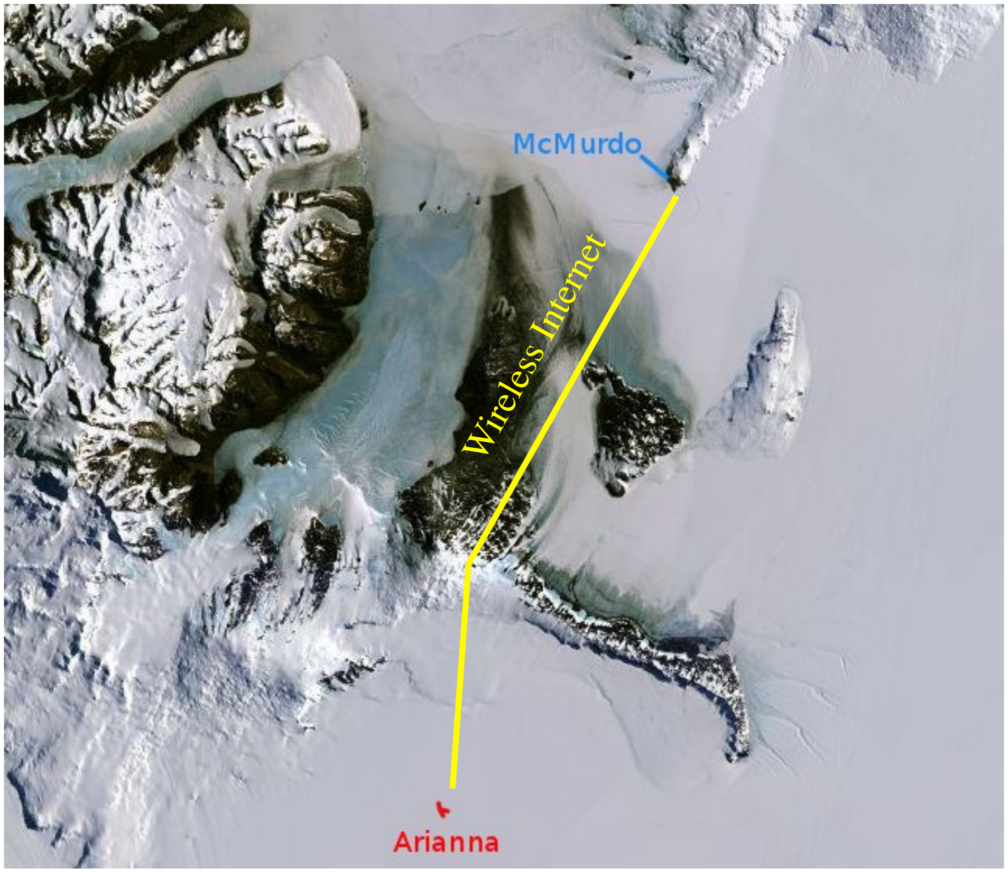
Aperture and Rates (3 year)

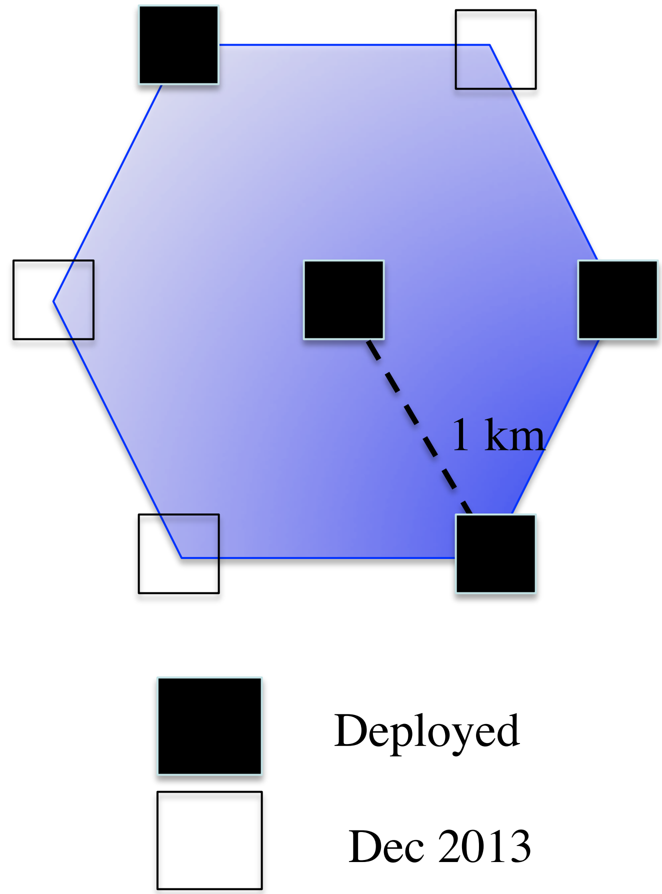
Model and Reference	Model Class	Predicted N_ν
ESS Fig. 4 ($\nu_e + \nu_\mu$) [71]	No source evo.	30.8
Kotera (2010) Fig. 1 [33]	SFR1, Pure Proton	37.1
ESS Fig. 9 [71]	Strong evo.	104.9
Kalashev Fig. 2 [69]	High E_{max}, $z \leq 2$	96.1
Barger Fig. 2 [42]	Strong evo.	114.9
Yuksel, Kistler (2007) [53]	SFR evo.	45.4
Yuksel, Kistler (2007) [53]	QSO evo.	55.5
Yuksel, Kistler (2007) [53]	GRB evo.	156.1
Ave et al. (2005) [24]	Pure Fe comp.	11.3
Todor Stanev [80]	Fe, CMB+IRB	2.40
Kotera Fig. 7 upper [33]	Mixed comp.	21.7
Kotera Fig. 7 lower [33]	Pure Fe	7.50
Fermi-LAT [22]	$E_{cross} = 10^{17.5}$ eV	15.5
Fermi-LAT [22]	$E_{cross} = 10^{18.0}$ eV	21.1
Fermi-LAT [22]	$E_{cross} = 10^{18.5}$ eV	32.9
Fermi-LAT [22]	$E_{cross} = 10^{19.0}$ eV	42.8
WB (1999) [17]	No source evo.	22.4
WB (1999) [17]	QSO evo.	67.1
Olinto review (2011) [23]	Fe, $E_{max} = 100$ EeV	0.14
Olinto review (2011)	Mixed, $E_{max} = 10$ EeV	0.068
Olinto review (2011)	Proton, $E_{max} = 3$ ZeV	101.3
Olinto review (2011)	Various protonic, SFR	37.1



J. Hanson, UCI
PhD Dissertation, 2013

Hexagonal Radio Array (HRA): 2012-2013

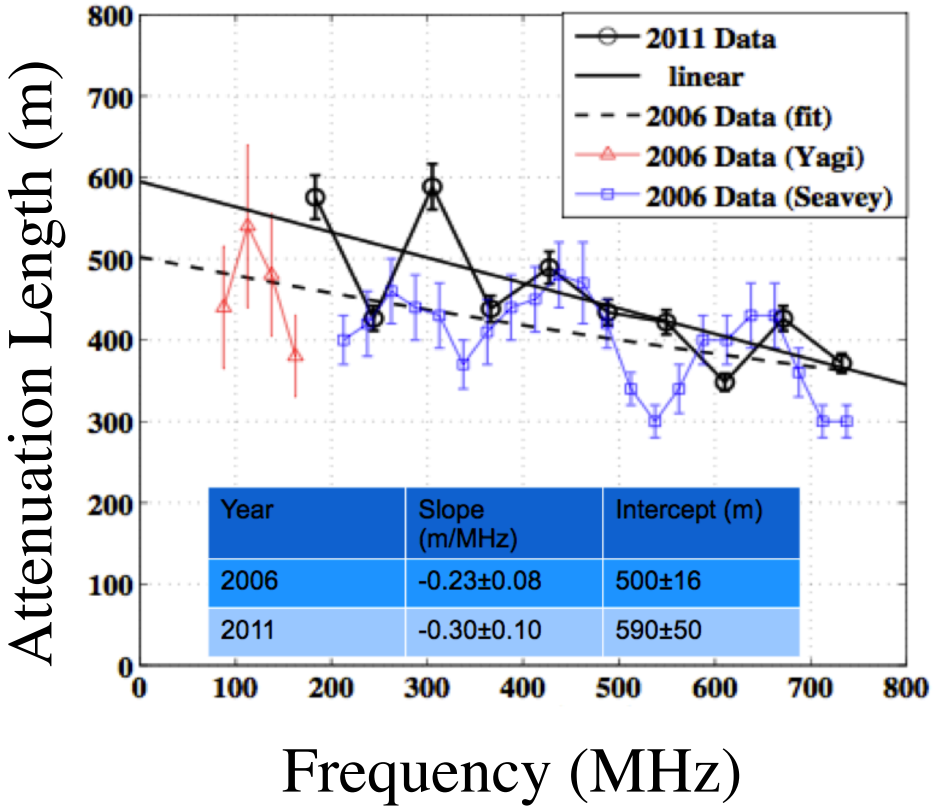




ARIANNA Advantages

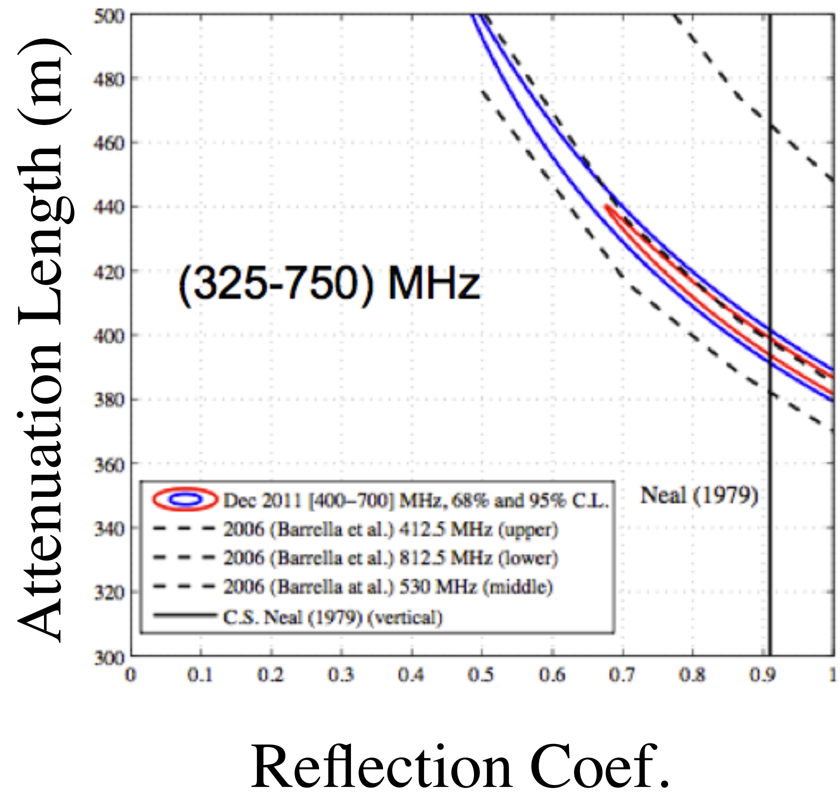
- Straightforward logistics
  - not far (~120 km) from main US science station
  - surface deployment (no drilling)
- Excellent site properties
  - Protected from man-made noise
  - Good attenuation length and reflectivity from bottom
- Lightweight, robust technologies (so low $$)
- Internet access 24/7
- Array is reconfigurable to follow science
- Green Technologies: solar and wind only

Ice Properties

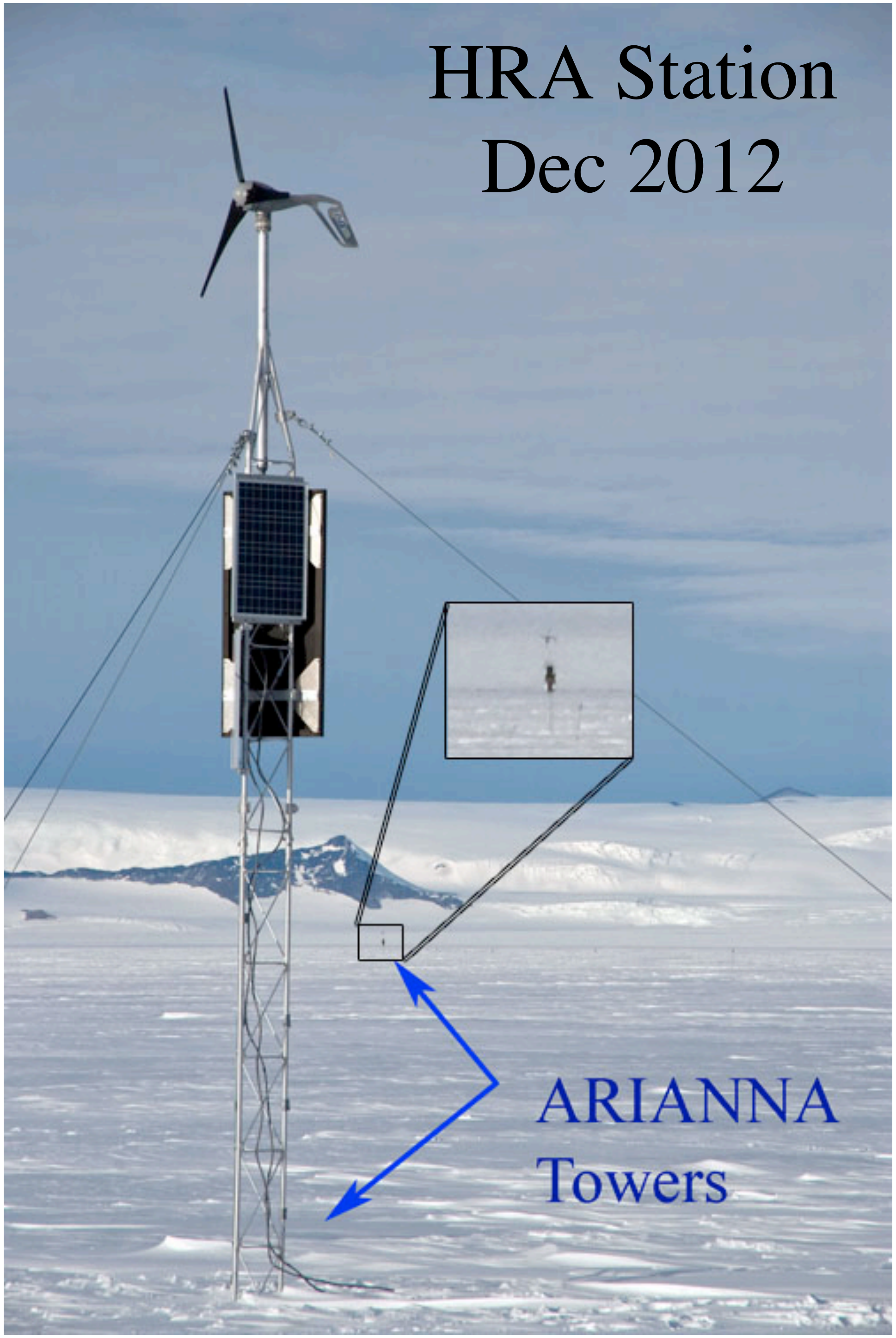


Year	Slope (m/MHz)	Intercept (m)
2006	-0.23±0.08	500±16
2011	-0.30±0.10	590±50

J.Hanson, UCI Dissertation, 2013

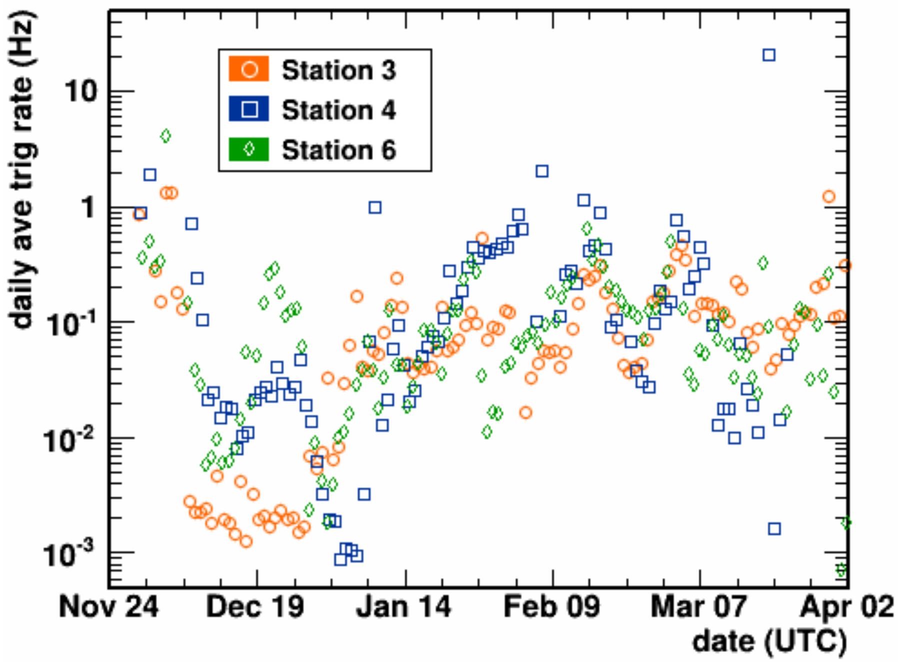


Reflection consistent with flat reflector ($R^{1/2}$=0.92)

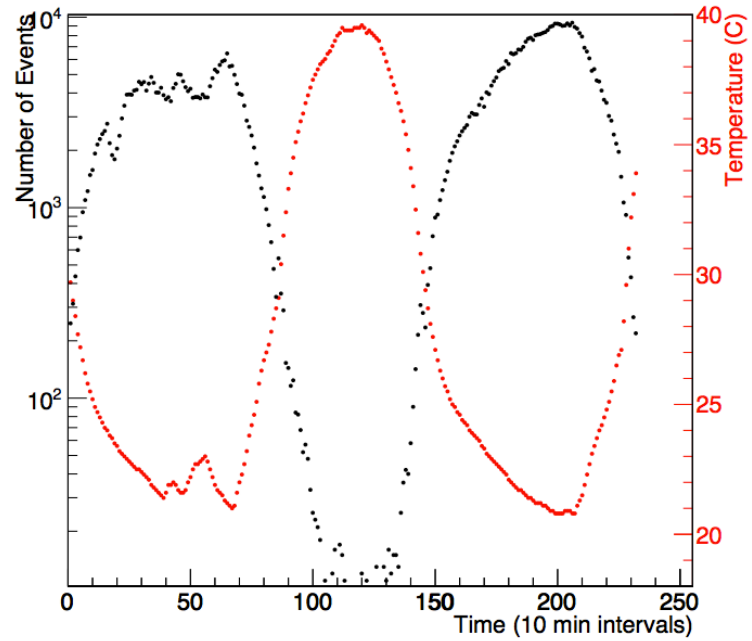


Electronics and base of
comms tower (AFAR+Irid)

Trigger Rates vs Temperature



Lab calibration of Rate vs Temp

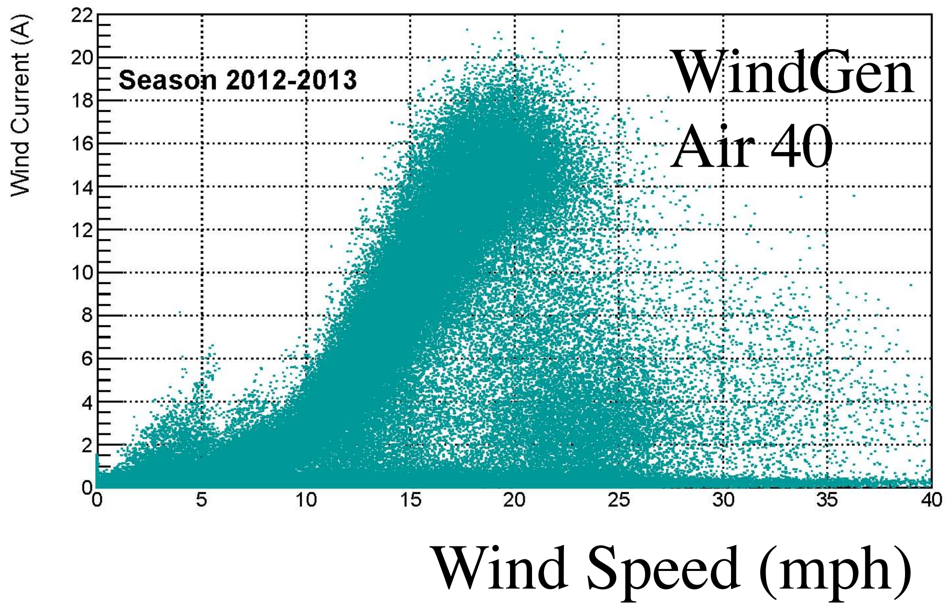


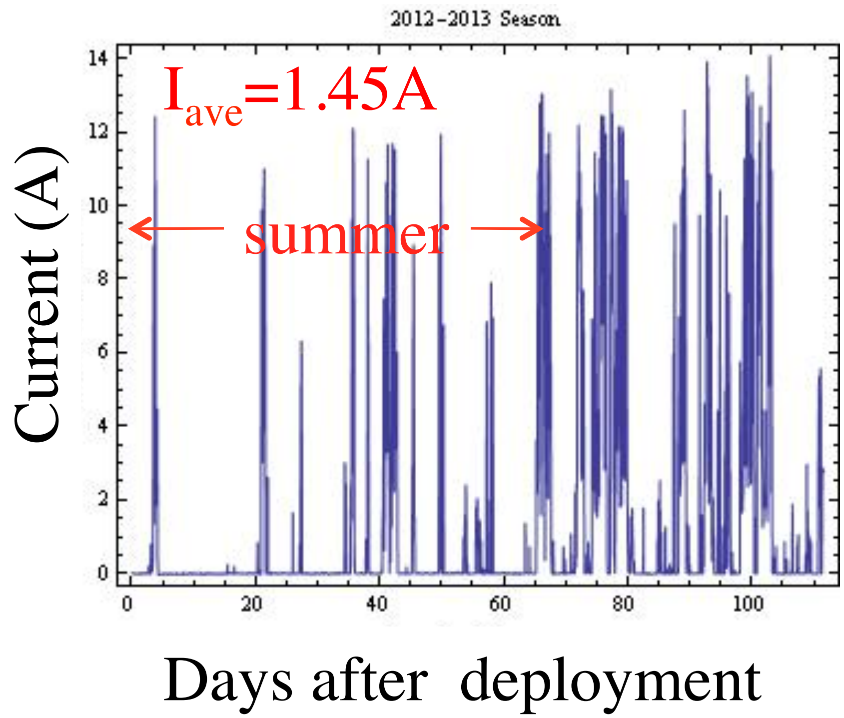
Variation in rates cause by temp variation. All rates far below max trigger rate of ~50 Hz, so no impact on livetime

Wind Power is Sufficient!

(Southwest WindPower Air 40)

V_{ave}= 7.4 mph during summer





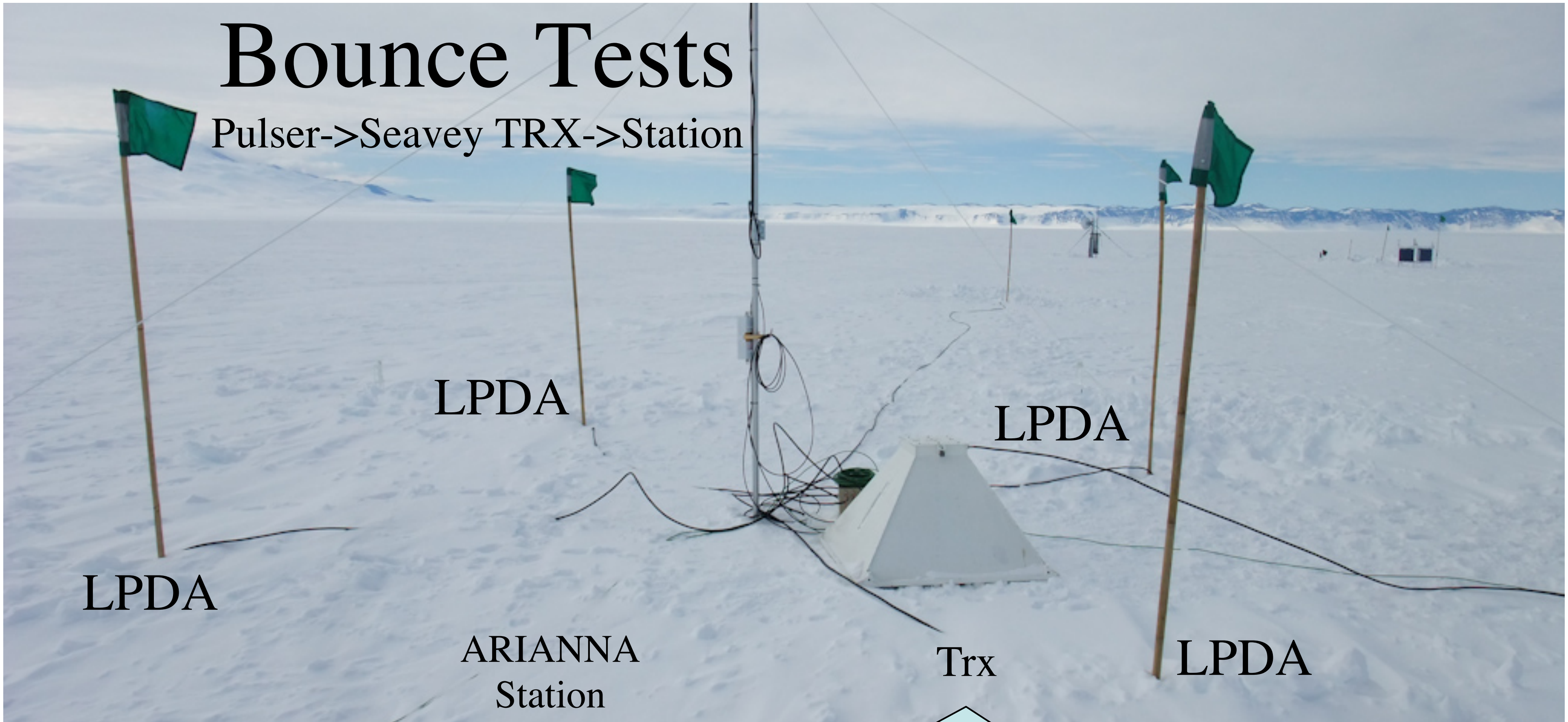
Require ~0.9A to operate station and station produced 1.45A

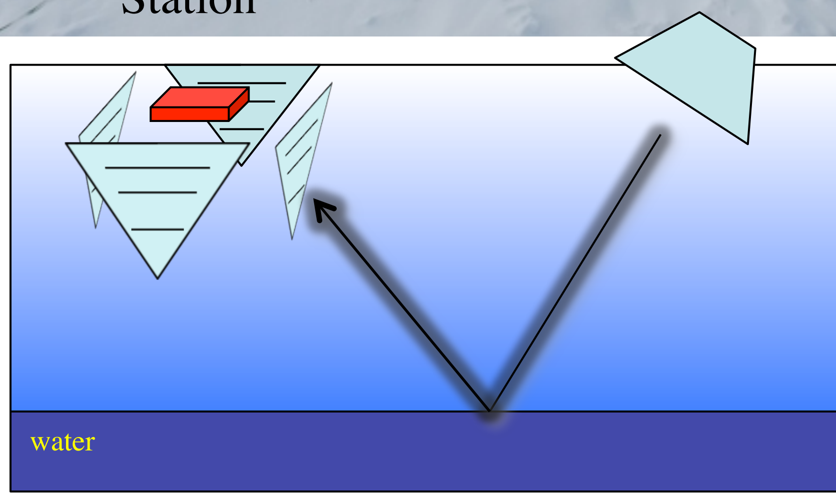
Wind expected to stronger in winter

However, low temps in winter lead to loss of efficiency

Bounce Tests

Pulser->Seavey TRX->Station

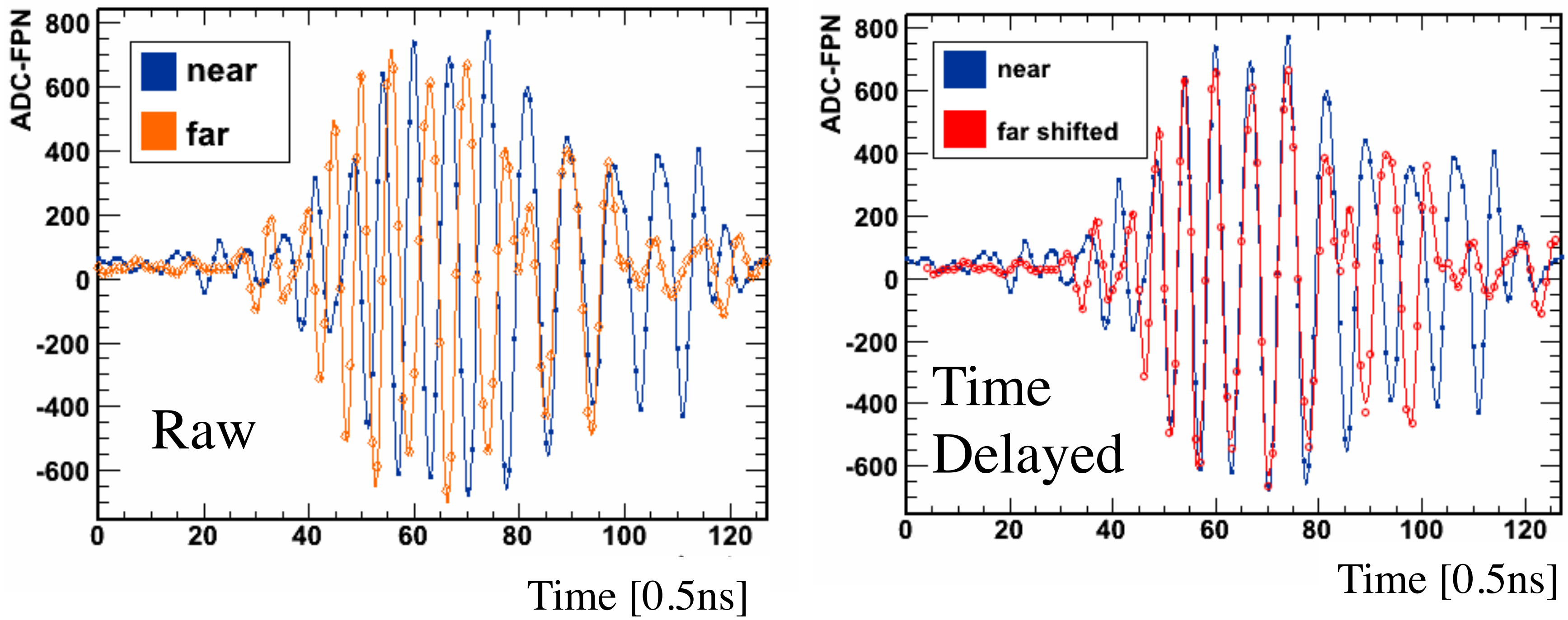




See C. Reed contribution in Wed poster session

Bounce Tests

Pulser->Seavey TRX->Station

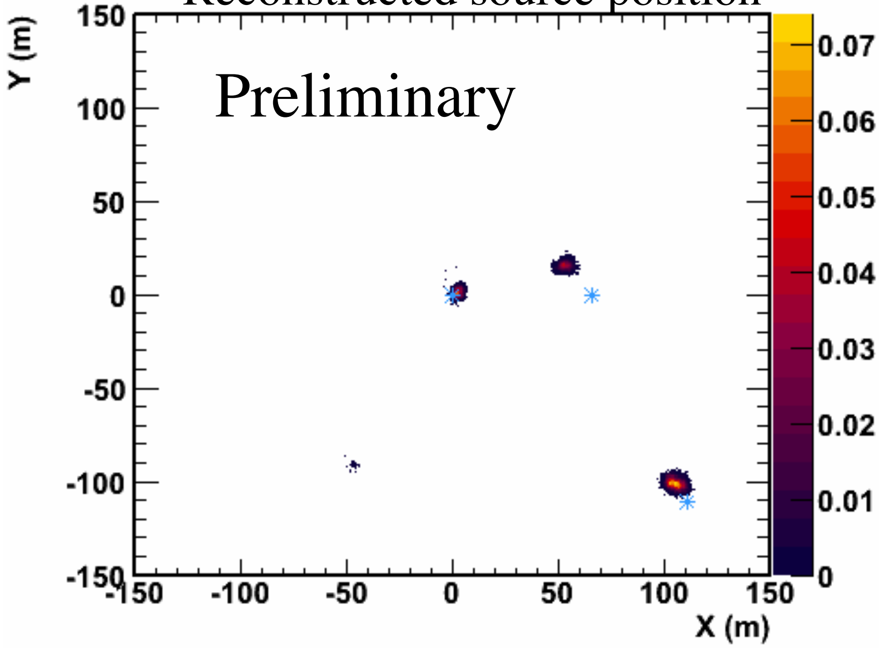


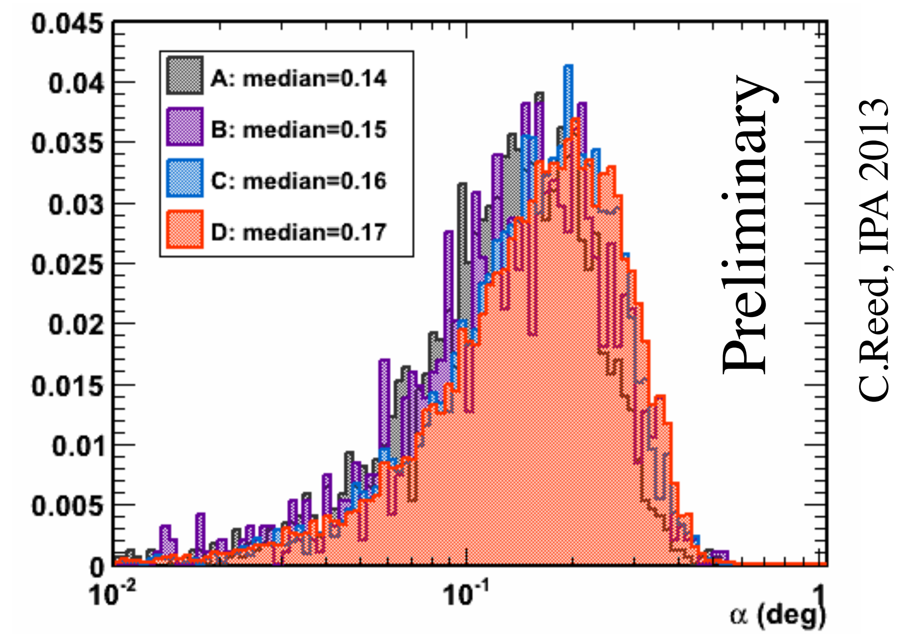
Notes: Time delays are determined from all 4 antennas, compatible with plane wave

Bounce Tests

Pulser->Seavey TRX->Station

Reconstructed source position





space-angle - <space-angle>

~0.16 deg angular resolution for EM wave

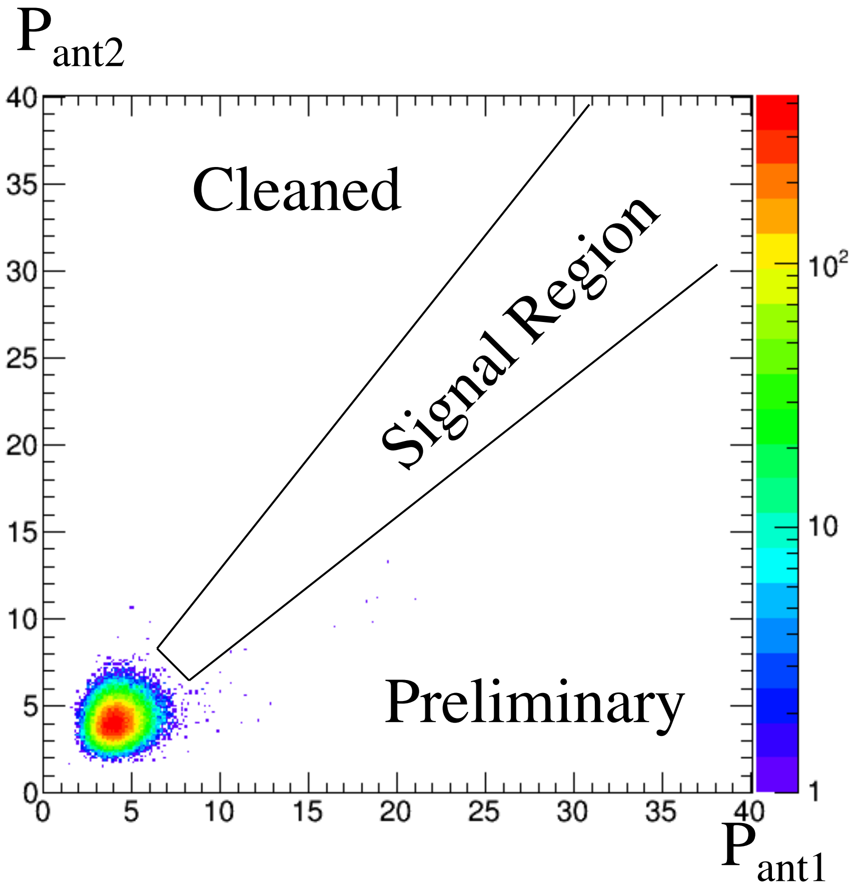
Data Analysis: HRA Station 3

(Dec 15, 2012 - Mar 15, 2013)

552473 events collected in 2/4 majority logic at 5 sigma thresholds on each channel

Remove event if

(1) Too much power below highpass
(2) Unusual peaks in power spectrum
(3) No waveforms consistent with time domain expectation
(4) Inconsistent power in parallel antenna



Complete rejection of BG without timing or event reconstruction

Summary: So far, so good

- New DAQ electronics function as expected and latest design operates on 10 Watts/station
- Station communicates via high speed wireless and Iridium satellites
- ProtoStation automatically restarted during austral spring, so technology survives winter.
- No evidence of impulsive background that resembles neutrinos -> straightforward analysis
- Significant power from wind gen in 2013
- Angular resolution of 0.16 deg of EM plane wave

On track for completing Hexagonal Array in Dec 2013

ARIANNA Projected Costs

Very hard to give precise number until HRA completed in December, 2013 and full proposal developed by collaboration, but here goes

Hardware: $10k/station	~ 9.6M	target
Personnel:	~10 M	
Logistics (3 year install):	~5 M	guess
Total:	~24.6M	

EHE ν detectors: Comments

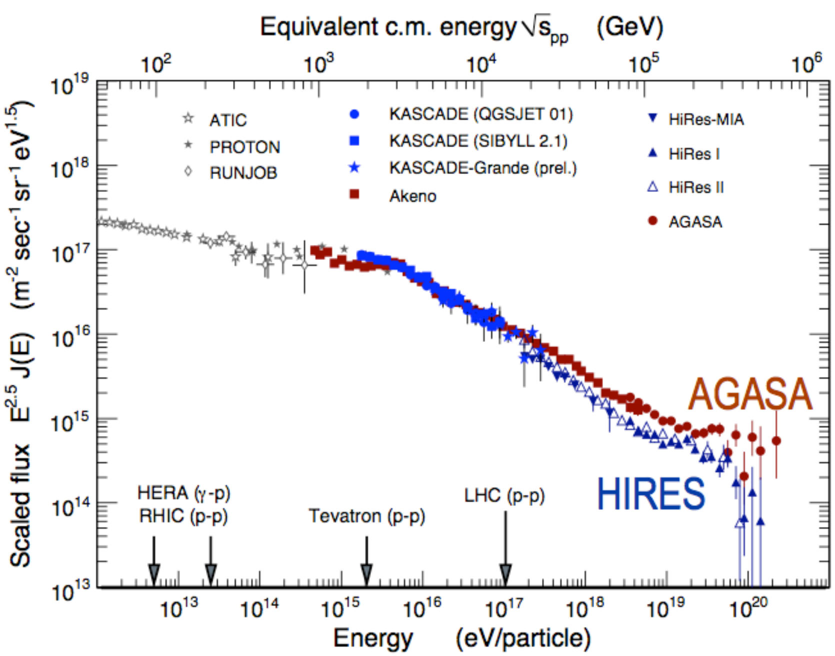
EHE neutrino detectors:

- Contribute to ongoing quest to understand CRs
  - Neutrino measurements provide independent confirmation of GZK mechanism
  - Combined with CR and photon measurements, can help to constrain source class, evolution, Emax, and composition of CR
- Search for new physics
  - Beam of EeV neutrinos can uncover new physics at ~5-10 x E_{cm} of LHC through cross-section and spectral modifications
- Search for new sources:
  - EeV neutrinos must point back to sources and direction can be measured with good precision and can be improved.

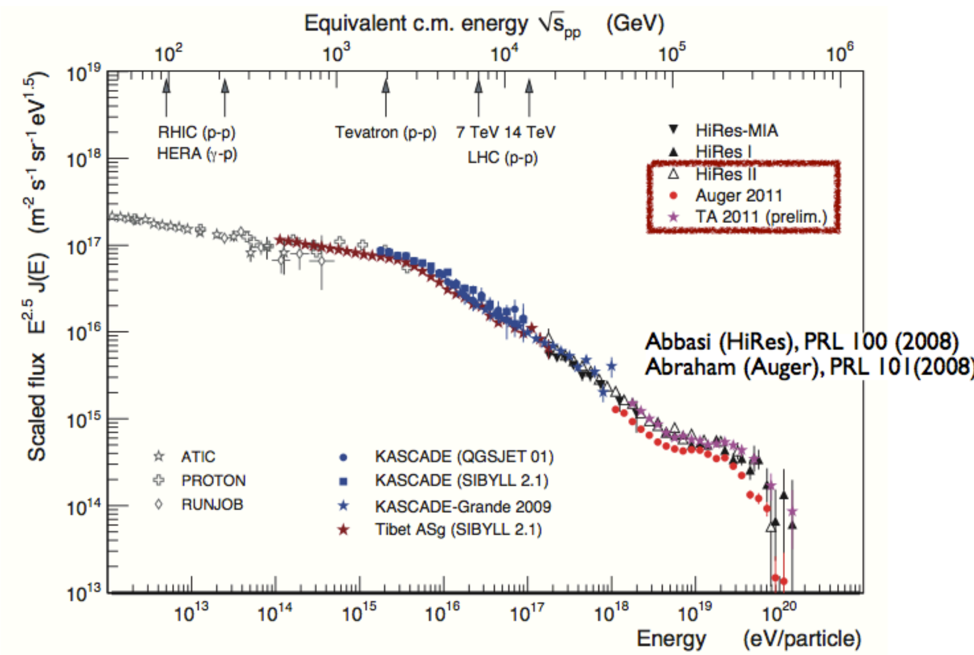
Huge upside at modest cost, development time, deployment and risk

Backup Slides

Cosmic Ray Spectrum

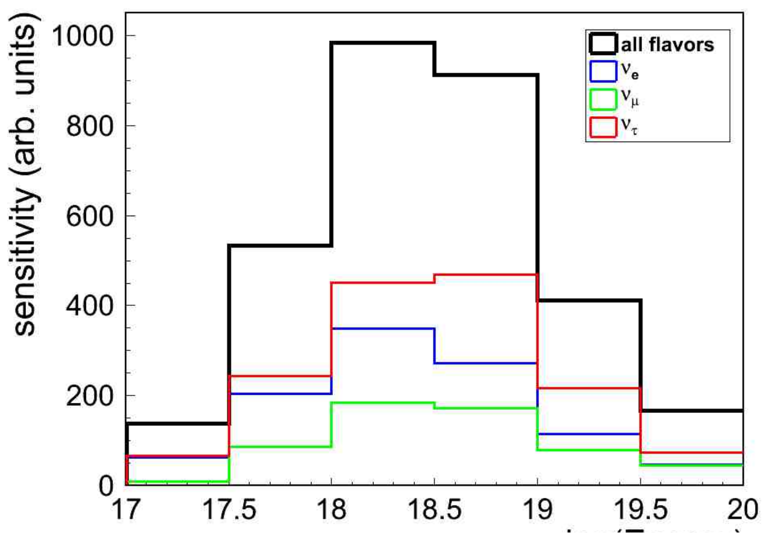


before 2008

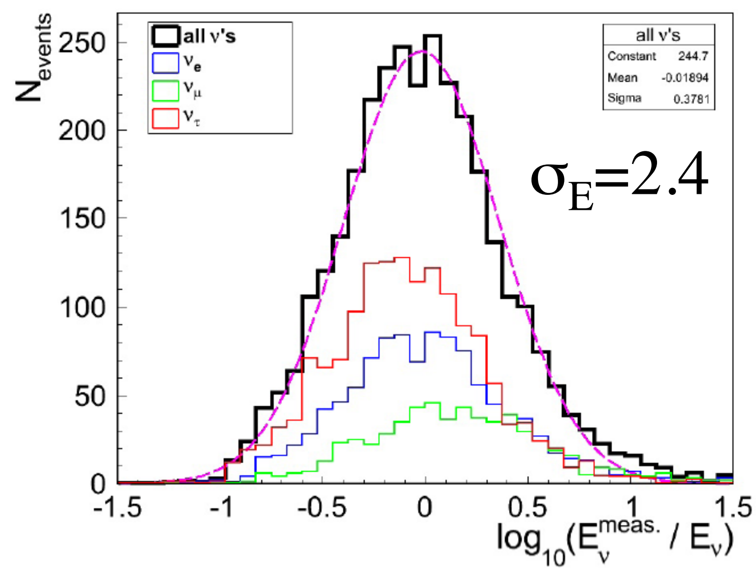


after 2008

ARIANNA Characteristics



$\log(E_\nu)$ eV



Prelim. , refl., ESS spectrum

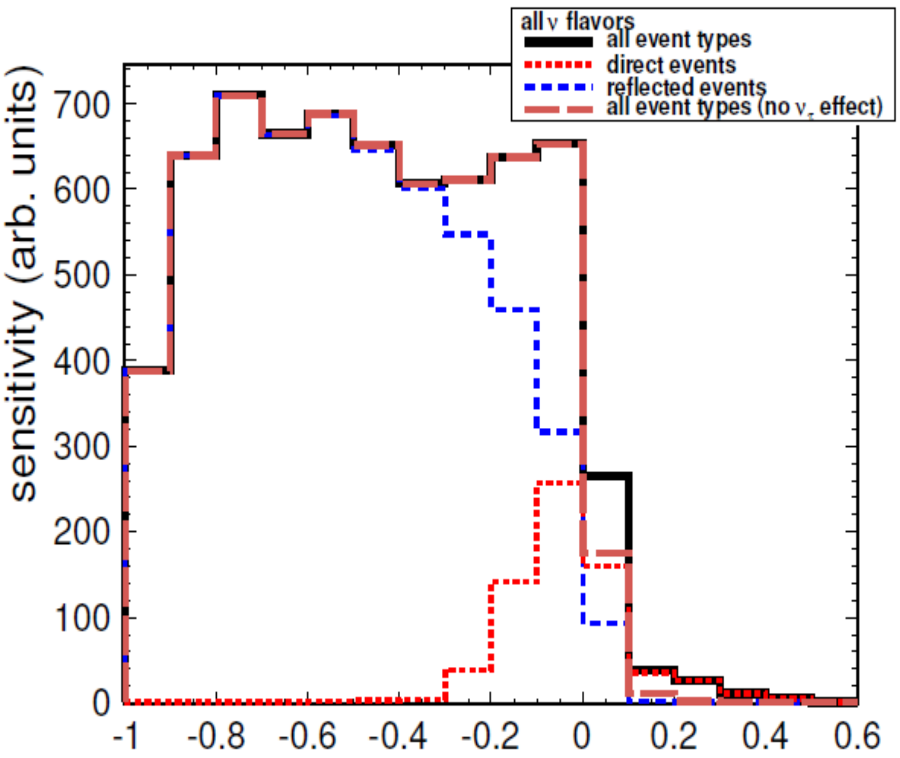
Energy Resolution

Peak response at "sweet spot" of GZK spectrum

Details of waveform give energy info

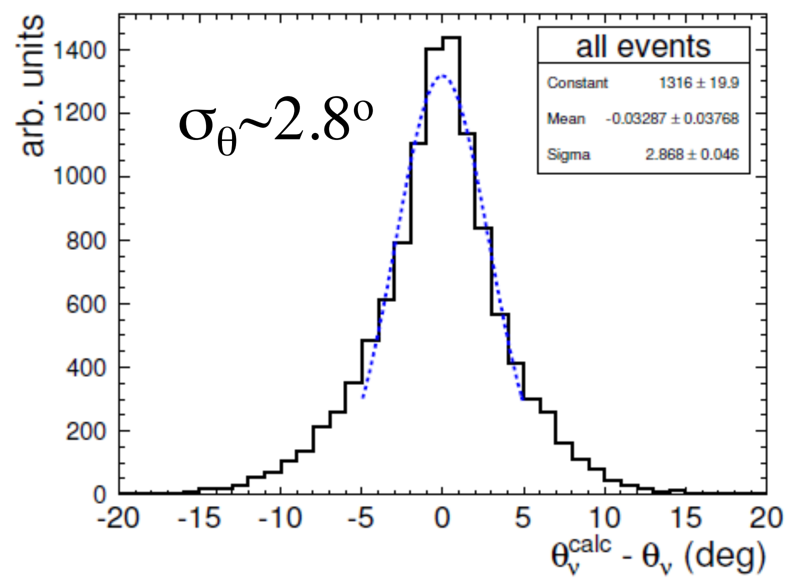
K. Dookayka, UCI PhD dissertation, 2011

Capabilities



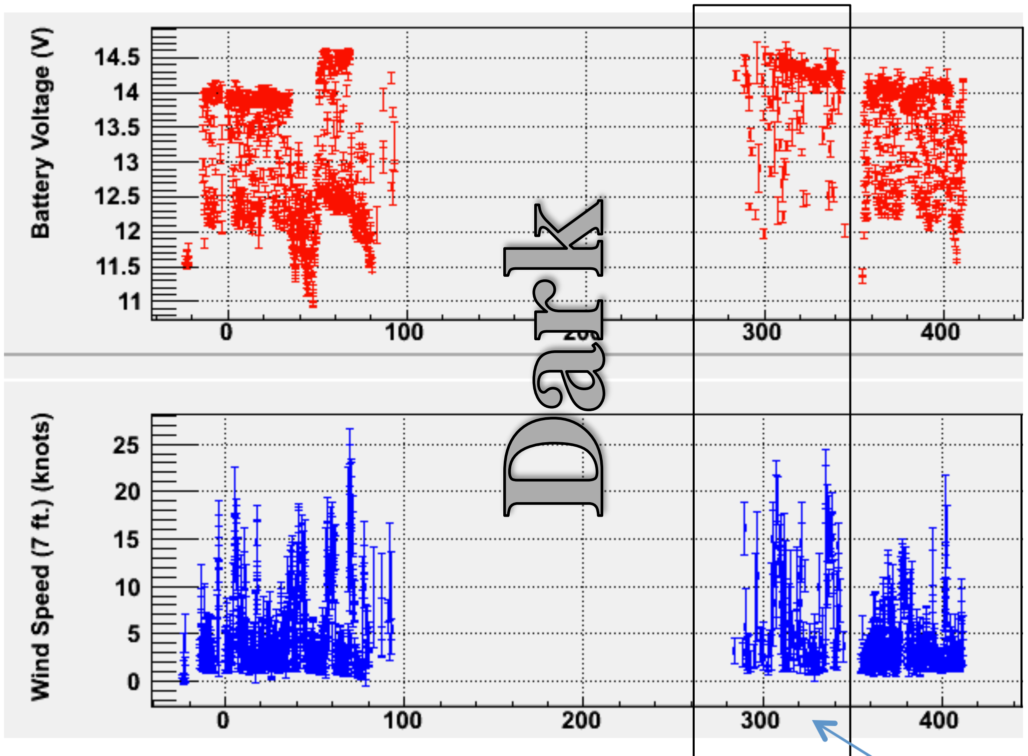
Down horizon cos(θ)

Angular resolution

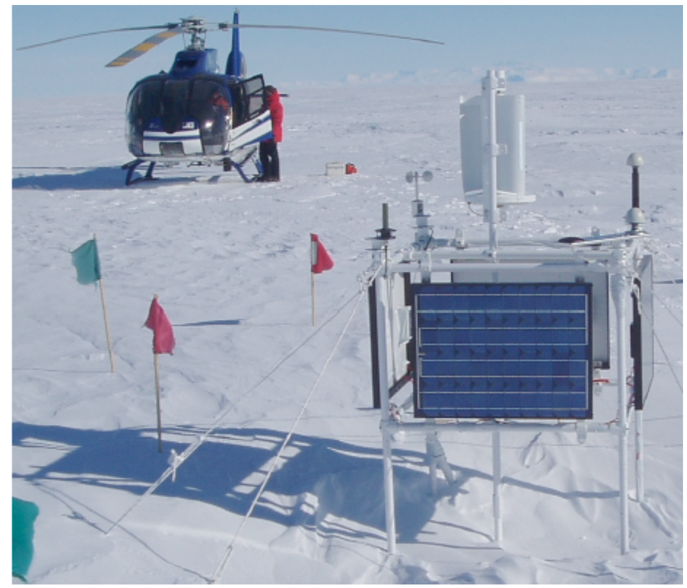


K. Dookayka, UCI PhD dissertation, 2011

Protostation LiveTime

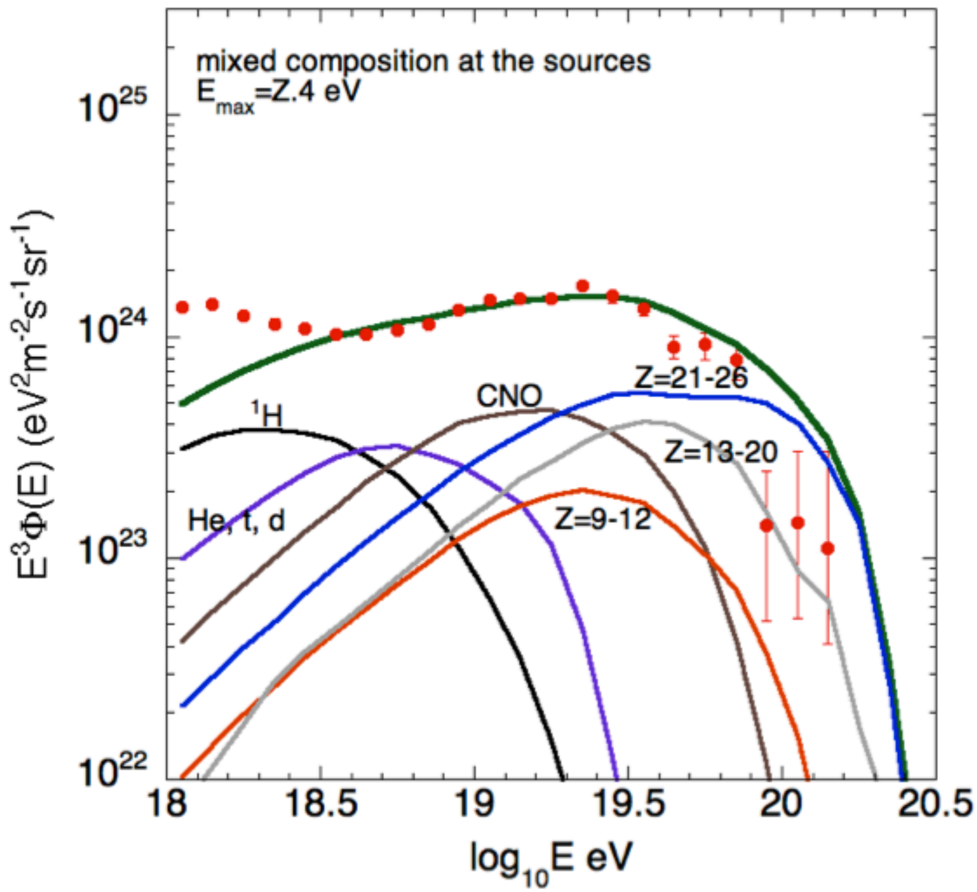


Day since Jan 1, 2010



Automatically restarted in Austral Spring

Low E_{max} Sources



D. Allard, APP 39-40(2012)33

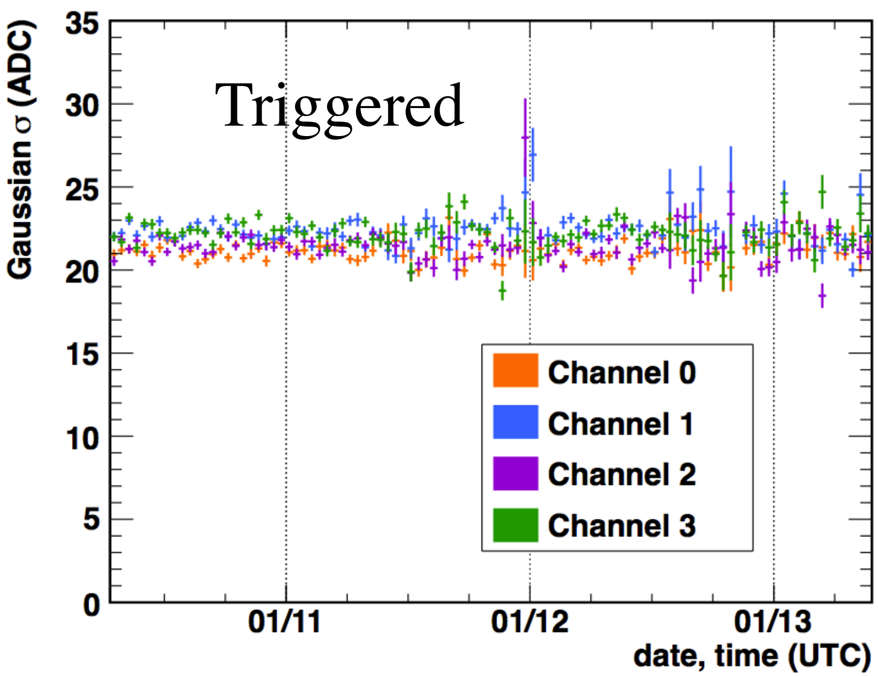
$dN/dE \sim E^{-1.6}$ (very hard)

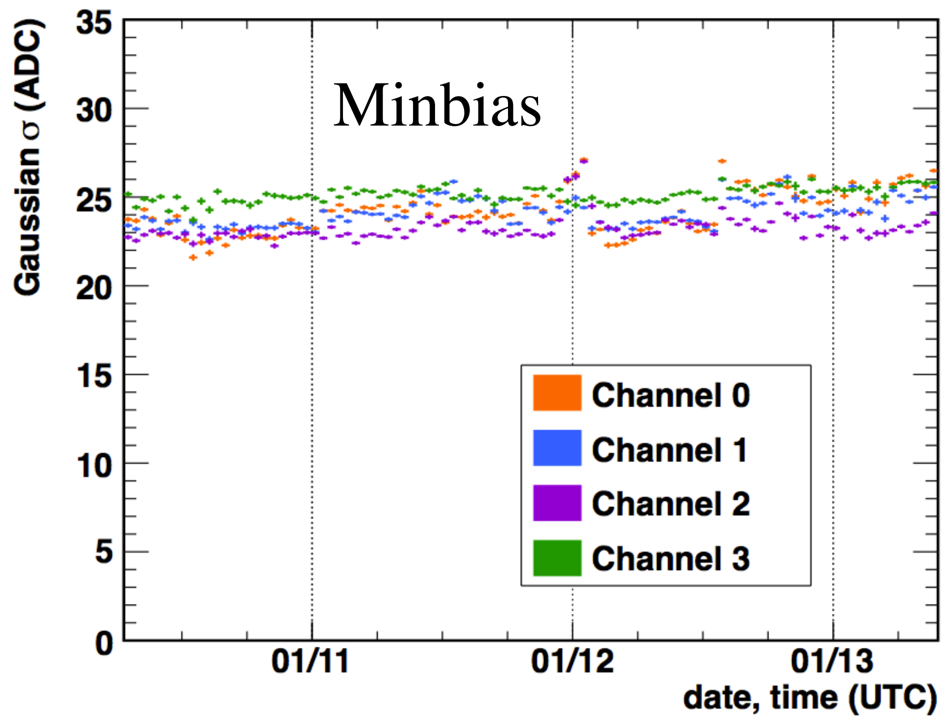
No magic number at $Zx10^{18.4}$ eV
Every source in Universe cuts off at this energy to prevent photodisintigration?

CR should not point (compatible with Auger anisotropy?)

Noise distributions are stable

Station 3





Noise characteristics

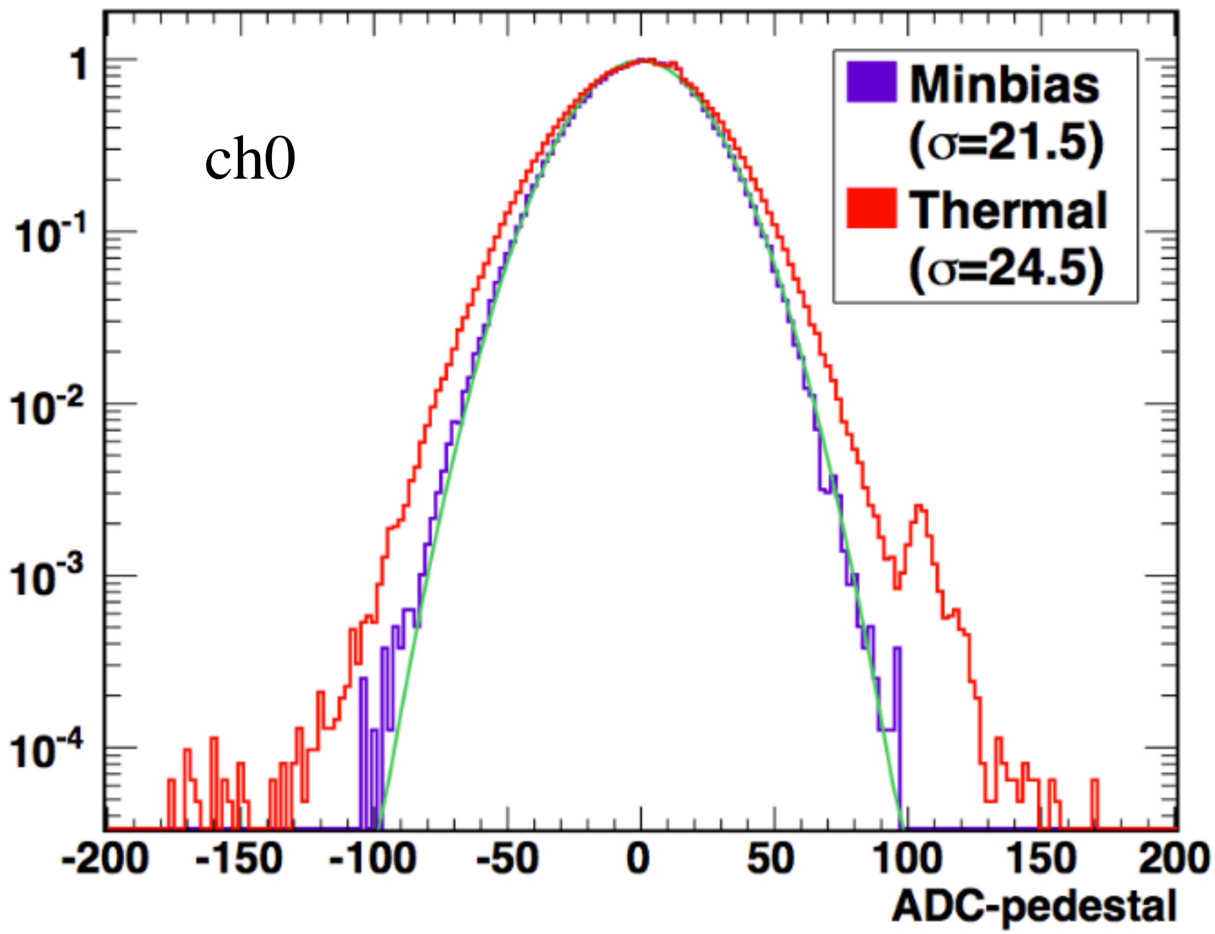
Channel 0 of station 3: all other channels similar

Minbias data is collected by randomly triggering in time.

Thermal data is biased by majority logic trigger

Gaussian structure shows measured noise is consistent with pure thermal

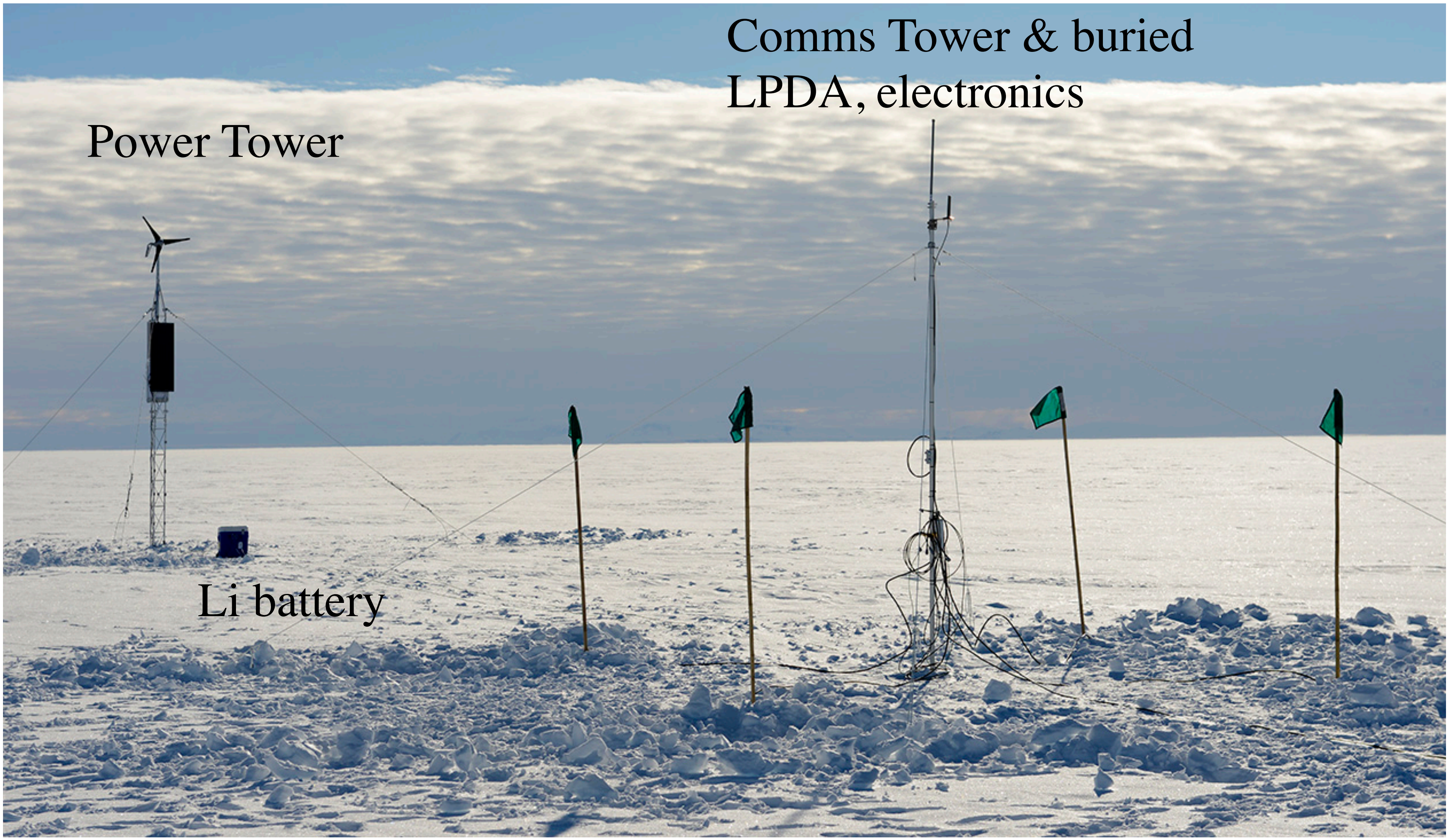
Extra width from trigger is expected. High side peak is artifact of digitizer



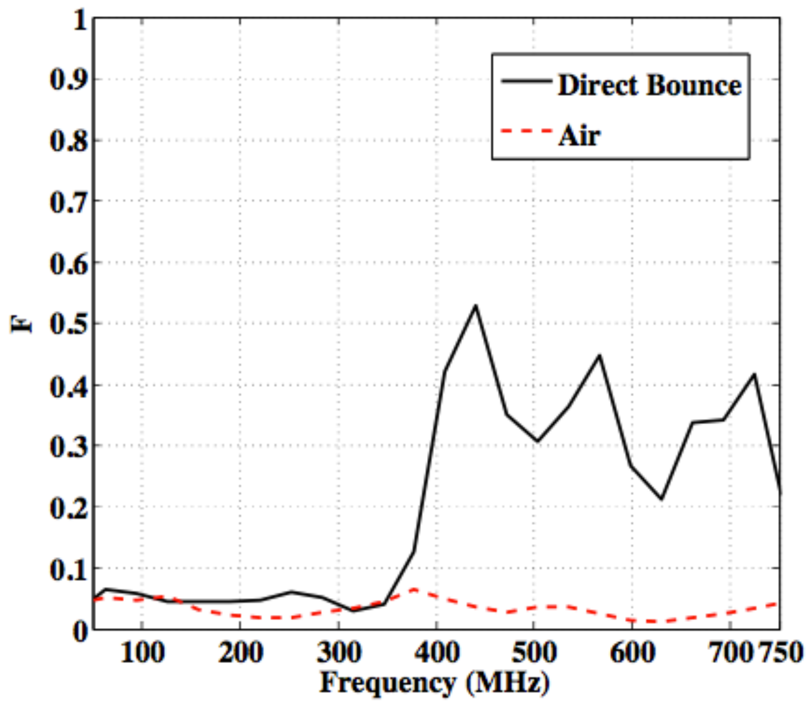
Preliminary Goals for Dec 2013

1. Focus on cost reduction, deployment speed and overwinter operation
2. Replace 3 current stations with improved MotherBoard power system
    1. Use components rated to 23V
    2. Encapsulate to mitigate radiation leaks through AFAR port
3. Install 4 new stations (including site of monitoring station)
    1. We have 3 complete stations at UCI (or stored in the field) and plan to fabricate 1-2 more
    2. Improve Amp design to reduce costs and match physics
4. Investigate less costly wireless comm for local communication to more central AFAR link. Comm should be coaxial throughout
5. Improve calibration
    1. Bounce tests for all stations
    2. Thorough study of pattern trigger to reduce threshold

Station Overview



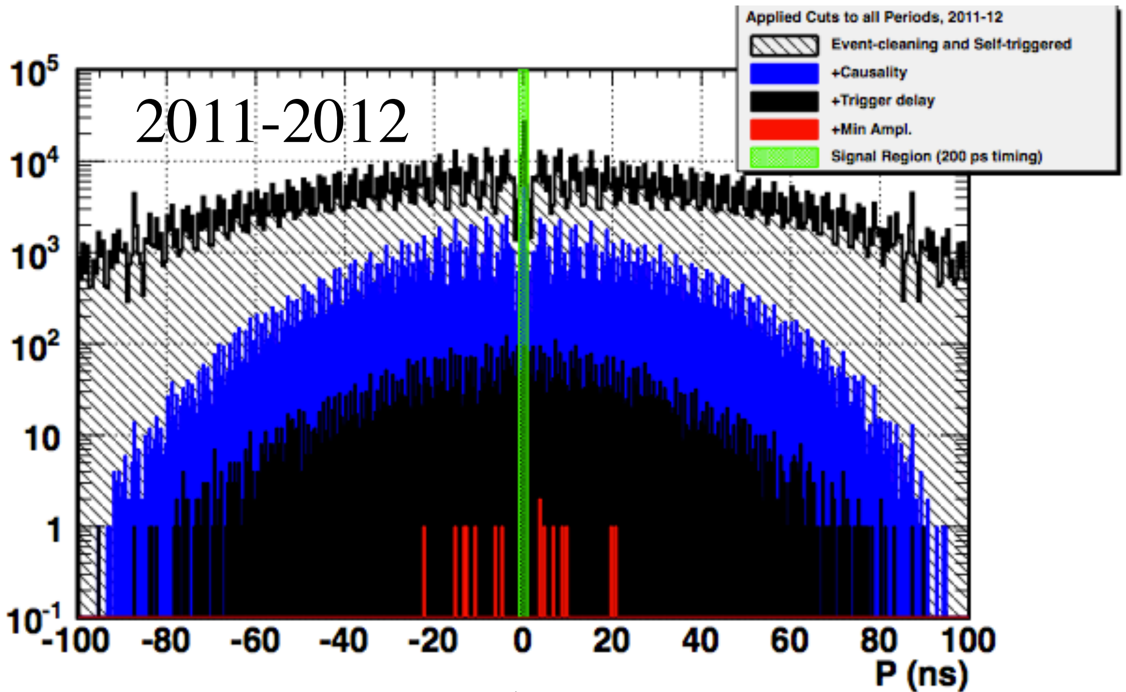
Polarization of Reflected Signals



Polarization preserved in frequency band (100-350MHz) where sufficient power exists to measure cross-pol component.

Protostation Event Analysis

(J. Hanson, UCI Dissertation, 2013)



No events in signal region

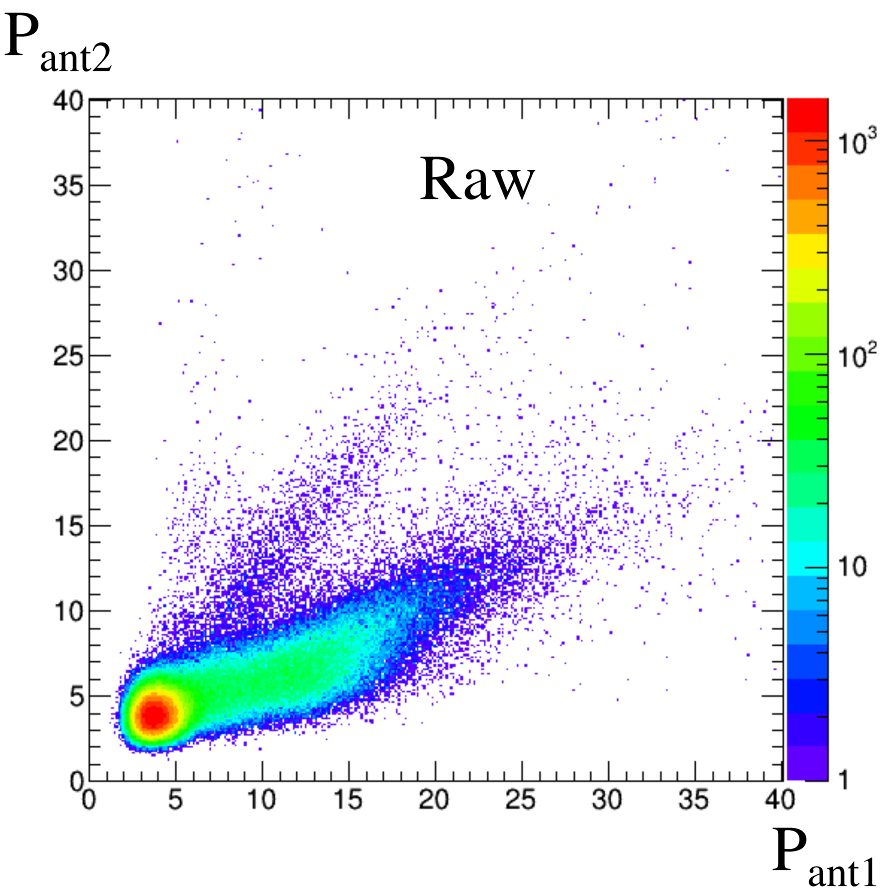
Data collected over 3 years (2009-2012)

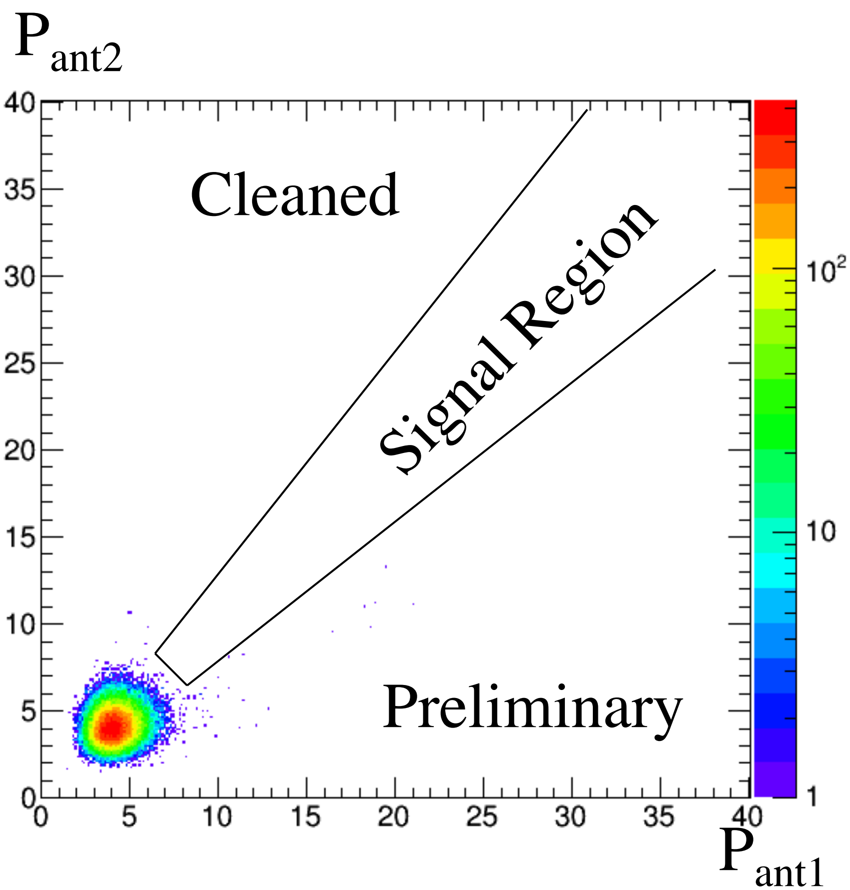
No impulsive backgrounds which mimic neutrino signals

Cut	Value	Events Remain.	Cut efficiency
Event Cleaning, 1	Δt analysis	1717295	96.5%
Event Cleaning, 2	Self-triggered	1645466	96.0%
Causality	$\lvert\tau_{ij}\rvert < nx_{ij}/c$	174043	$\geq$ 99%
T_{pp}	$\geq$ 60 ns all chan.	8077	$\geq$ 99%
A	$\geq$ 5 (excl. West)	15	64.2%
Plane wave	$\lvert P\rvert \leq 1.0$ ns	0	$\geq$ 99%
–	–	–	59.5%

Data Analysis: HRA Station

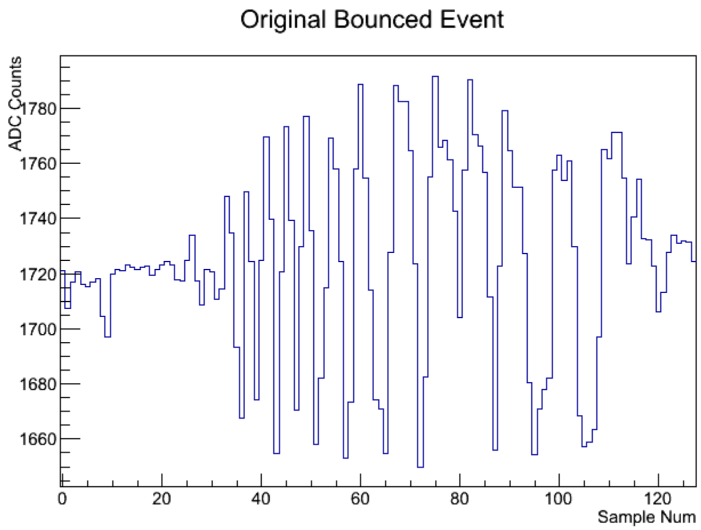
(Dec 15 2012 - Mar 15, 2013)





Complete rejection of BG without timing or event reconstruction

Signal-Like Event



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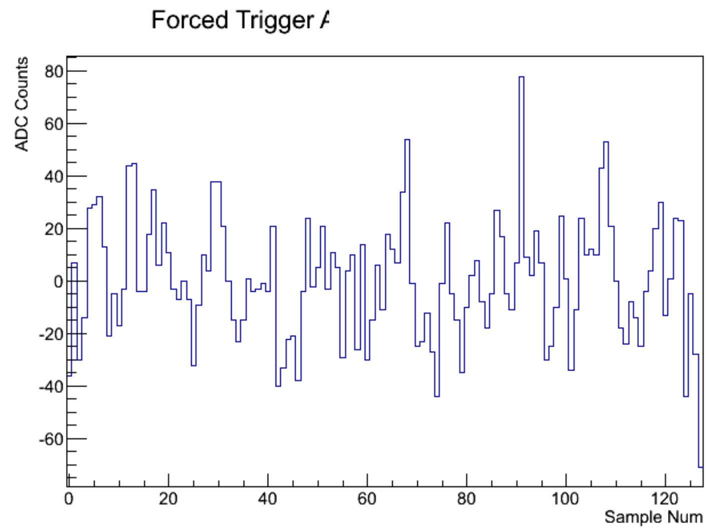

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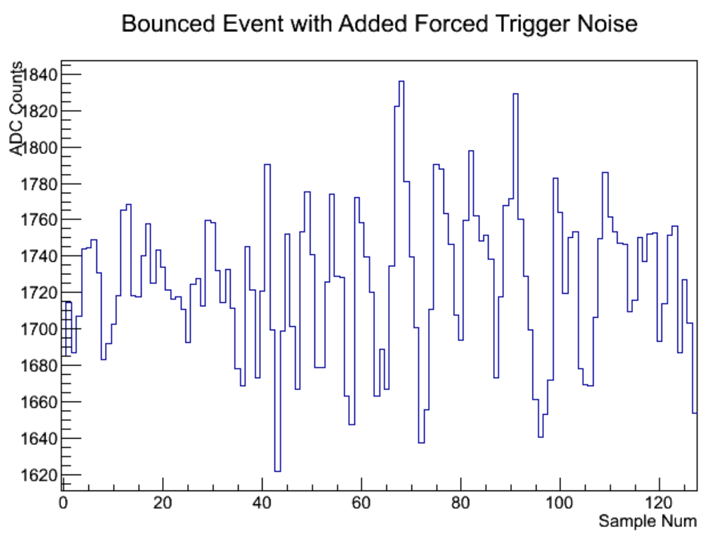
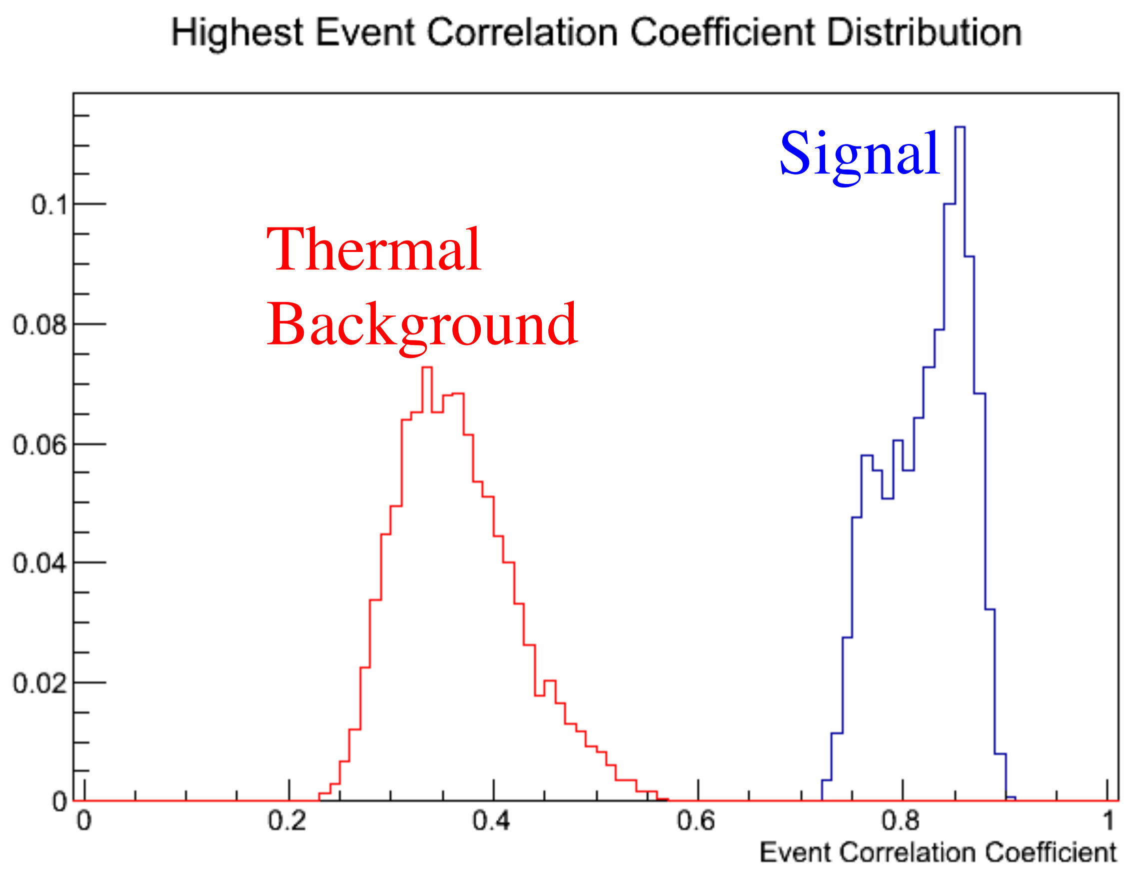


Scaled signal event

Preliminary

Waveform shape correlation



Select antenna channel with largest correlation coefficient in given event