ARIANNA
Antarctic Ross Ice-shelf Antenna Array

Copenhagen Astroparticle Neutrino
Physics in Antarctica Workshop

2014-01-13

Allan Hallgren/Uppsala University

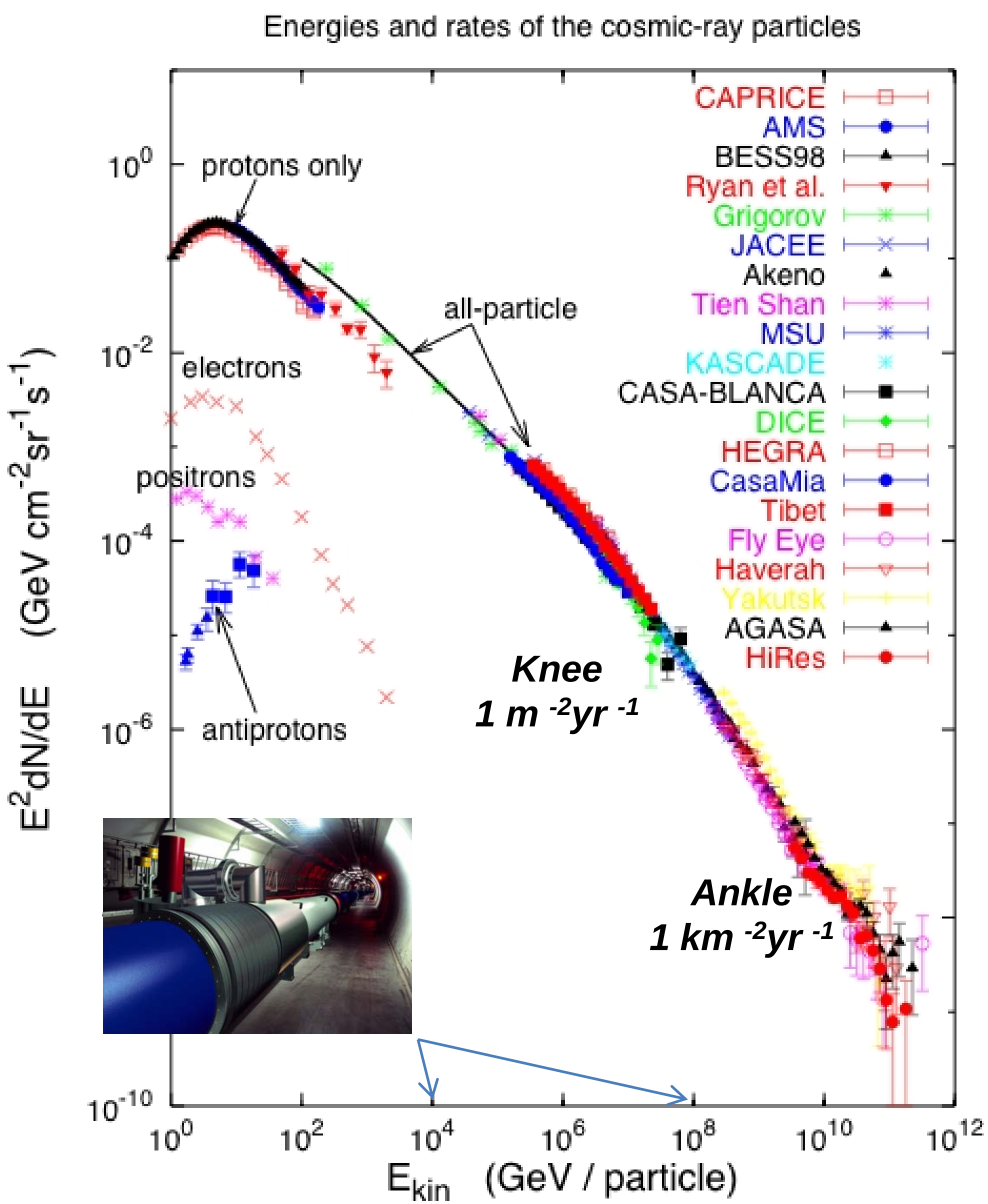
Disclaimer

- I’m NOT an expert………
- I’ve collected various material from slides and papers I’ve found, thus I do not know details…..
- Many features on slides may have been lost, or distorted, in various ’translational’ procedures.
- Many presentations I used are rather technical

So why do I do this?

I find the project interesting

→ I hope this will be seen in the presentation.



The Cosmic Ray spectrum

- Nature does create particles that have very high energies
- And we don't know where!
- Neutrinos can tell !(?)
- IceCube to small for the very highest energies.....
- <u>Extending IceCube sufficiently is to expensive (but IC^3 expansion is needed)</u>

The proton and γ ray horizons

- photons interact electromagnetically
  - in the interior of stars
  - with starlight

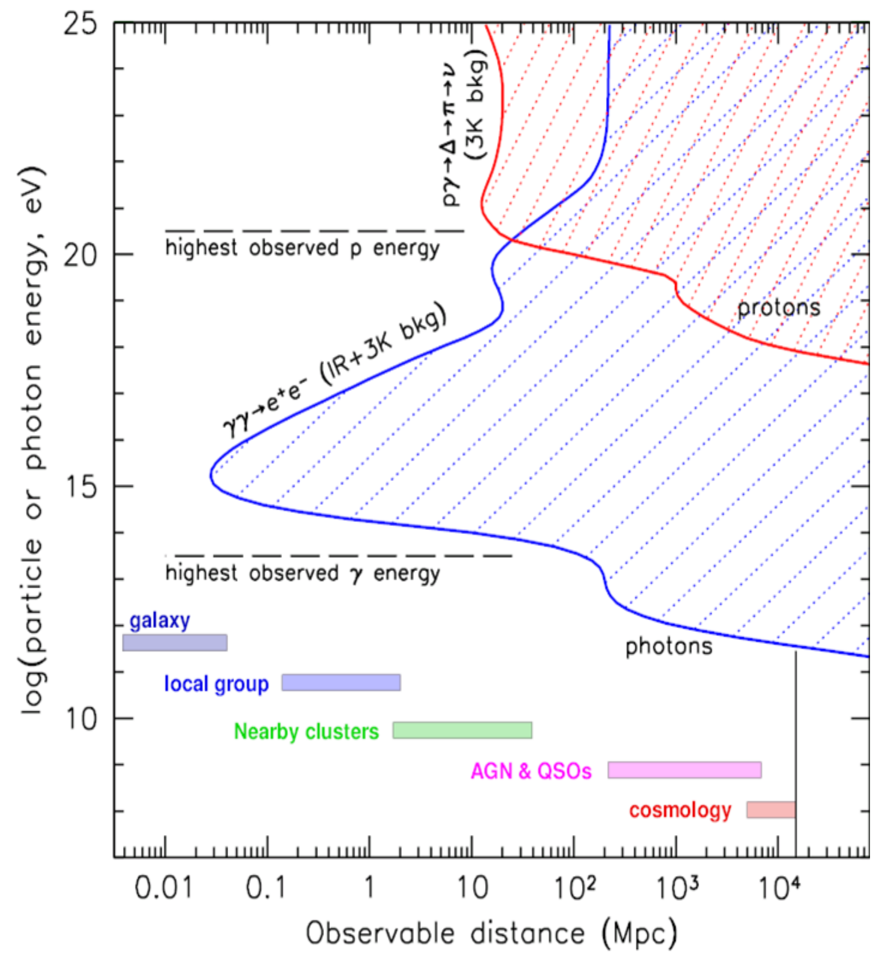
    inter-stellar matter

    CMBR

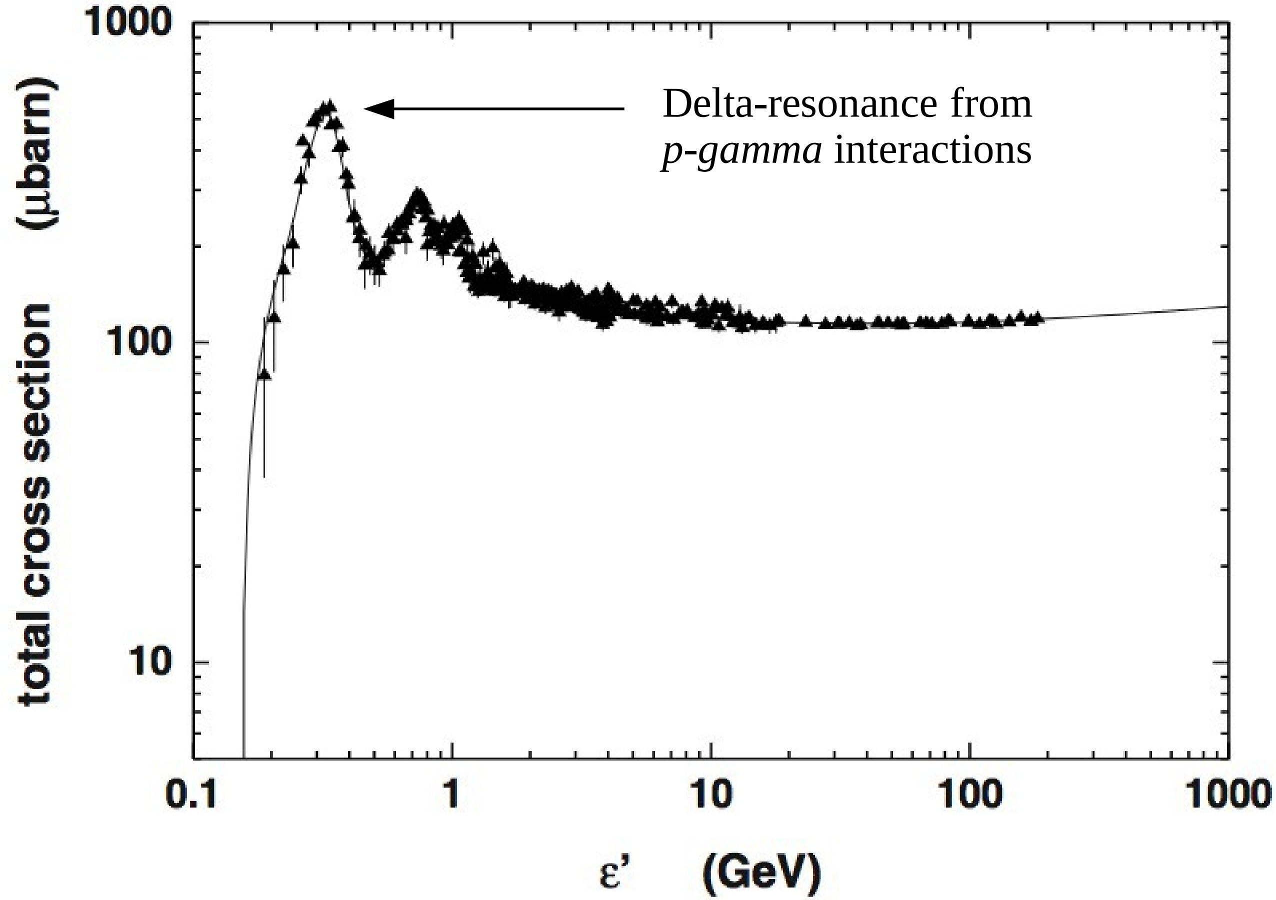
$$\gamma + e \rightarrow \gamma + e$$

$$\gamma + \gamma \rightarrow e^{+} + e^{-}$$

$$\gamma + N \rightarrow N + e^{+} + e^{-}$$



With 10^{15} eV energy, photons do not reach us from the edge of our galaxy because of their small mean free path in the CMBR



A UHE cosmic ray proton interacting with a cosmic microwave background (CMB) photon ***is the same as*** a 300 MeV photon interacting with a proton at rest

UHE neutrinos are an expected by-product, with a electroweak eigenstate distribution of ***1:2:0 oscillating to 1:1:1 after propagating to Earth***

High Energy Cosmic Rays, 2nd Ed. Todor Stanev, p. 226

$$p^+_{CR} + \gamma_{2.7\,K} \rightarrow \Delta^+ \rightarrow p^+ + \pi^0 \rightarrow p^+ + 2\gamma$$

$$p^+_{CR} + \gamma_{2.7\,K} \rightarrow \Delta^+ \rightarrow n^0 + \pi^+ \rightarrow n^0 + \mu^+ + \bar{\nu}_\mu \rightarrow n^0 + e^+ + \bar{\nu} + \nu_e + \bar{\nu}_\mu \quad \mu$$

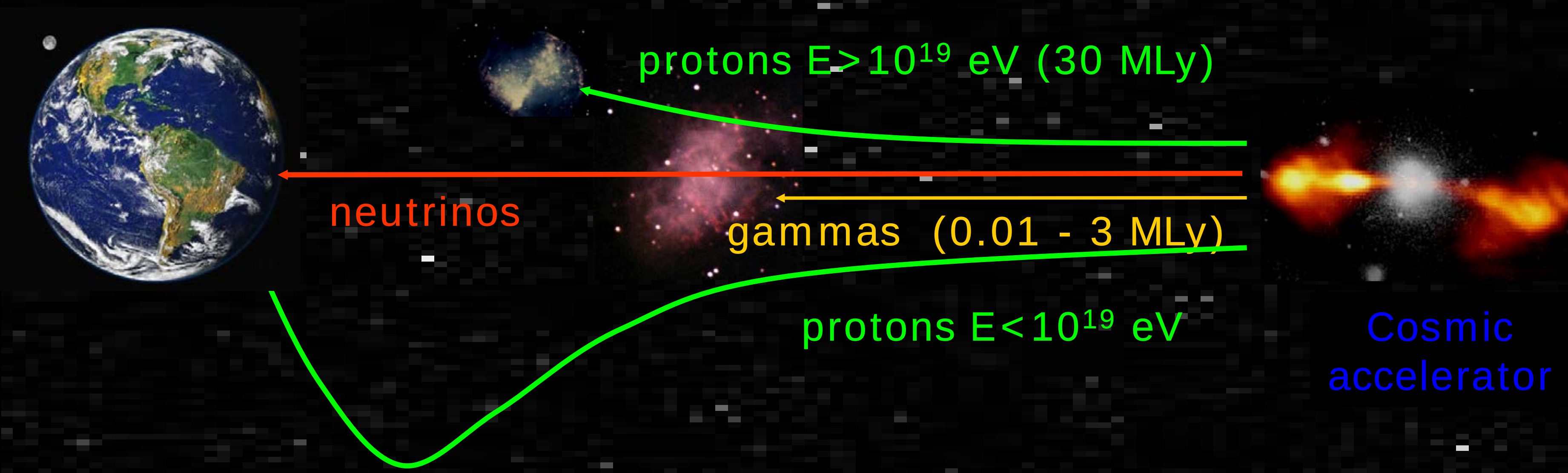
Apologies typography…

UHE neutrinos: ~1/20 the energy of the incident cosmic ray
High energy gamma rays: interaction twice as likely (isospin)

ν's are the "perfect" messengers

can reach us from cosmological distances

can escape optically thick sources

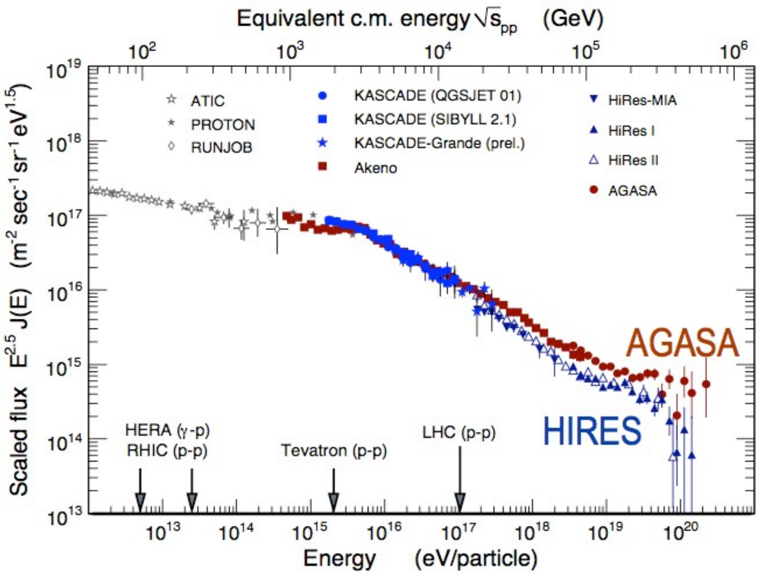


Photons: absorbed on dust and radiation

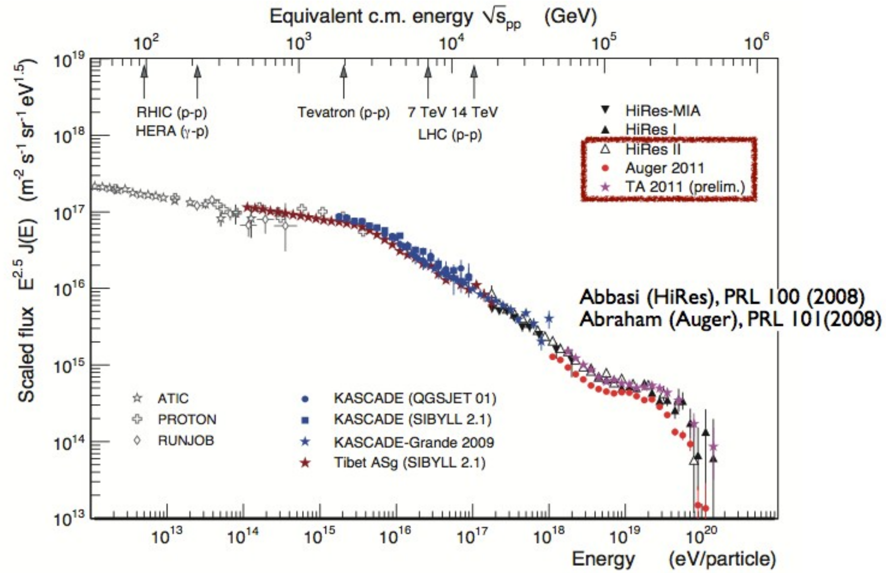
Katz

High energy (> 10^{15} eV) photons do not reach us from the edge of our galaxy because of their small mean free path in the CMBR

Cosmic Ray Spectrum



before 2008

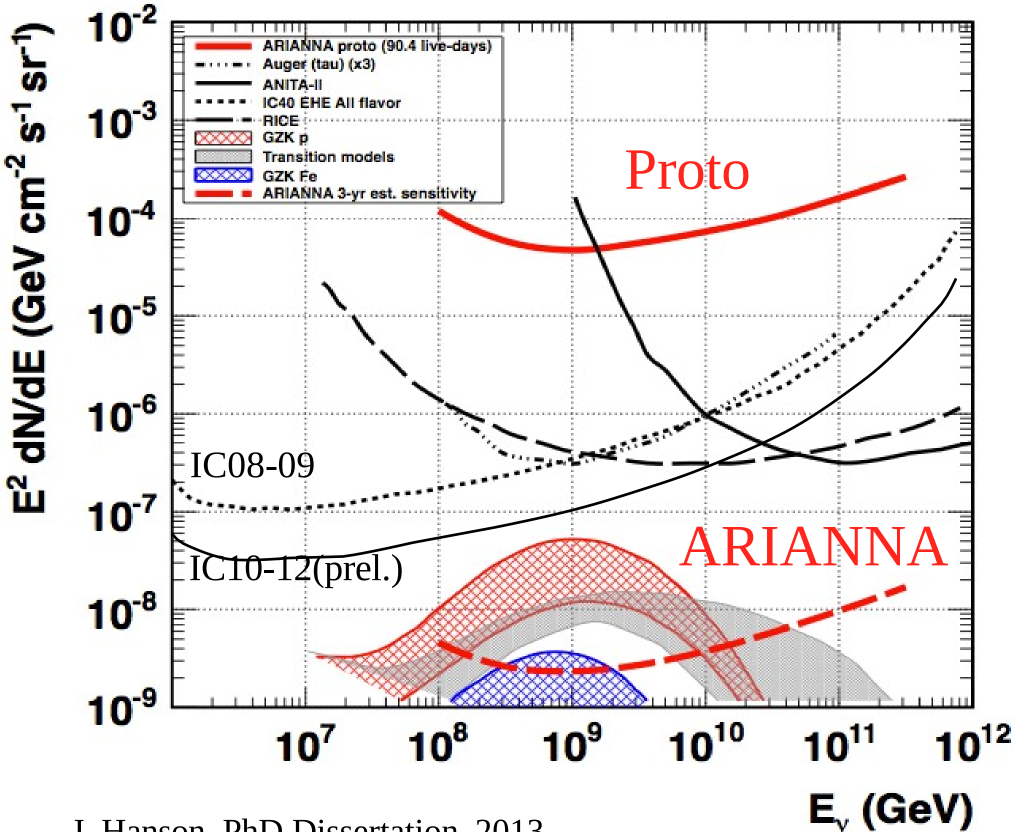


after 2008

- *The cosmic ray energy spectrum. The GZK suppression (which was not observed by AGASA) has been detected by the more recent experiments HiRes, Auger and Telescope Array (from [3]).*

Influential NRC Committee on Physics of the Universe articulated
"How do cosmic accelerators work and what are they accelerating?"
as one of 11 science questions.

Cosmogenic neutrino flux



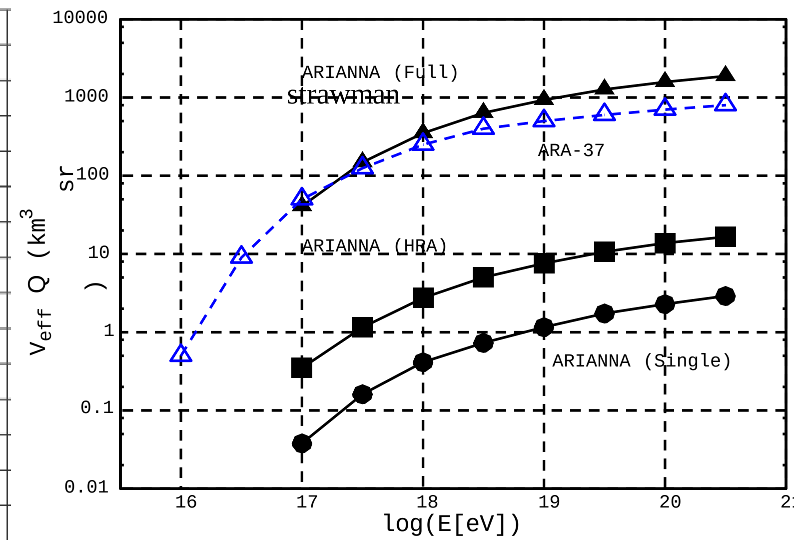
J. Hanson, PhD Dissertation, 2013
Fig. adapted from
Kampert&Unger

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

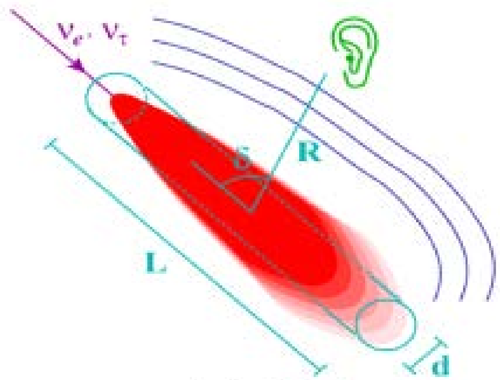
Acoustic detector?

in ice : λ_{abs}(radio)~ λ_{abs}(sound)~1000m cf λ_{abs}(optical)~100m

G.A. Askaryan JETP 14 (1962) 441
G.A. Askaryan, At. Energ., vol 3/8 (1957) 152

Radio methods

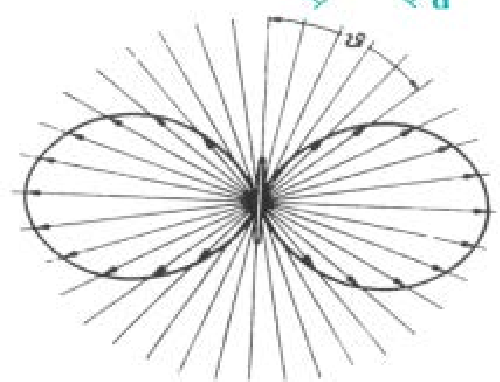
- detect mainly the hadronic showers from ν's interacting via CC or NC
- such showers in matter develop a (10-30)% e^- over e^+ excess since target material contains atomic e^-'s
- resulting EM emission coherent for wavelengths longer than lateral shower size (O(few cm))
- effect confirmed by measurements in silica sand, and in ice.



Acoustics methods (only on next slide)

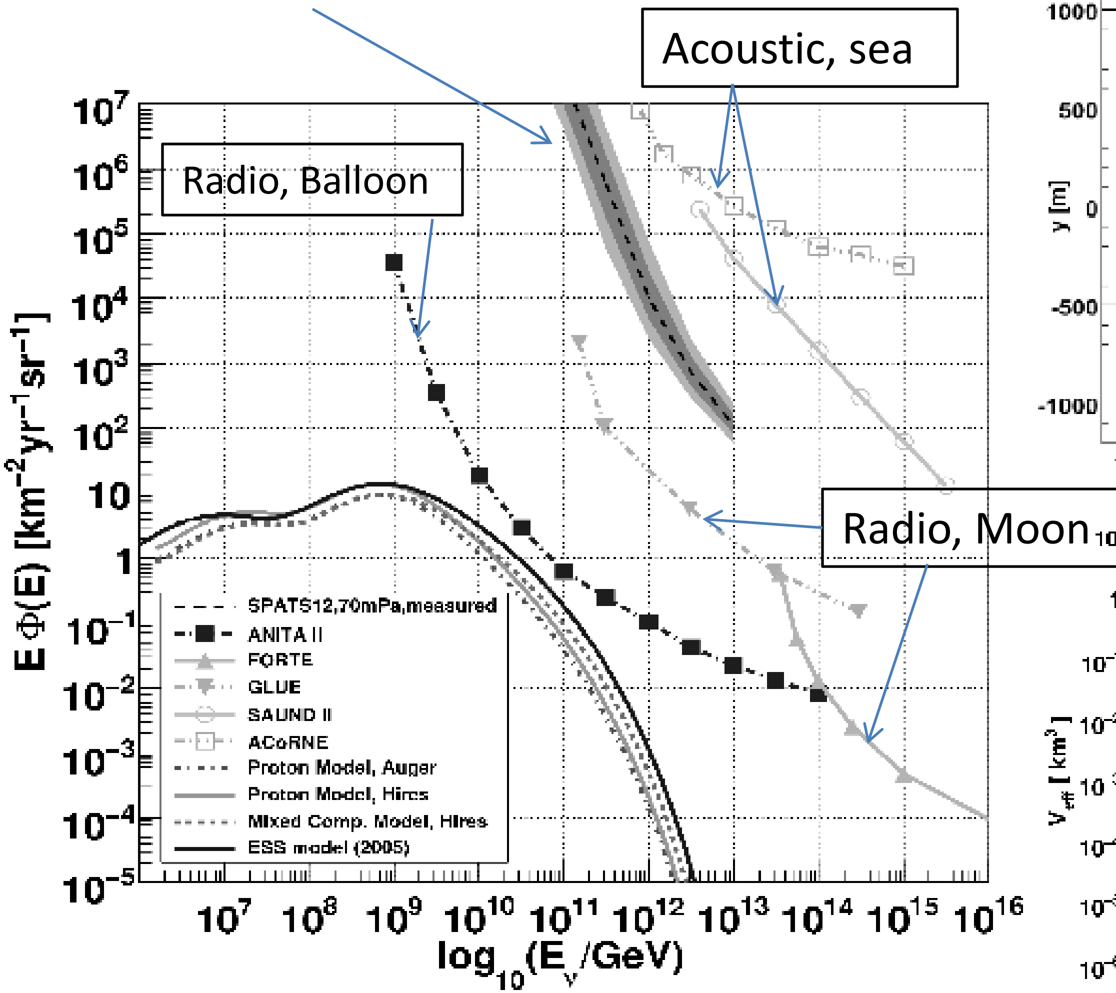
- a ν at 10^{21} eV produces a shower which deposits ~ 30J of heat in a highly localized region
- pressure pulse propagates outward
- pressure amplitude measures energy
- pressure distribution measures incoming direction

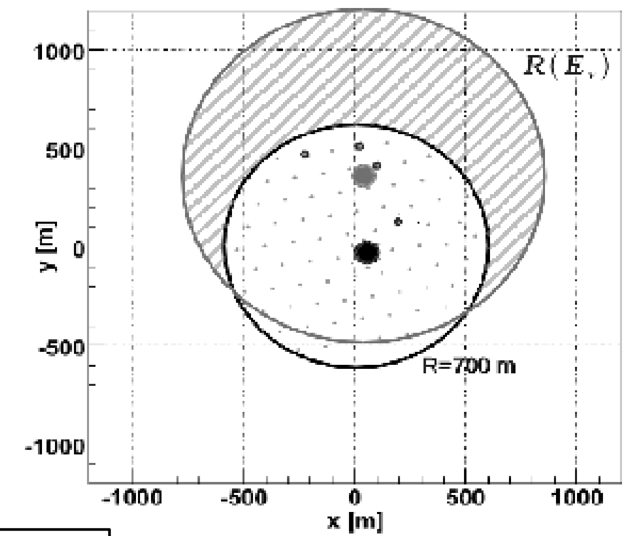
•Tested by group in IceCube, SPATS, actual $\lambda_{abs,ice}$<500 m

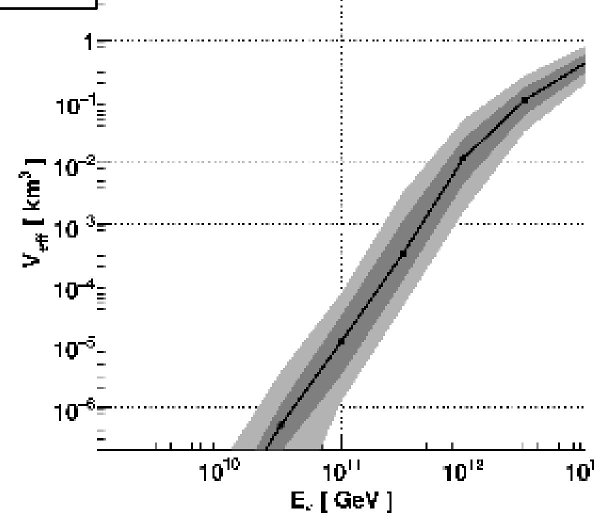


ApP 35 312-324 (jan 2012)

SPATS neutrino flux limit







arXiv:astro-ph/1103.1216 accept. in APP

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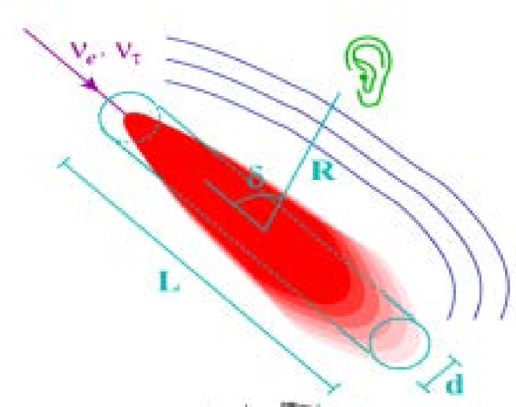
- resulting EM emission coherent for wavelengths longer than lateral shower size (O(few cm))
- effect confirmed by measurements in silica sand, and in ice.

- Two ice-based proposals, ARIANNA and ARA



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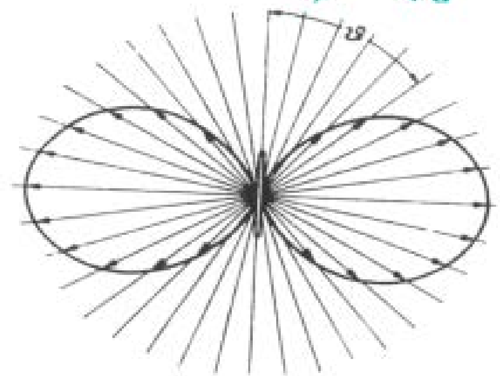
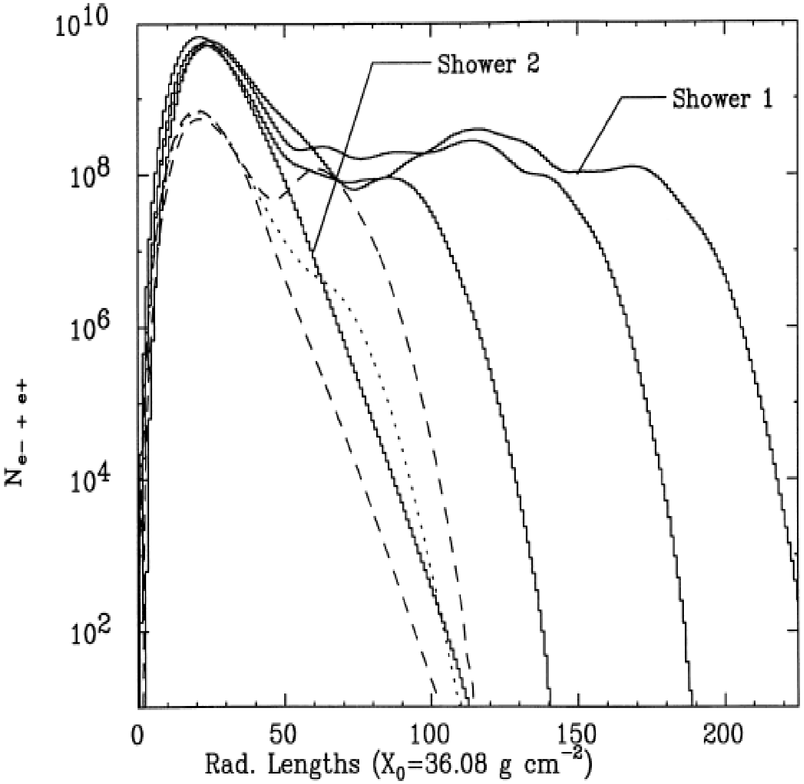


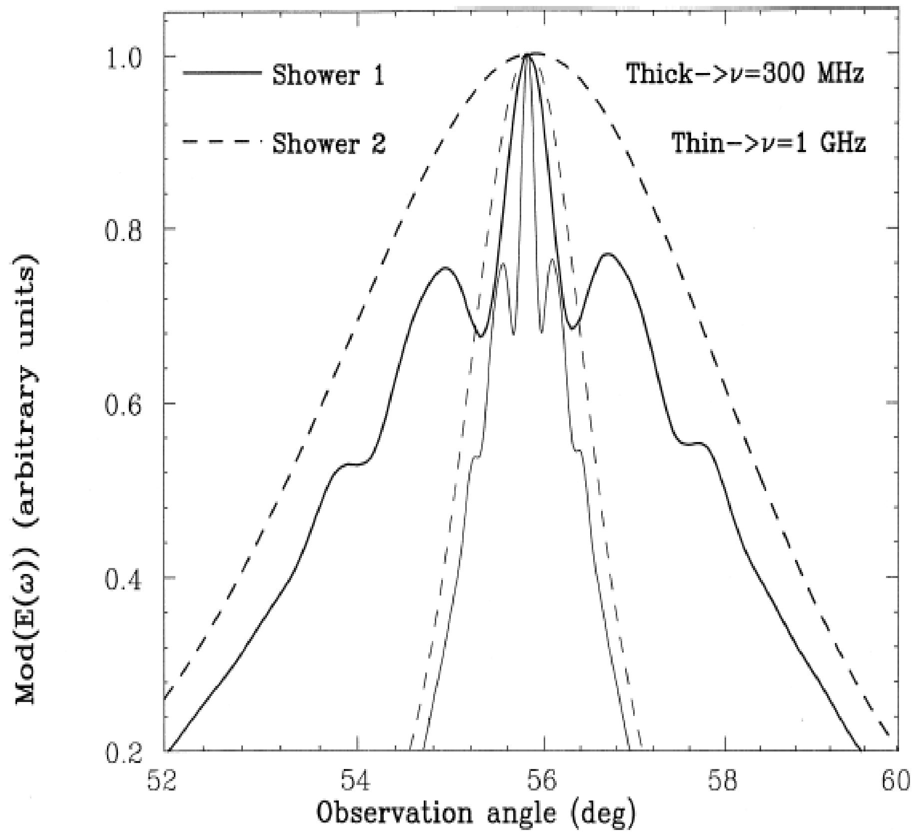
- Need to go close to emission to lower the energy threshold -> embedd antenna in medium.
- Need large volume target with good radio transmission
- Need low noise environnement

Below I concentrate on ARIANNA

Something on ARA at the end

Shower development differences → Radio emission differences

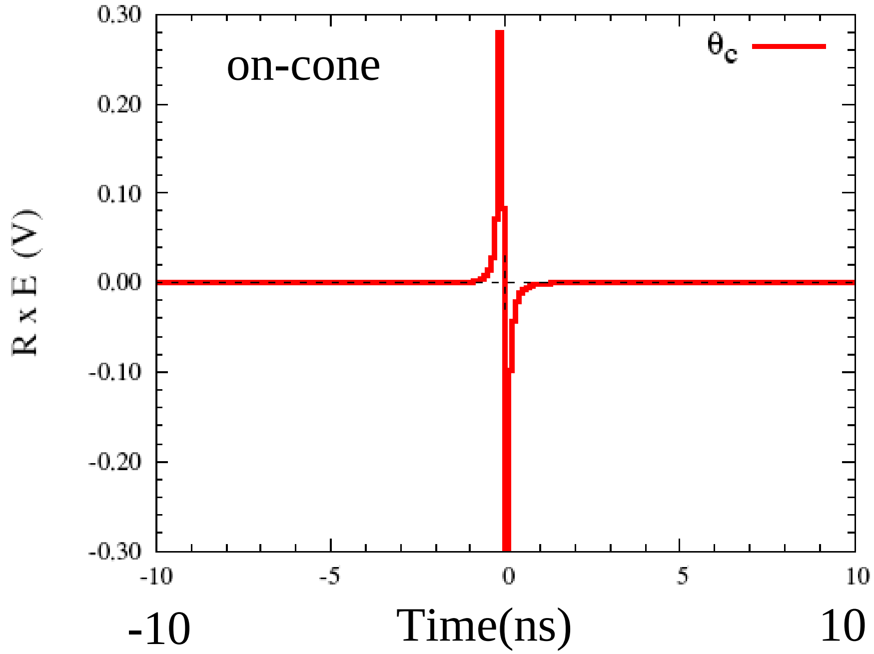


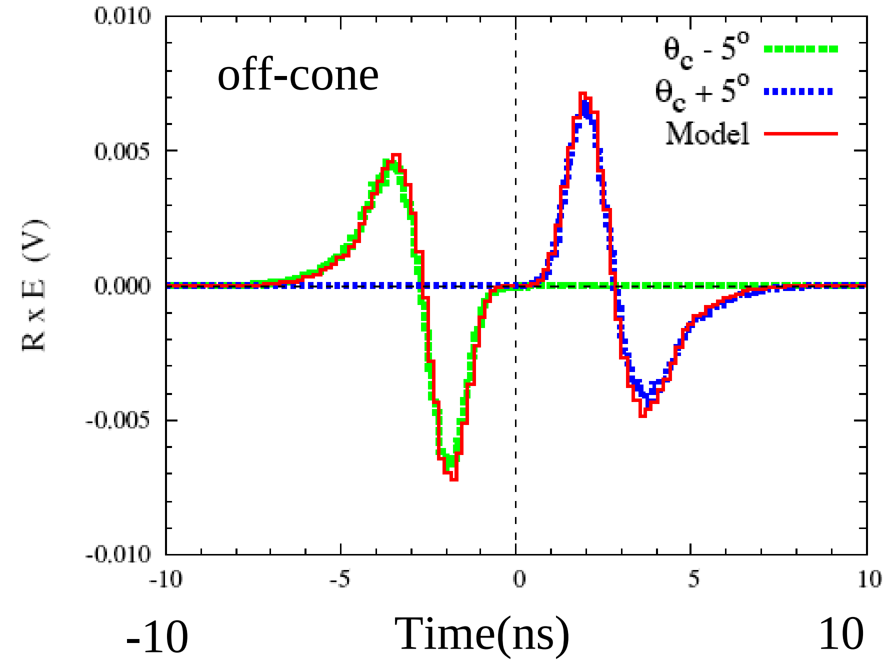


- *Left: Shower development of individual showers of energies 10^{19} eV (solid lines) and 10^{18} eV (dashed).*
- *Right: Radio pulse angular distribution around the Cherenkov angle illustrating the individual variations from shower to shower at the same energy, and the narrowing of the angular distribution with higher frequency (from [6]).*

From KAW application febr 2013

Time-domain is rich in information





J. Alvarez-Muniz, A. Romero-Wolf, and E. Zas, arXiv:1002.3873v1

Counting neutrinos

A high-energy neutrinos constantly stream through all objects on Earth. Occasionally, a neutrino hits the nucleus of atoms and generates a blast of particles, generating a pulse of radio emissions that can be recorded. Here is a look at why the antarctic is a good place to monitor those radio emissions:

31 * 31 stations

Goal for Arianna array field is for 960 monitor stations.

NEUTRINOS ENTER ICE

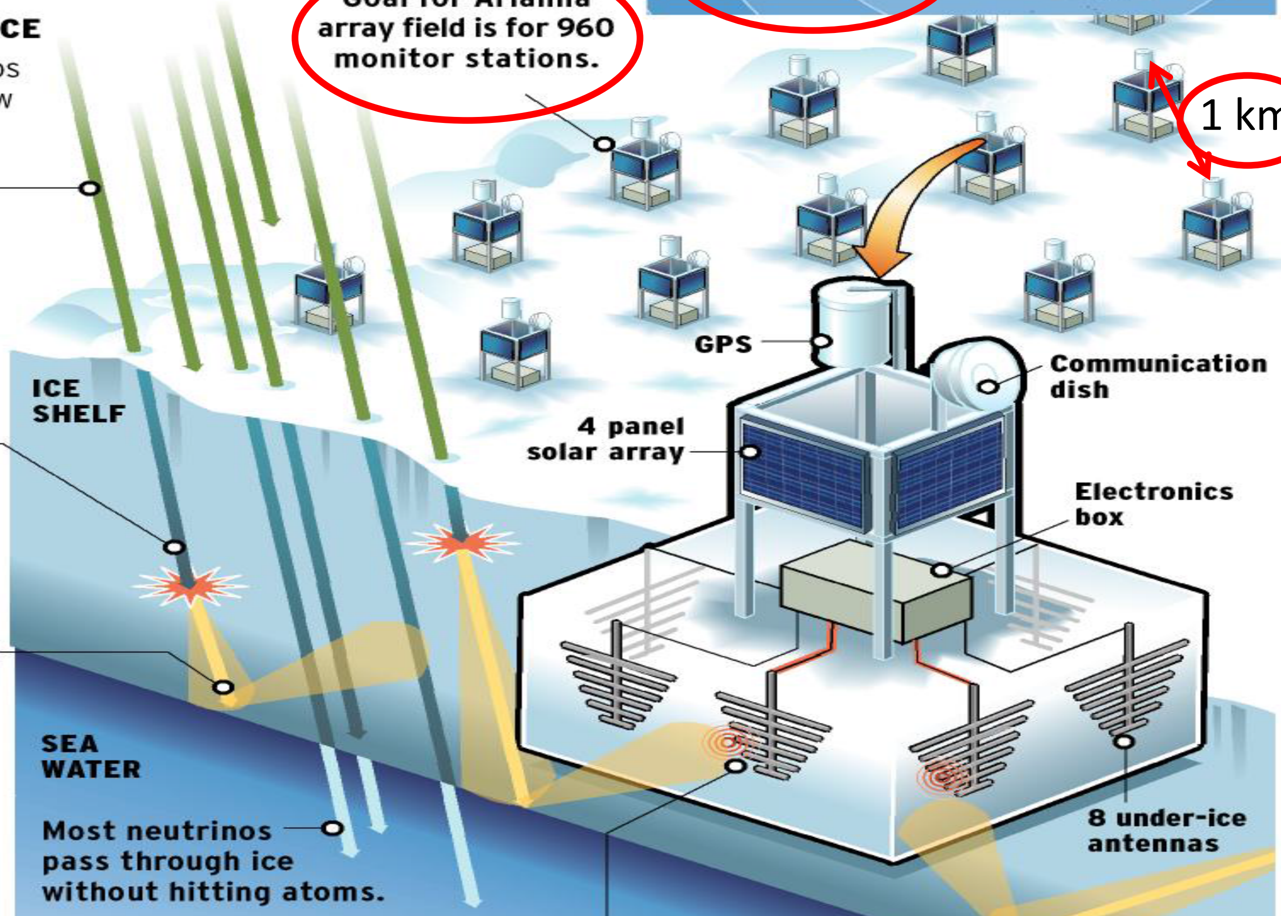
1 Countless neutrinos enter the ice, a few occasionally strike hydrogen and oxygen atoms in the ice.

COLLISION IN ICE

2 The force of the collision blasts particles from the nucleus of the atoms. The spray of particles emit radio waves in the form of a "cone" that points in the same direction that the neutrino was moving.

BLOCKED BY WATER

3 The Ross Ice Shelf is ideal for monitoring these emissions due to the water below the ice blocking the radio emissions. They bounce off the water and travel back through the ice.



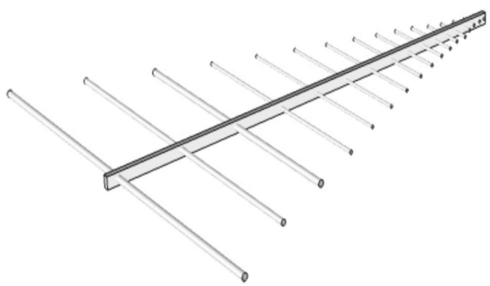
RECORDED BY MONITORING STATION

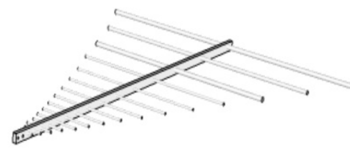
4 Since the emissions pass through the ice, they are eventually picked up by a monitoring station, which has eight antennas buried in the ice. The station collects and transmits the level of neutrinos based on the amount of particle emissions.

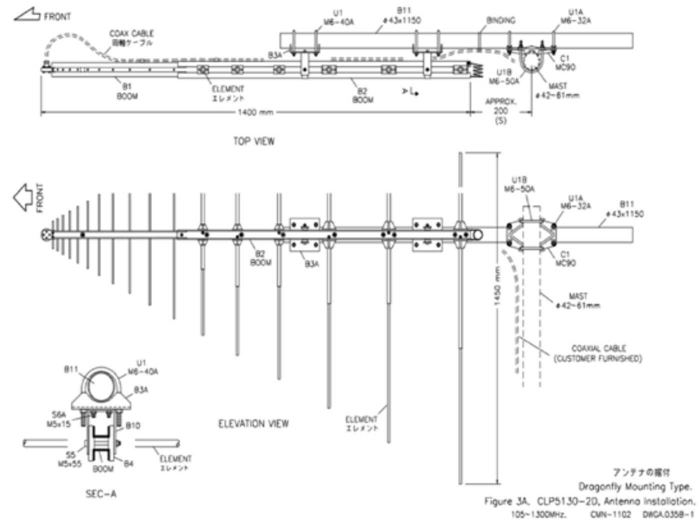
Source: UCI Professor Steven Barwick

Graphic by Scott Brown / The Register

The signal antenna: Log-Periodic Dipole Array







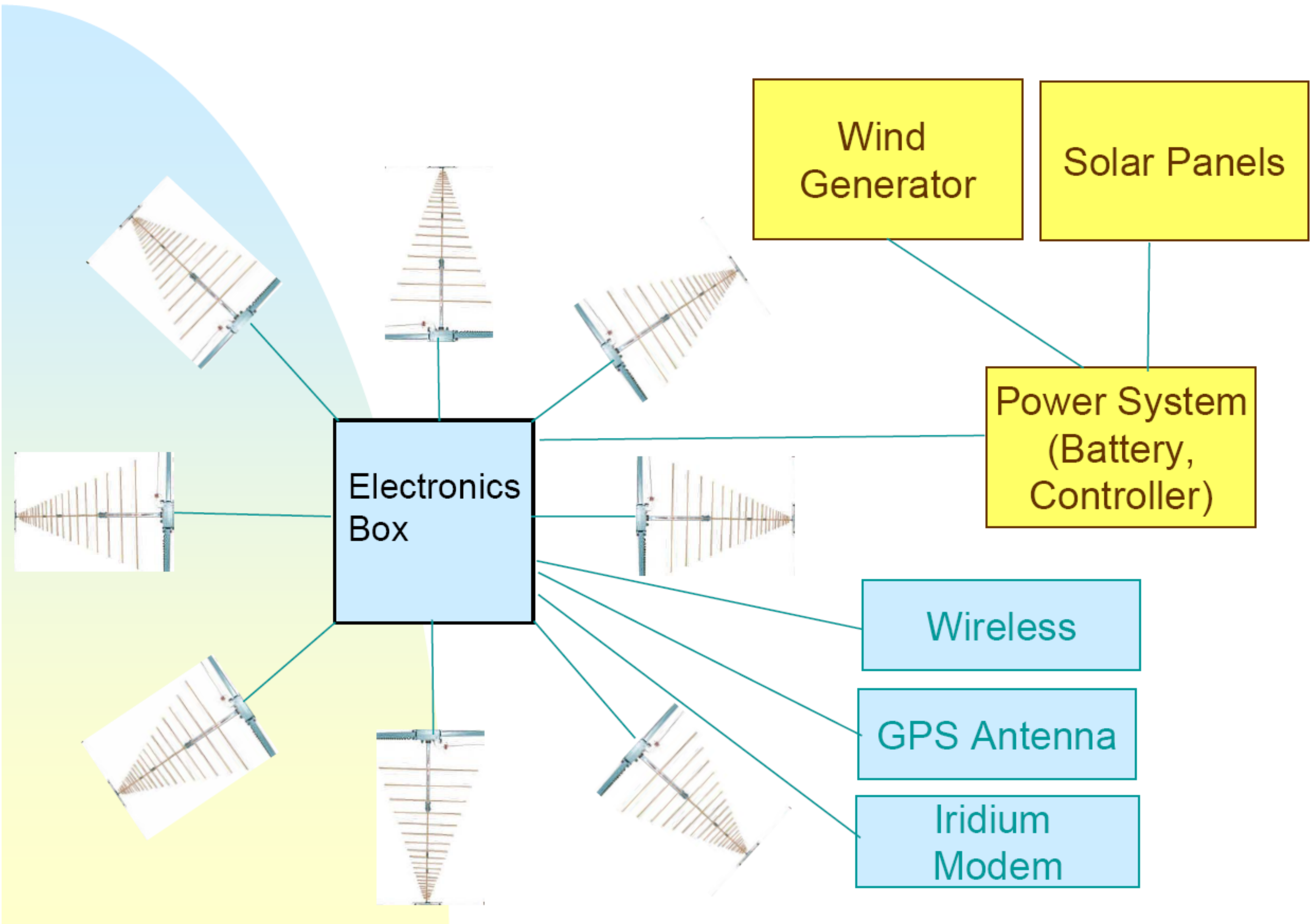
Example of a ***frequency-independent*** antenna (bandwidth of 100-1300 MHz)

Radiation pattern is maximal in direction of ***bore-sight*****.** The *bore-sight* configuration (shown above) optimizes reception.

Linearly polarized**.** The E-plane is the plane containing the dipole elements, the H-plane is perpendicular to E-plane, containing only the spine of the antenna

spine of the antenna

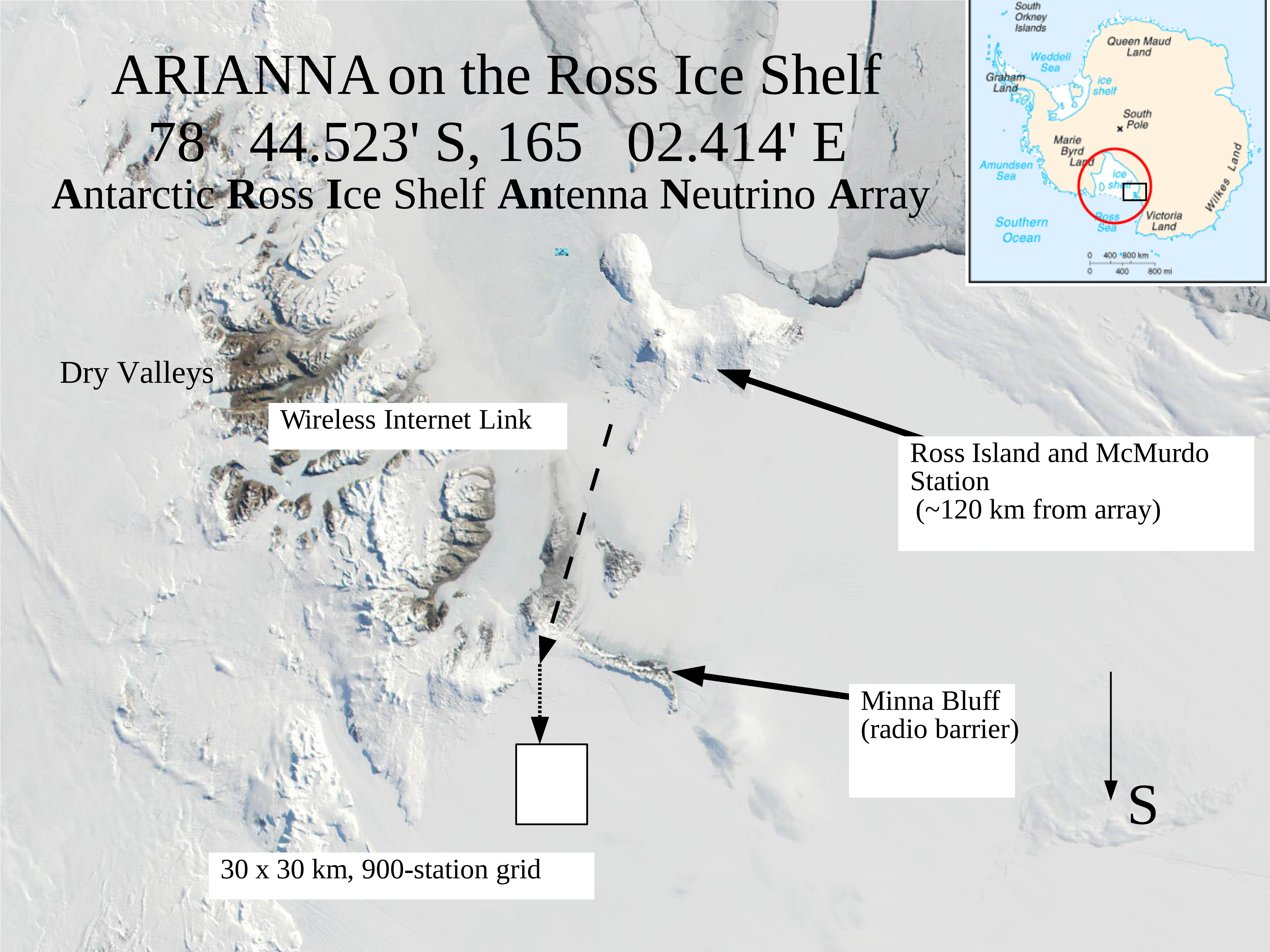
ARIANNA Detector



ARIANNA on the Ross Ice Shelf

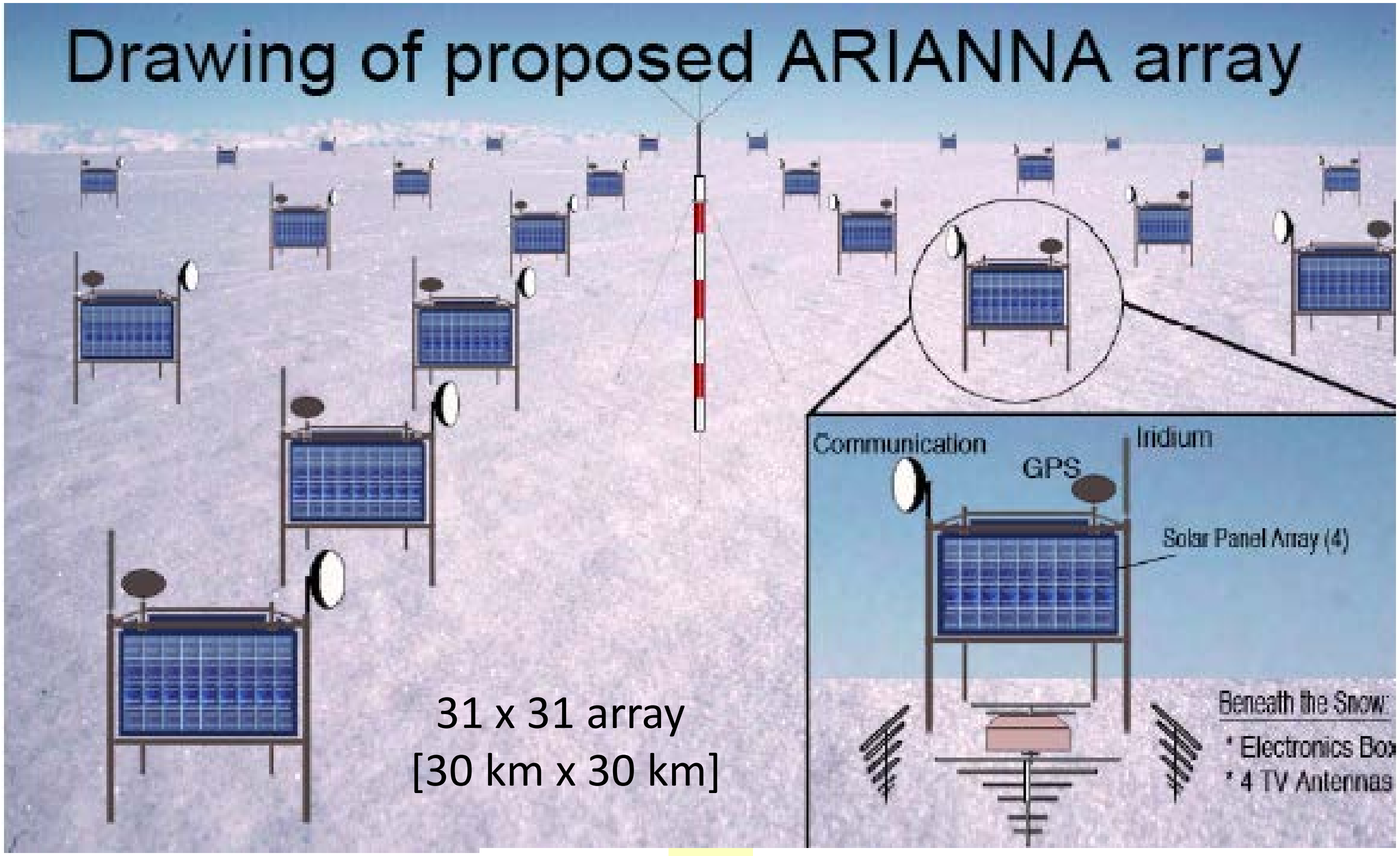
78   44.523' S, 165   02.414' E

Antarctic **R**oss **I**ce Shelf **An**tenna **N**eutrino **A**rray

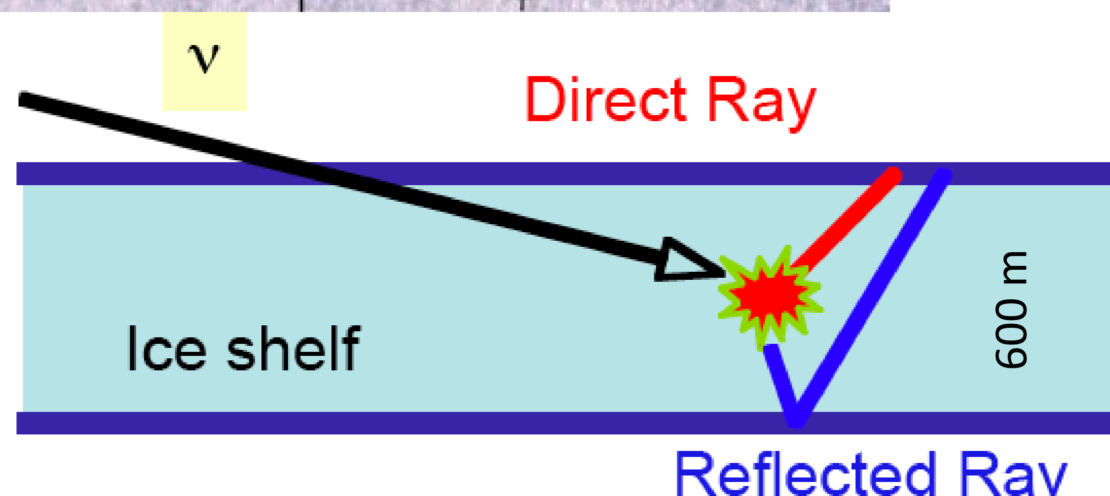


ARIANNA Advantages

- 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



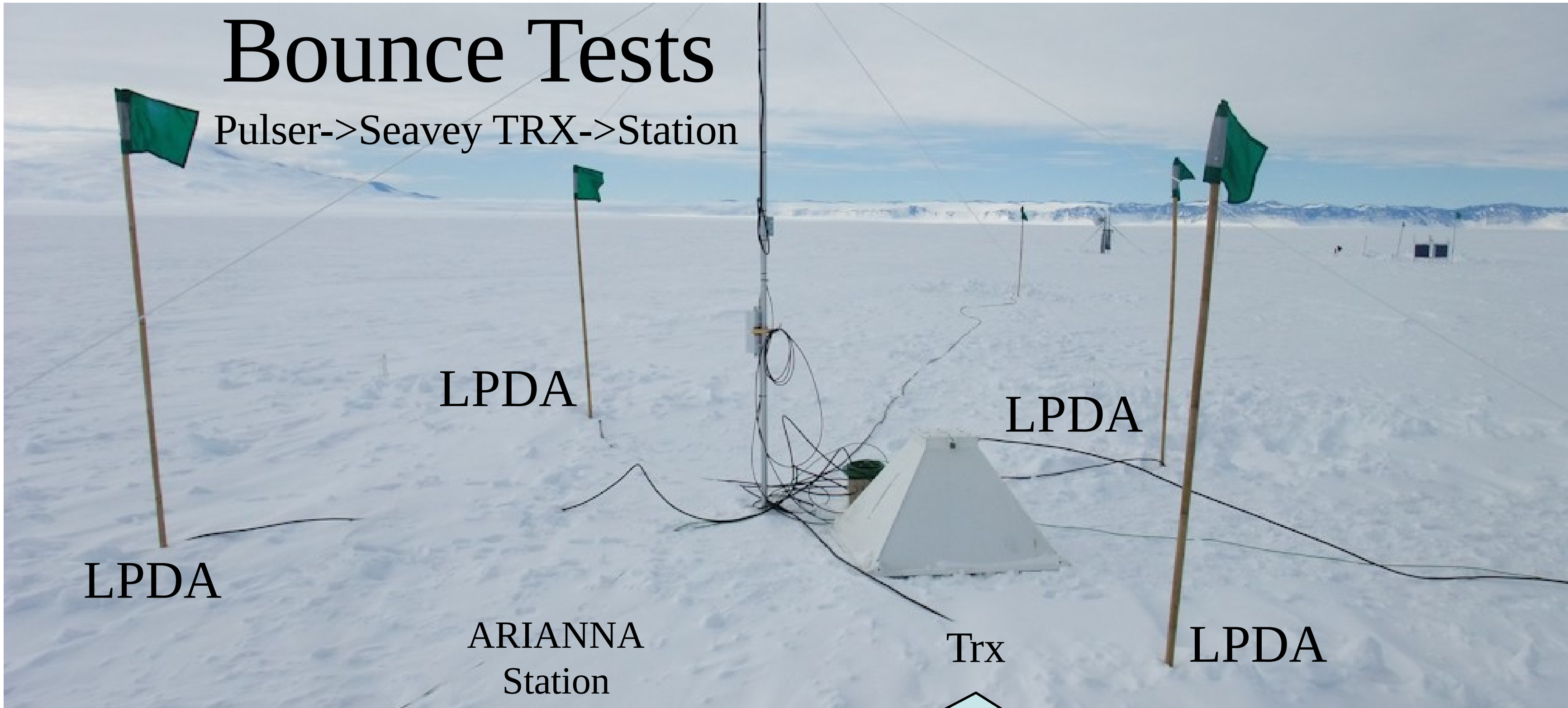
ARIANNA

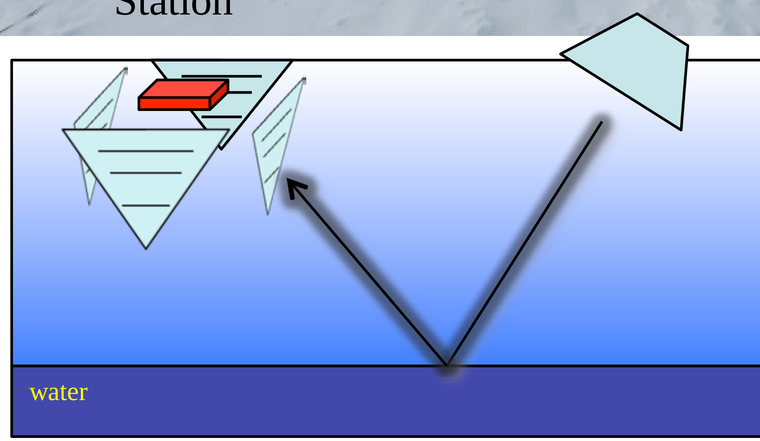


Barwick, astro-ph/0610631

Bounce Tests

Pulser->Seavey TRX->Station

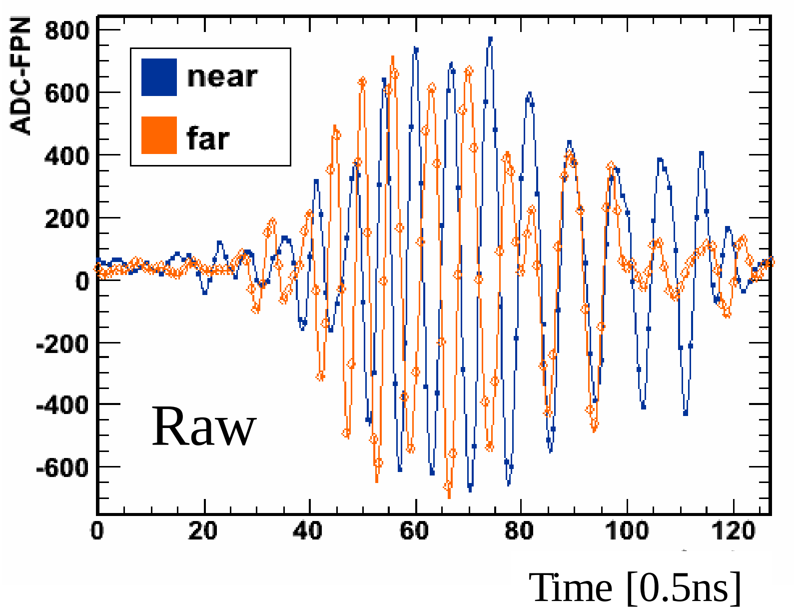


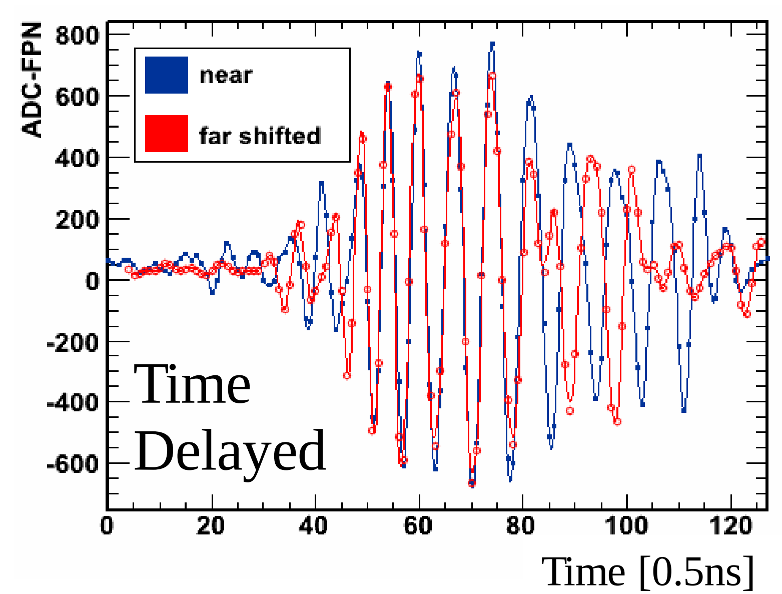


See C. Reed contribution in Wed poster session

Bounce Tests

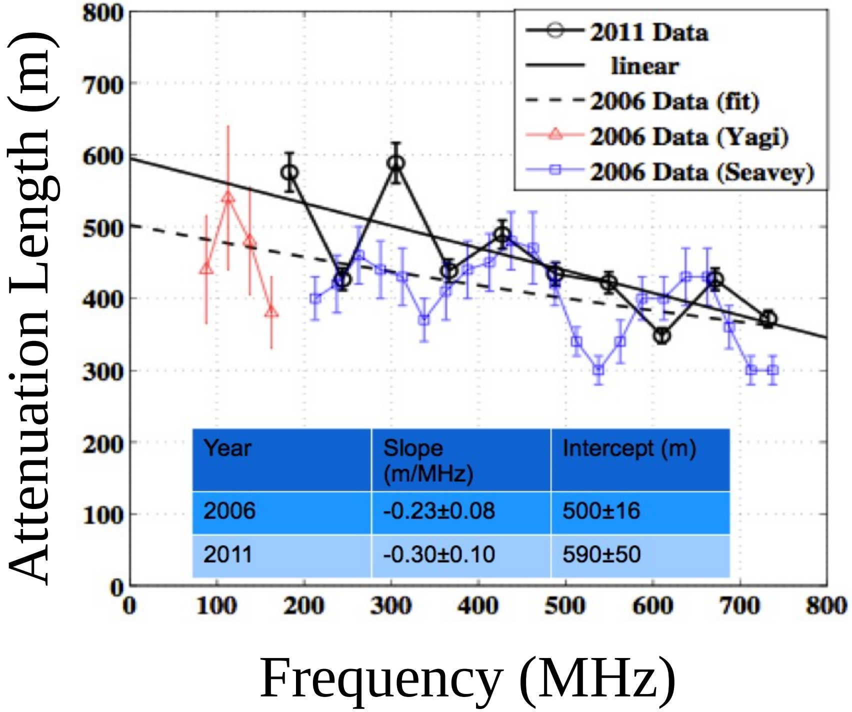
Pulser->Seavey TRX->Station





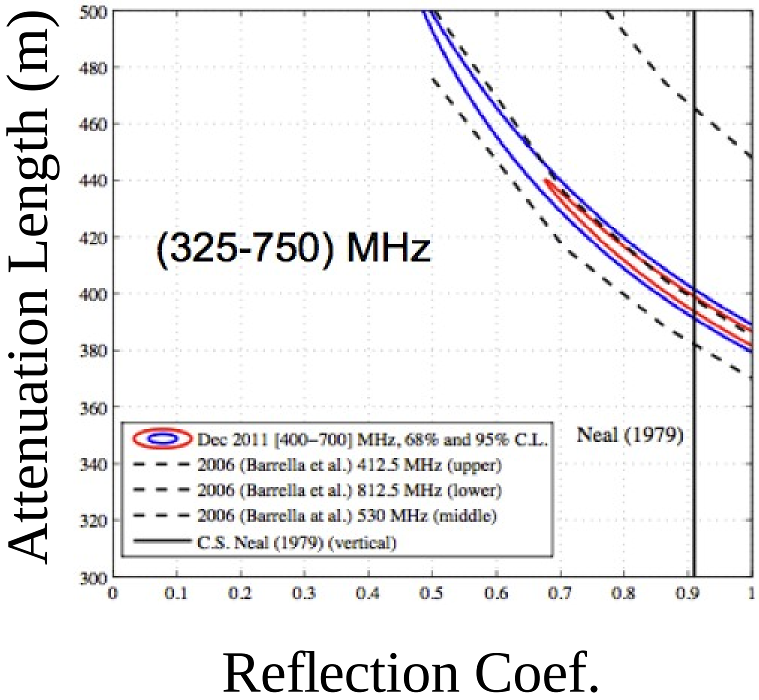
Notes: Time delays are determined from all 4 antennas, compatible with plane wave

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

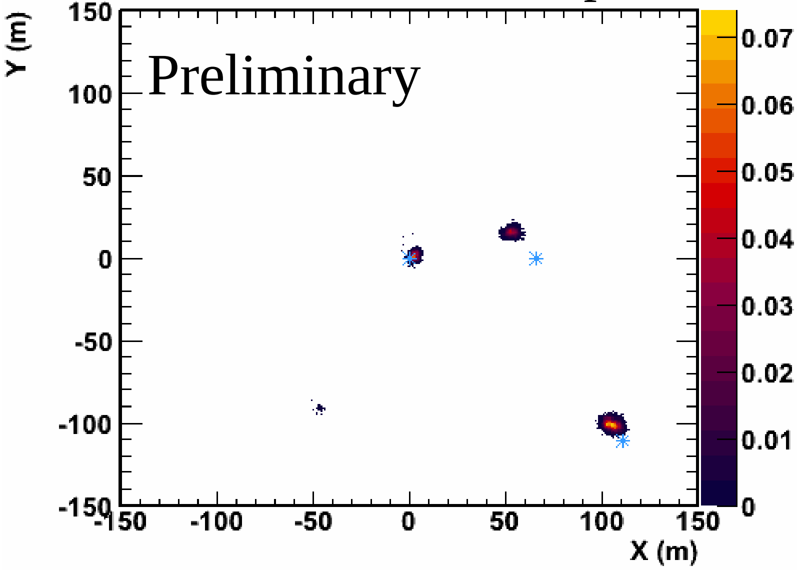


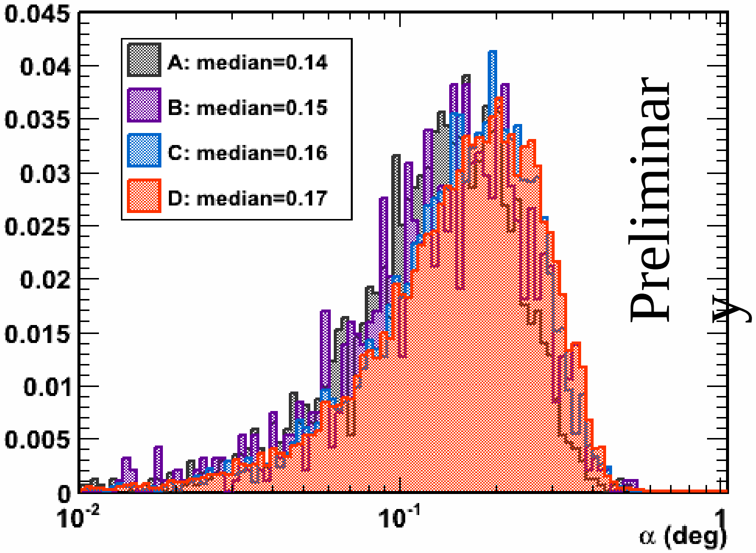
Reflection consistent with **<u>flat reflector</u>** ($R^{1/2}$=0.92)

Bounce Tests

Pulser->Seavey TRX->Station

Reconstructed source position



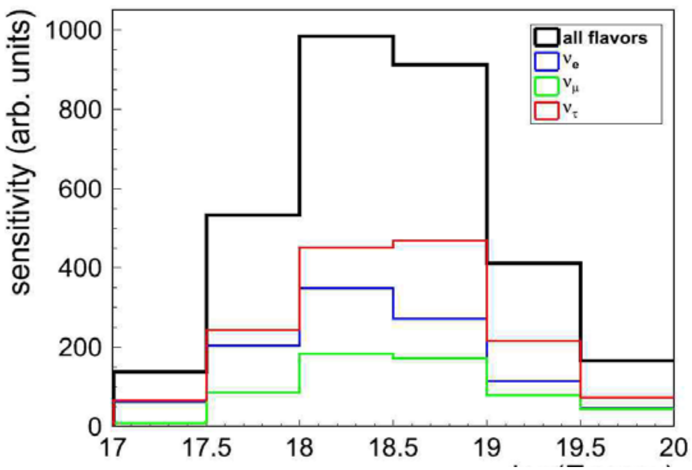


space-angle - <space-angle>

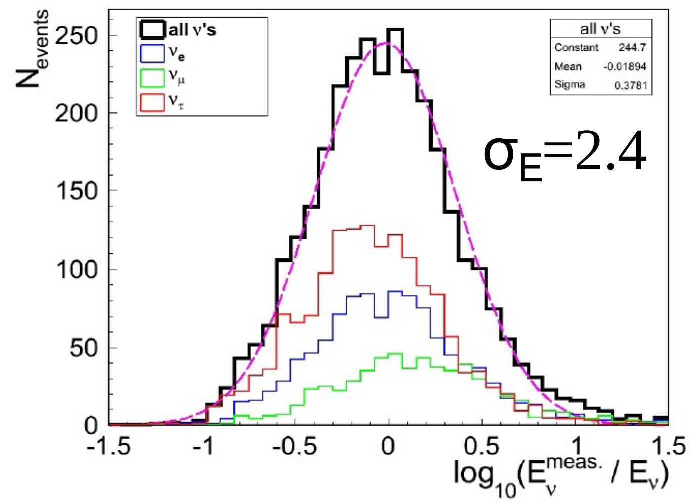
C.Reed, IPA 2013

~0.16 deg angular resolution for EM wave

ARIANNA Characteristics



log(E_ν) eV



Prelim. , refl., ESS spectrum

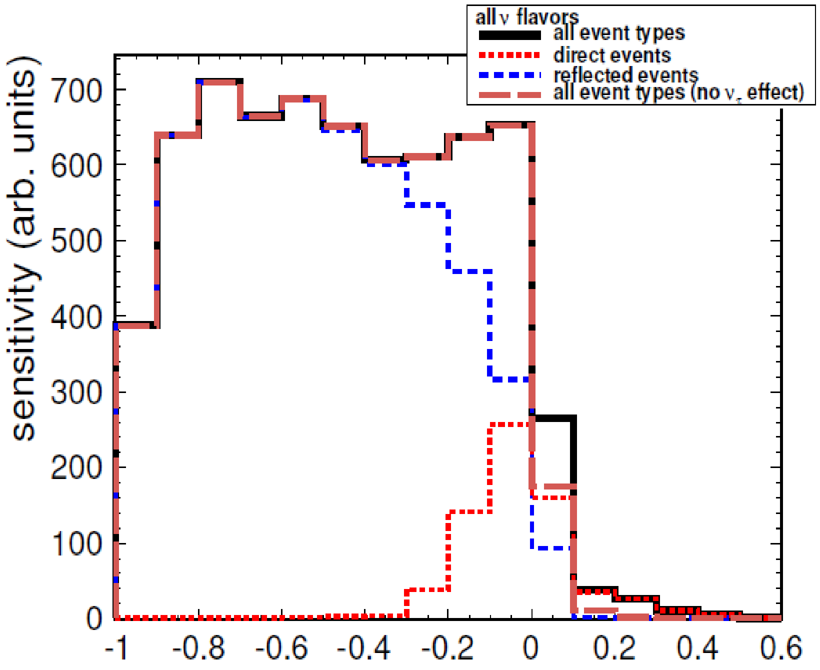
Energy Resolution

Peak response at "sweet spot" of GZK spectrum

Details of waveform give energy info

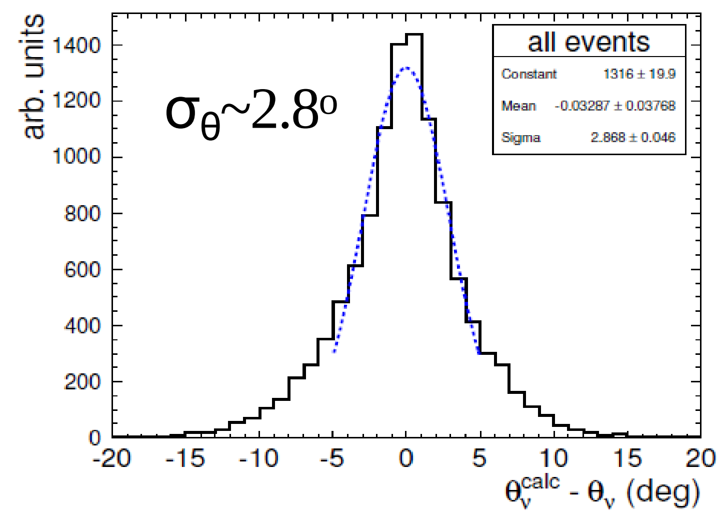
K. Dookayka, UCI PhD dissertation, 2011

Capabilities

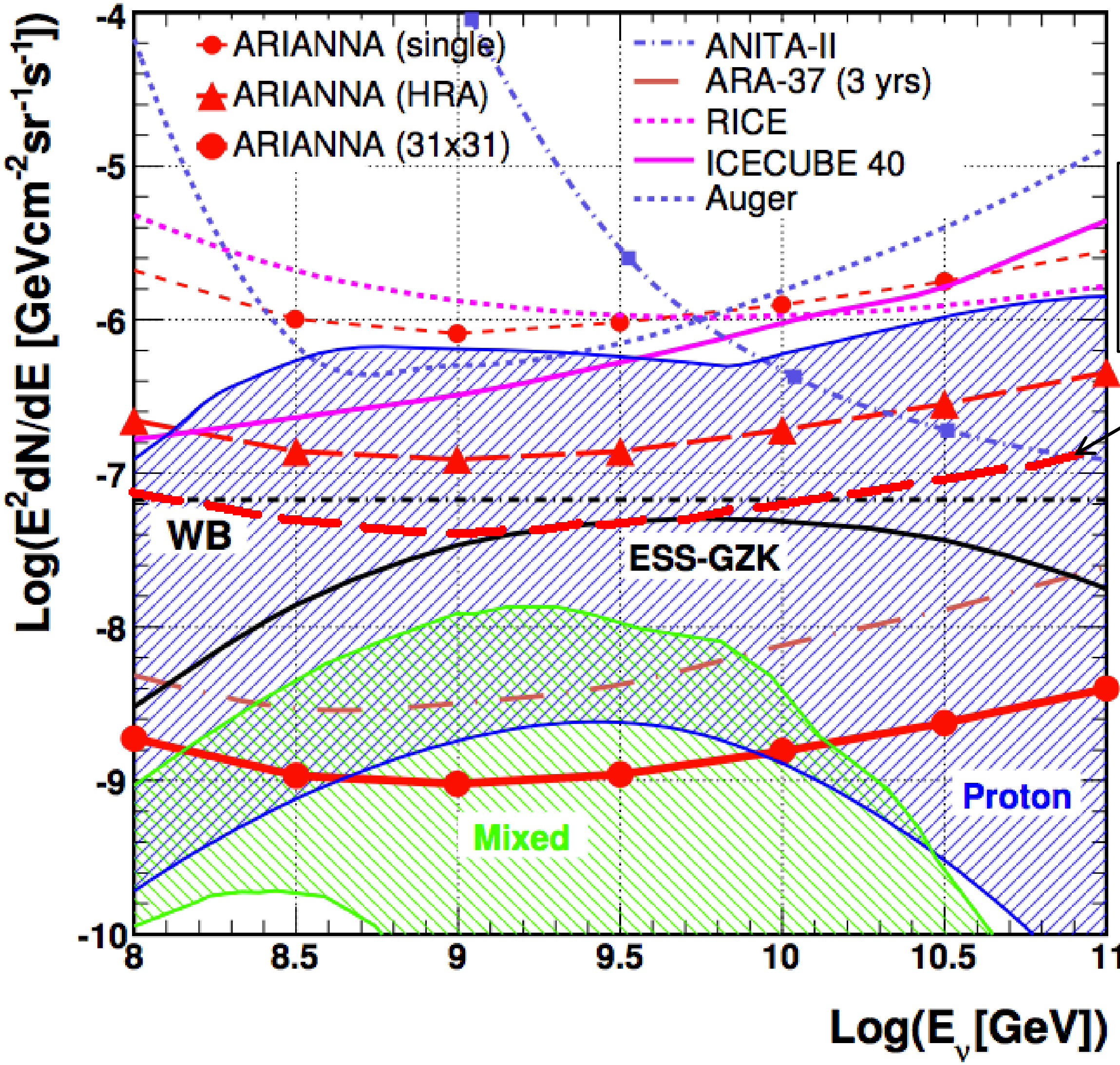


Down horizon $\cos(\theta)$

Angular resolution



K. Dookayka, UCI PhD dissertation, 2011



expected sensitivity of the proposed 19 station array. (from KAW application -13)

ARIANNA
+ ESS Flux:
35 events/yr

Energy Res: dE/E~2.4,
Angular Res: σ_θ~2.8°

From K. Dookayka [11]. References ANITA [9], IceCube 40 [12], Auger [13], RICE [10], ARA-37 [14]. Shaded areas indicate the expectations for the GZK neutrino flux with varying CR composition (proton, mixed). The Engel-Stecker-Stanev (ESS) [15] model is used as standard. The ARA-37 and the ARIANNA sensitivities correspond to 3 years live time. The thick red dashed line indicates the expected sensitivity of the proposed 19 station array.

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	guess
Logistics (3 year install):		~5 M	
Total:		~24.6M	

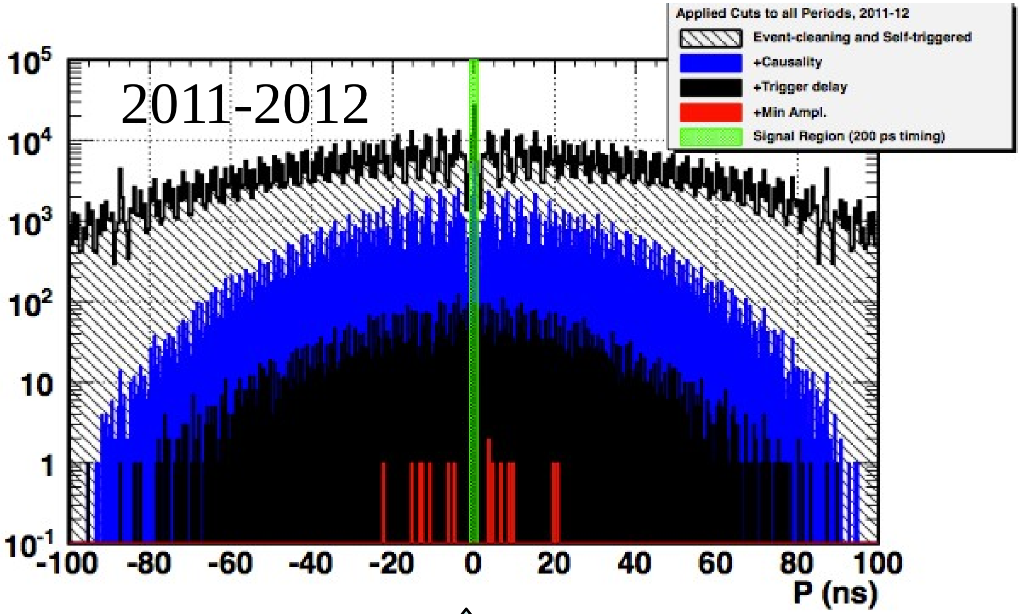
ARIANNA Prototype Station
(deployed in Antarctica Dec. 2009)

Technological Goals

- Station costs: ~$10k US per station
- Fully "green" power system
  - Solar and wind only; no fossil fuels
  - Scalable to vary large areas
- Deployment at rate of 1 station/person/day
- 3 year construction for 960 stations

Protostation Event Analysis

(J. Hanson, UCI Dissertation, 2013)



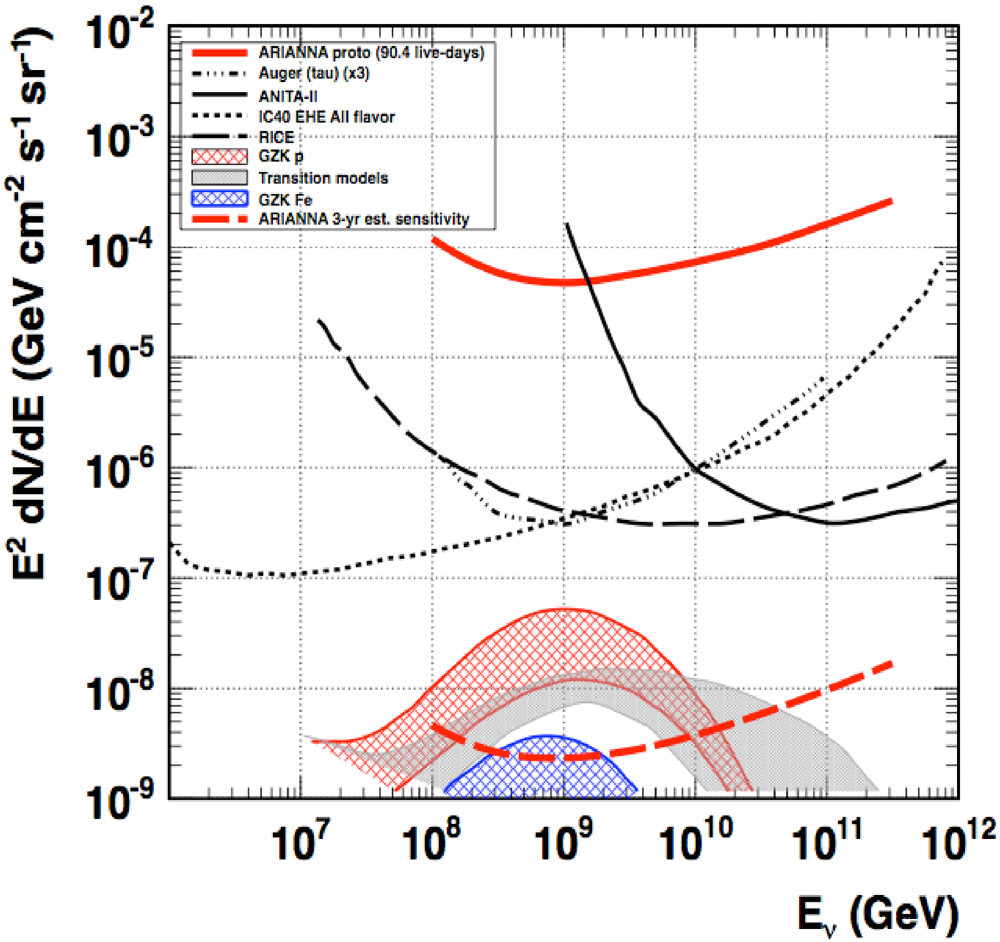
No events in signal region

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	$\|\tau_{ij}\| < nx_{ij}/c$	174043	$\geq 99\%$
T_{pp}	$\geq$ 60 ns all chan.	8077	$\geq 99\%$
A	$\geq$ 5 (excl. West)	15	64.2%
Plane wave	$\|P\| \leq 1.0$ ns	0	$\geq 99\%$
–	–	–	59.5%

2013 Protostation limit



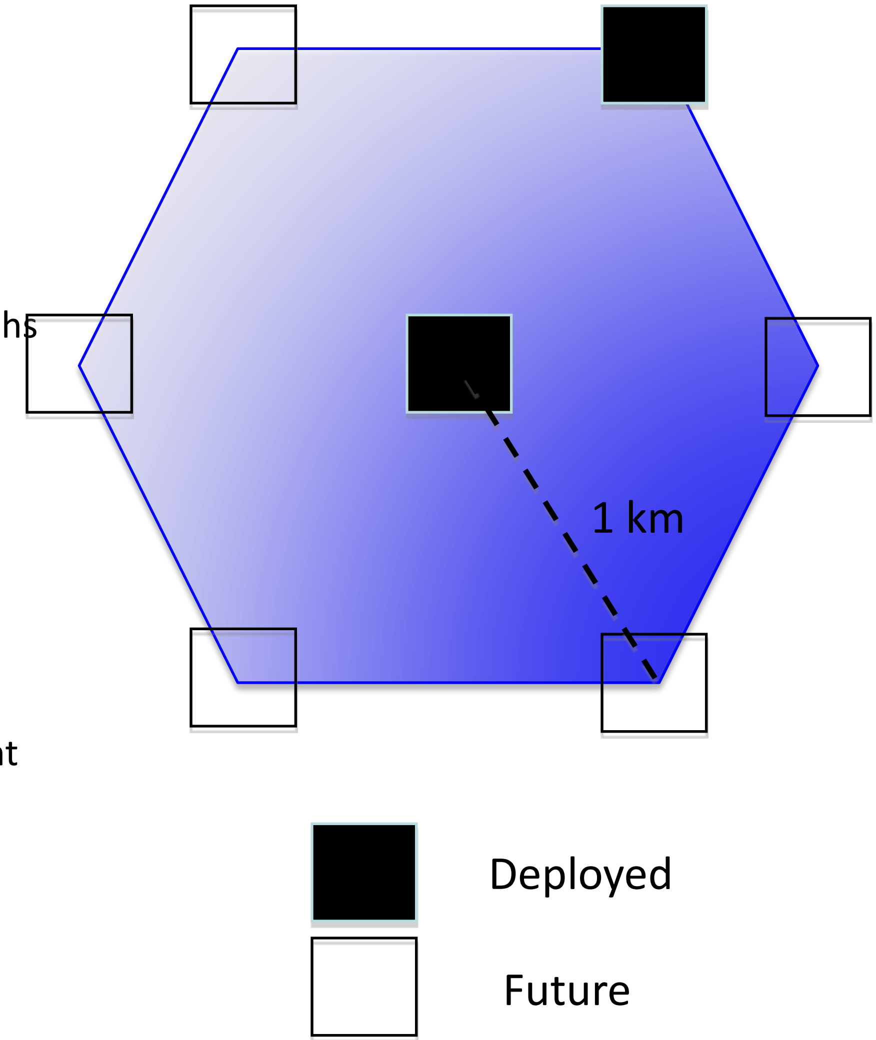
Representative survey of all-flavor neutrino differential flux limits, assuming 1:1:1 flavor ratio where needed, and widely-discussed theoretical predictions for cosmogenic neutrinos (colored and gray bands).

ARIANNA sensitivity is shown for 3 years of operation, assuming 2.3 events per half-decade of energy. See [68] for details of experimental limits, including those from ARIANNA Protostation, which operated from 2009-2012 before decommissioning (figure from [68], adapted from [66]).

Developing the Hexagonal Array

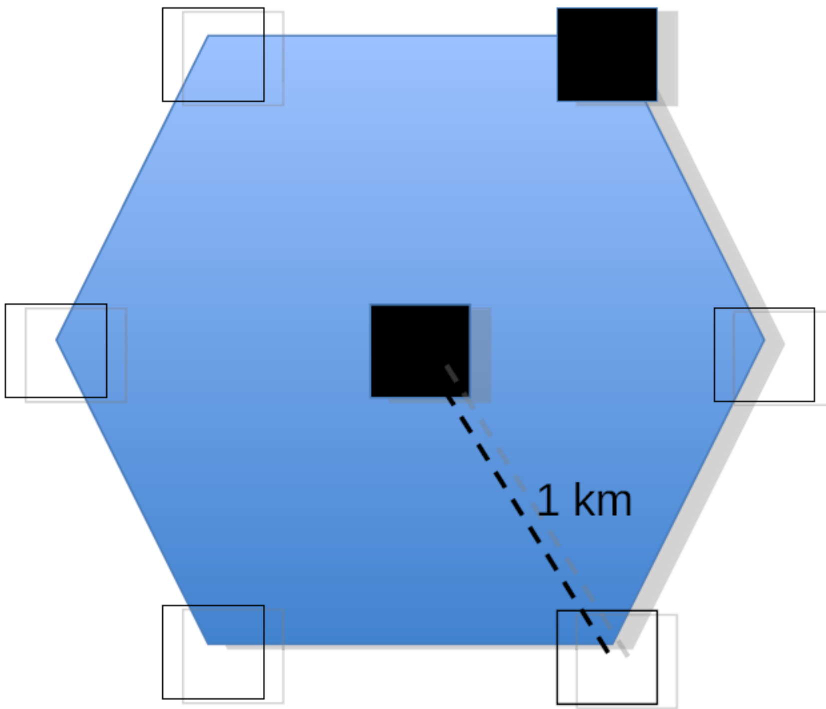
Funded by NSF (OPP, MEP, MRI)

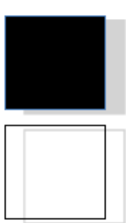
- Nov 2011:
  - Deploy 1 protostation w/new DAQ technologies
  - Establish wireless communication
- Nov 2012:
  - Deploy 3 stations for operation during sunlit months
  - Reduce power consumption to 10W
  - Deploy Wind/Solar system with $LiFePO_4$ battery technology
  - Establish communication/control with low power microcomputer
- Nov 2013
  - Deploy 4 stations to complete hex array
  - Focus on cost reduction and simplified deployment and commissioning
  - Investigate technologies for overwinter operation



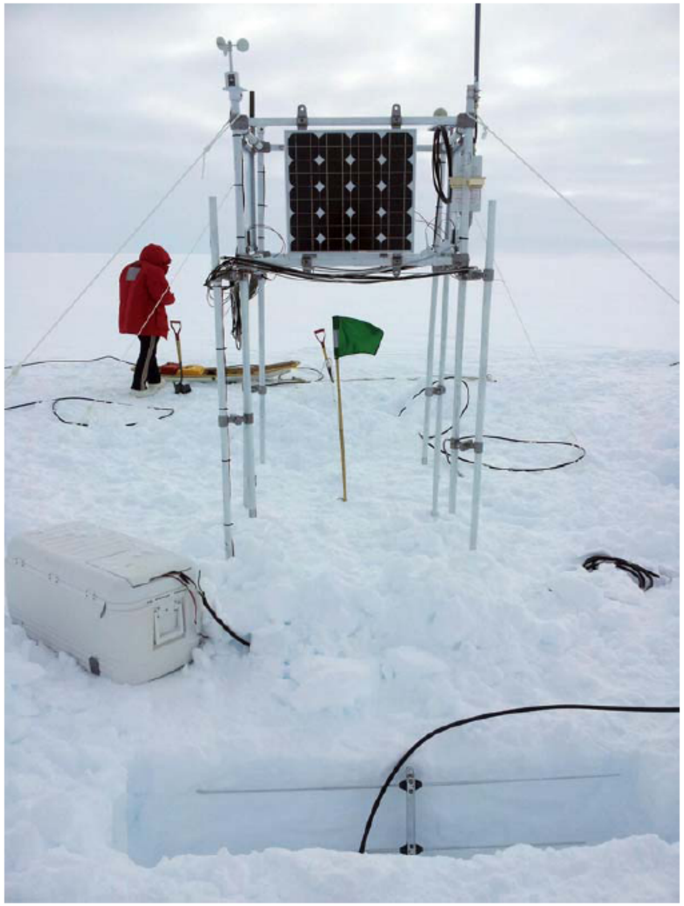
ARIANNA Hexagonal Array-2012

- Funded by OPP, MEP, and MRI within NSF ($900K MRI funding as of Sept. 2011)
- 3 year development and deployment: 3 x 8-ch stations in 2012/13 + 4 stations in 13/14

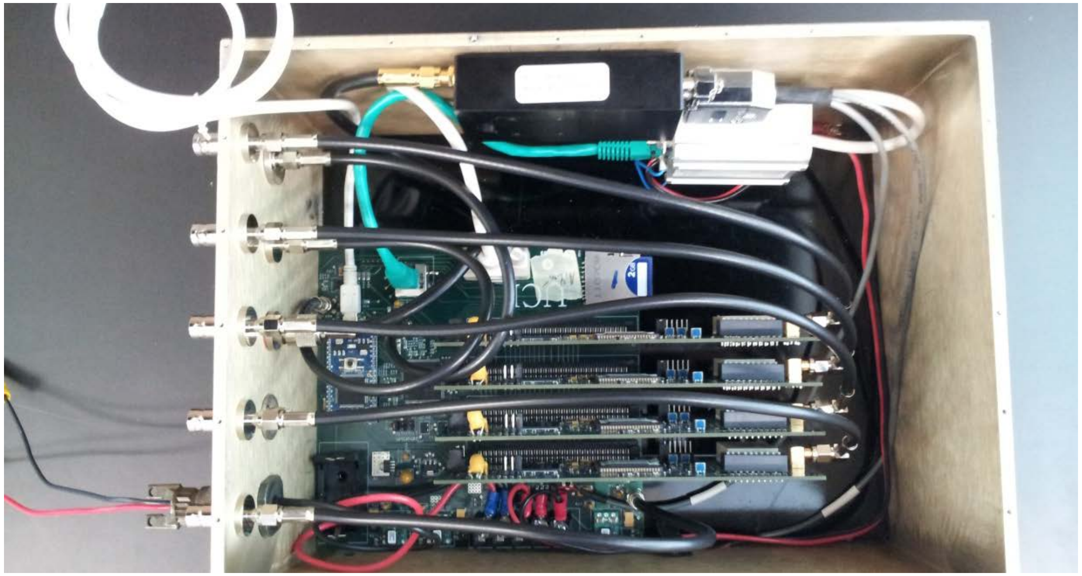




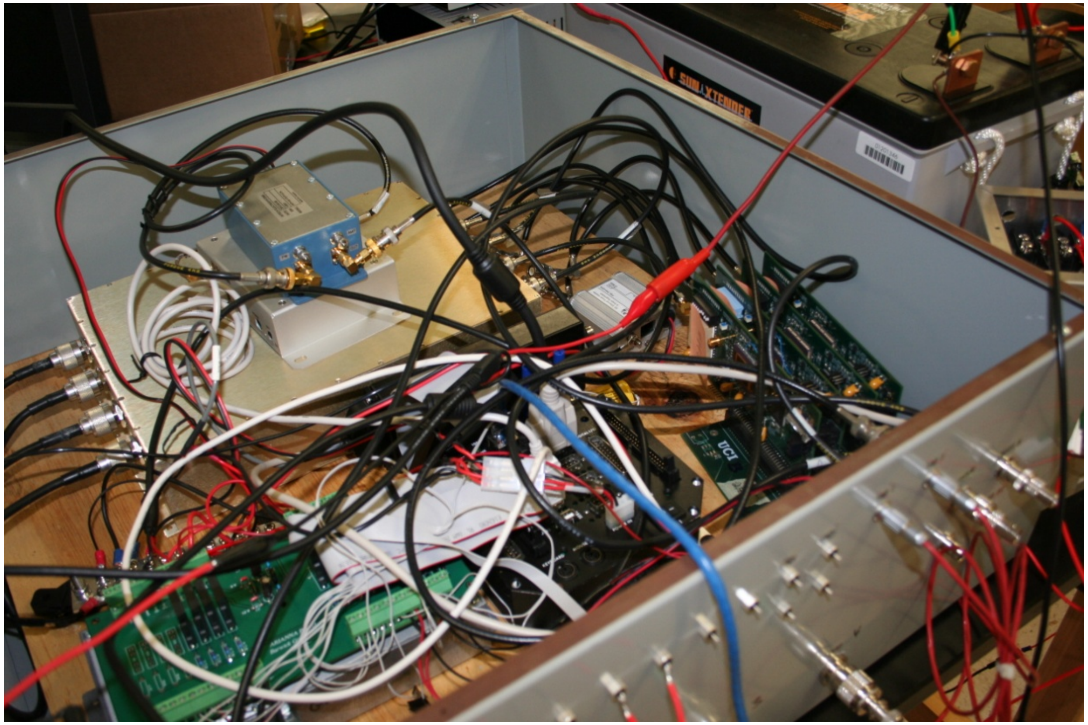
- Premium on
- LOW-Power w/
- wireless comms



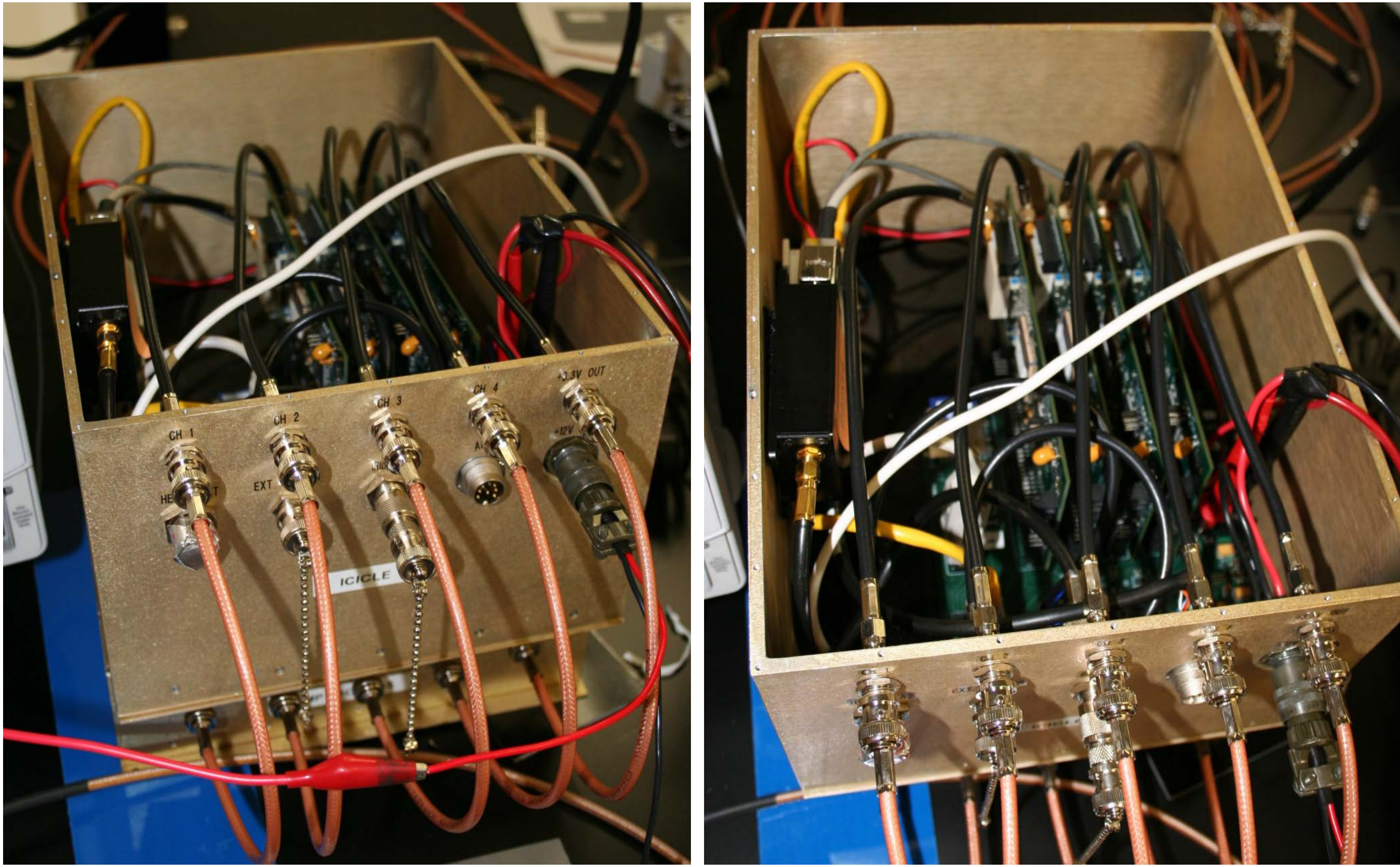
ARIANNA Station 2012



2012



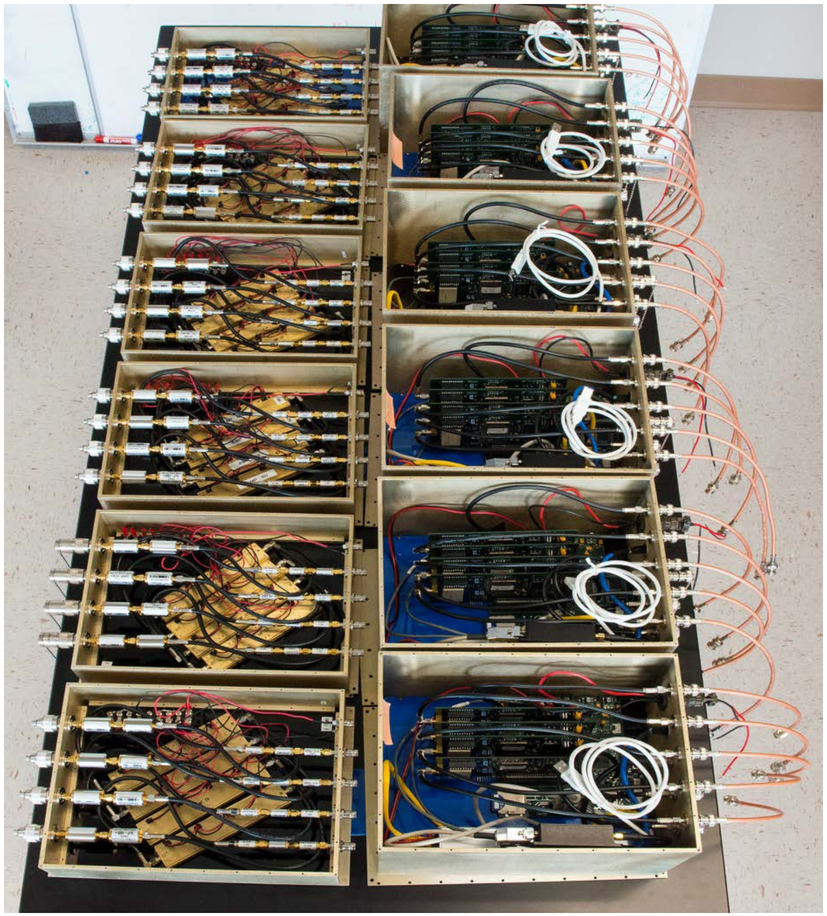
2011
Proto

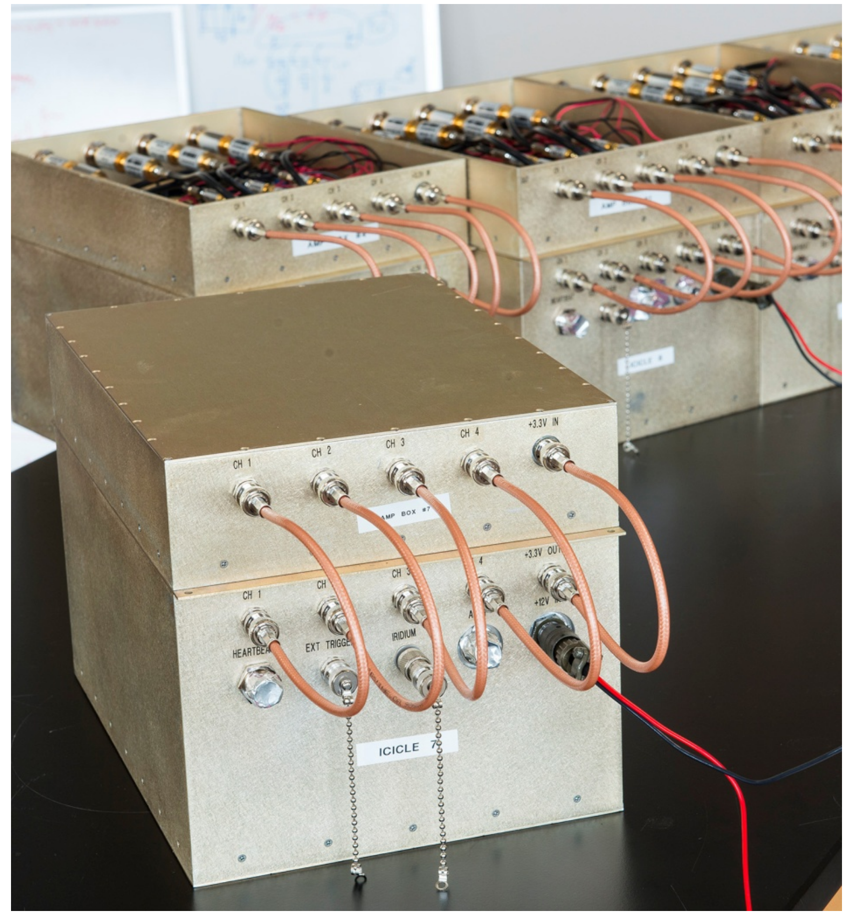


2012: More streamlined design
(smaller, lighter, less costly, more robust)

ARIANNA

“Mass” production

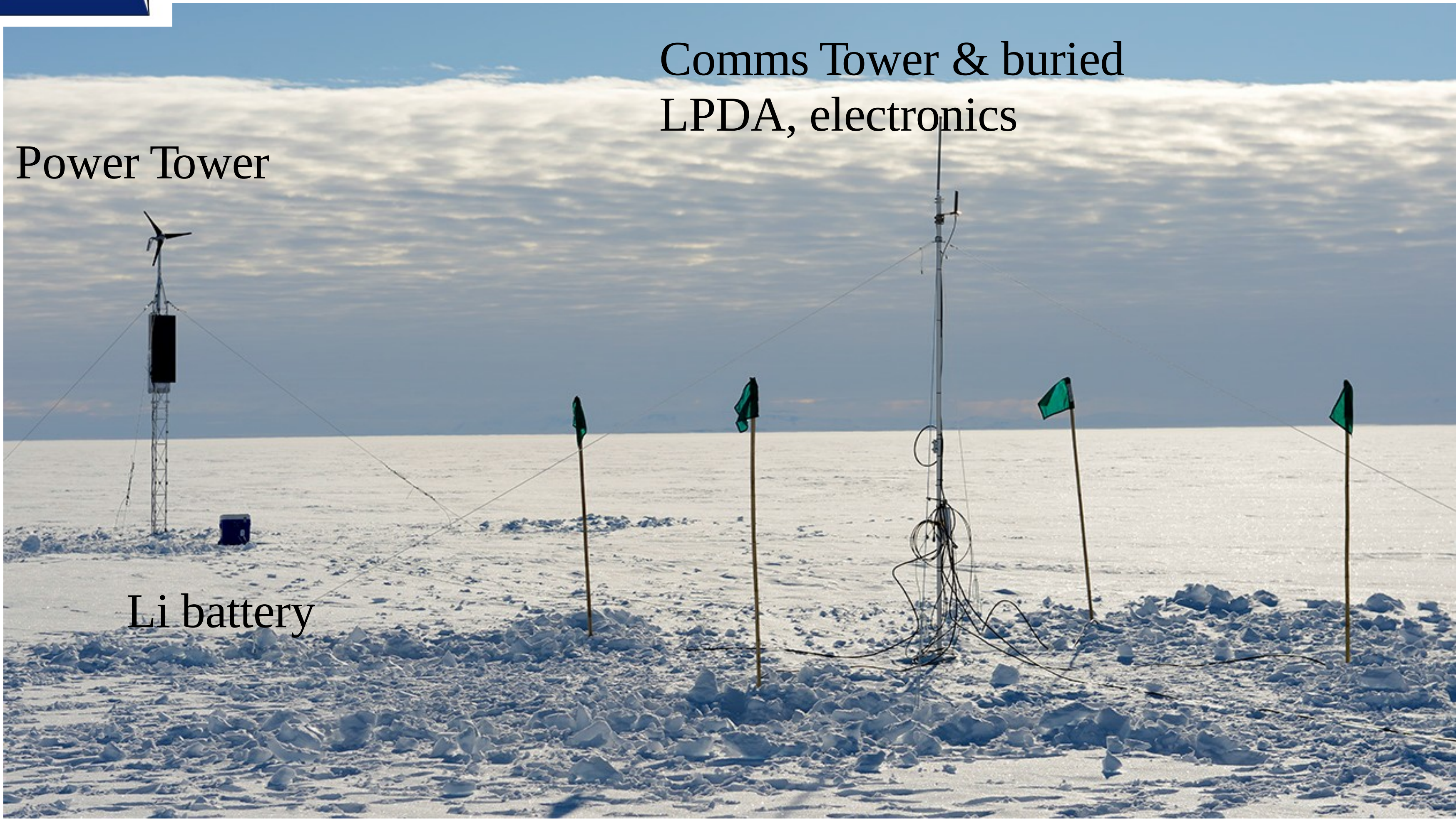




2012:
6 DAQ ready for integration

2012:
6 DAQ ready for calibration

Station Overview



Noise characteristics

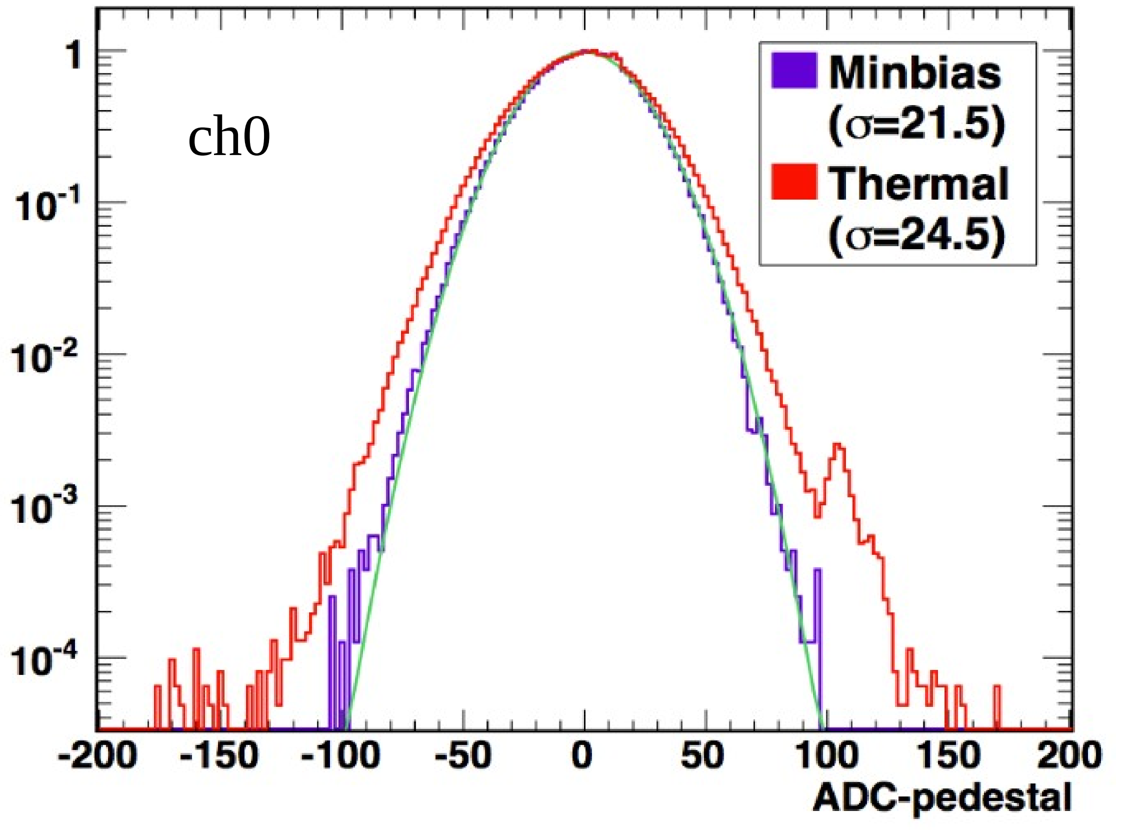
Channel 0 of station 3: all other channels similar

Minbias data is collected by randomly triggering in time.

Thermal data is biased by majority logic trigger

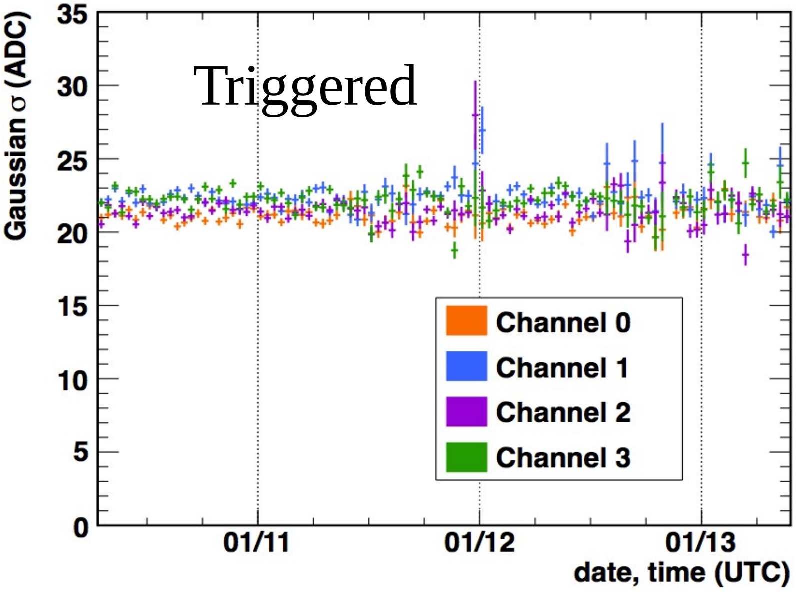
Gaussian structure shows measured noise is consistent with pure thermal

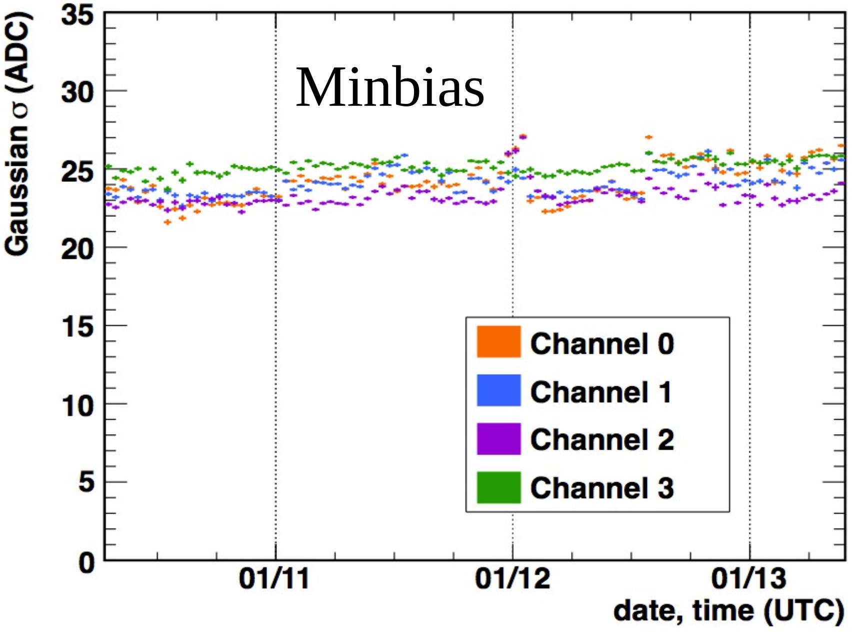
Extra width from trigger is expected. High side peak is artifact of digitizer



Noise distributions are stable

Station 3





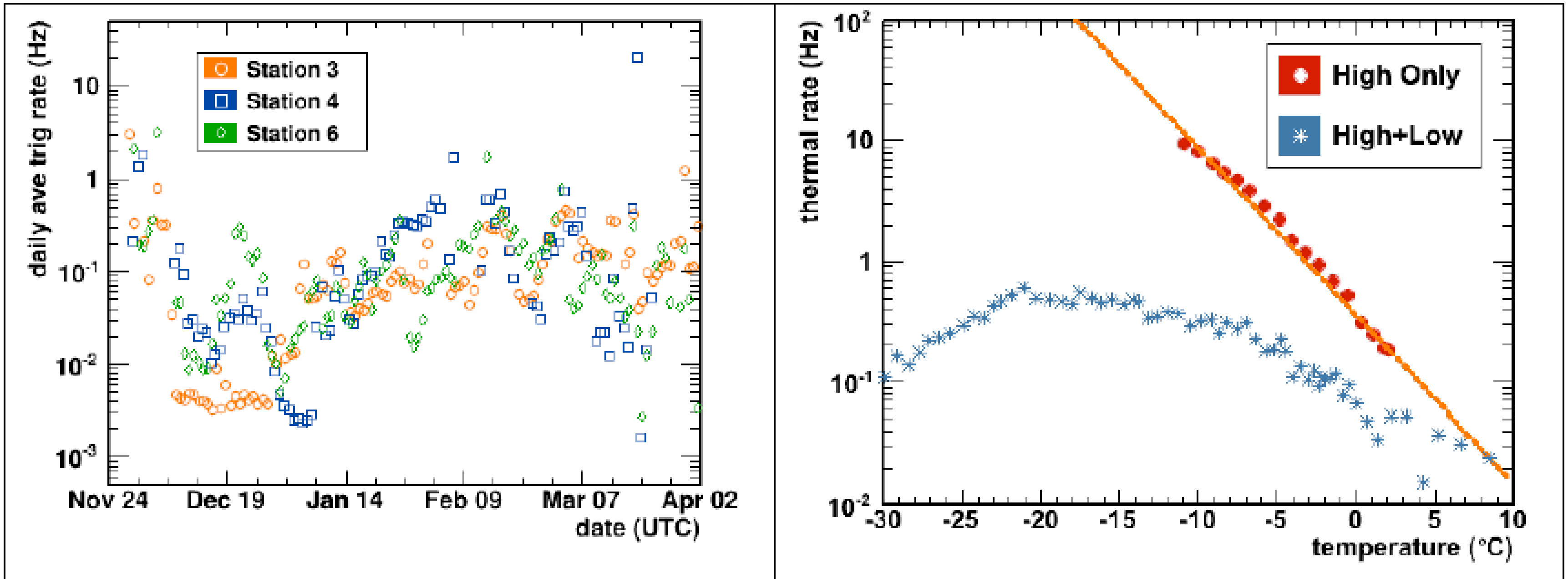
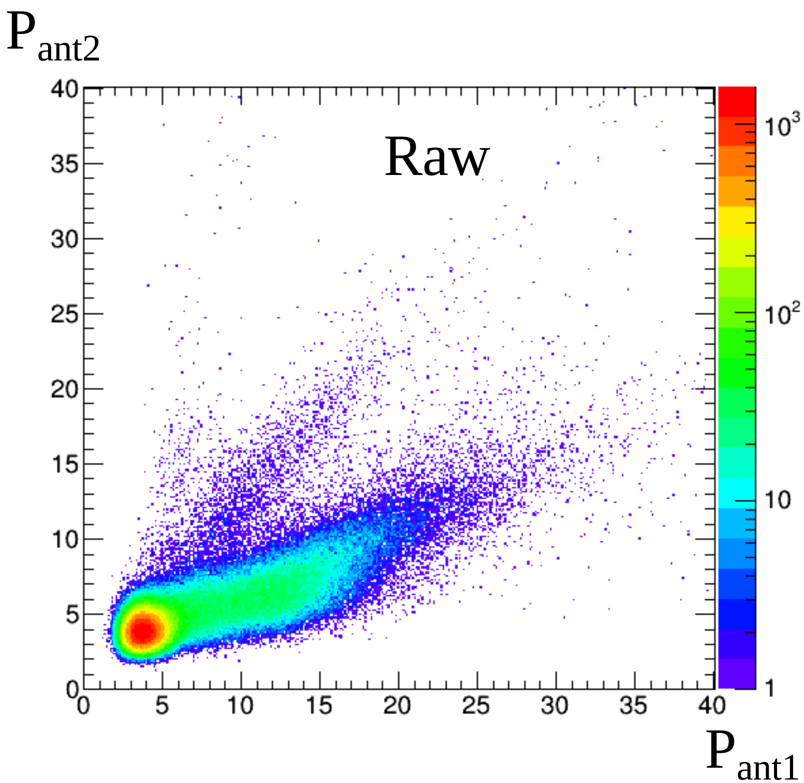
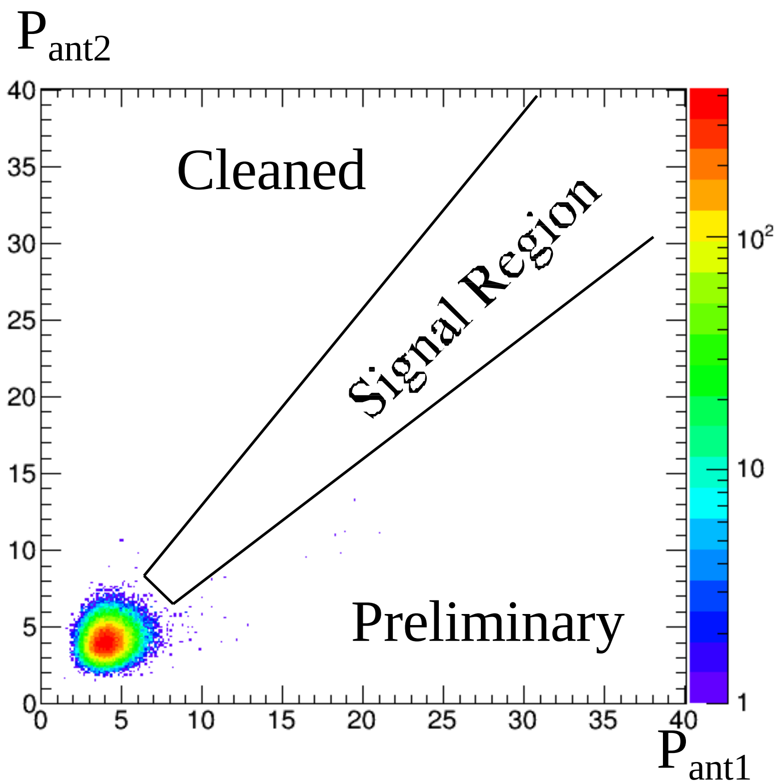


Fig. 9: (**left**) trigger rates for all stations through April 1, 2013 UTC (**right**) Two-fold majority trigger rates as a function of ambient temperature for the traditional non-pattern threshold trigger implemented in 2012-2013 season (High Only); and a pattern trigger that requires the waveform to exceed specified values for both positive and negative fluctuations (High+Low).

Data Analysis: HRA Station

(Dec 15 2012 - Mar 15, 2013)





Complete rejection of BG without timing or event reconstruction

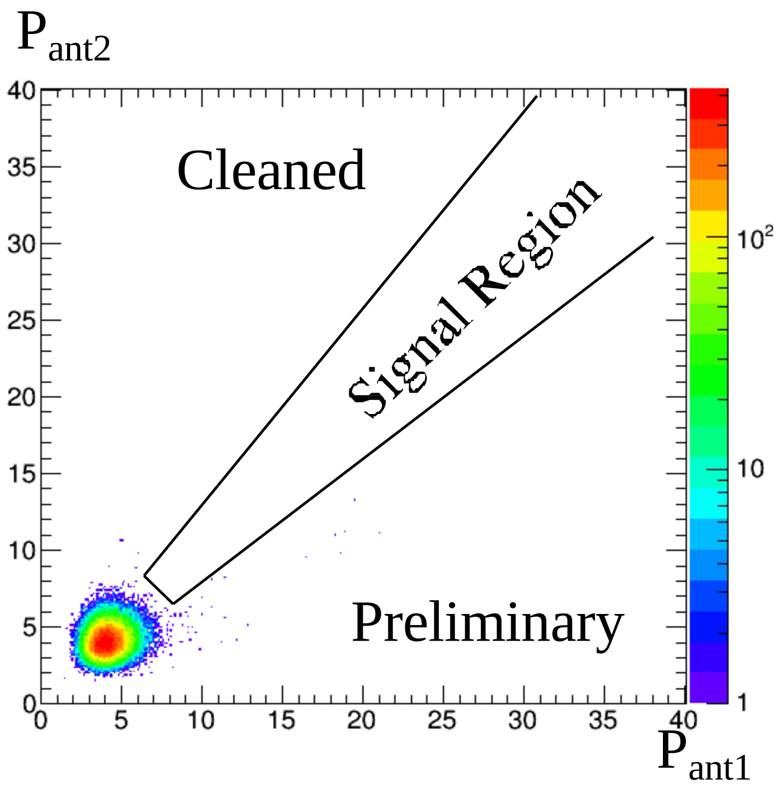
Data Analysis: HRA Station 3

(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

Analysis; simple cuts gives 90% efficiency, and the cuts should give sufficient rejection also for a full 960 station array

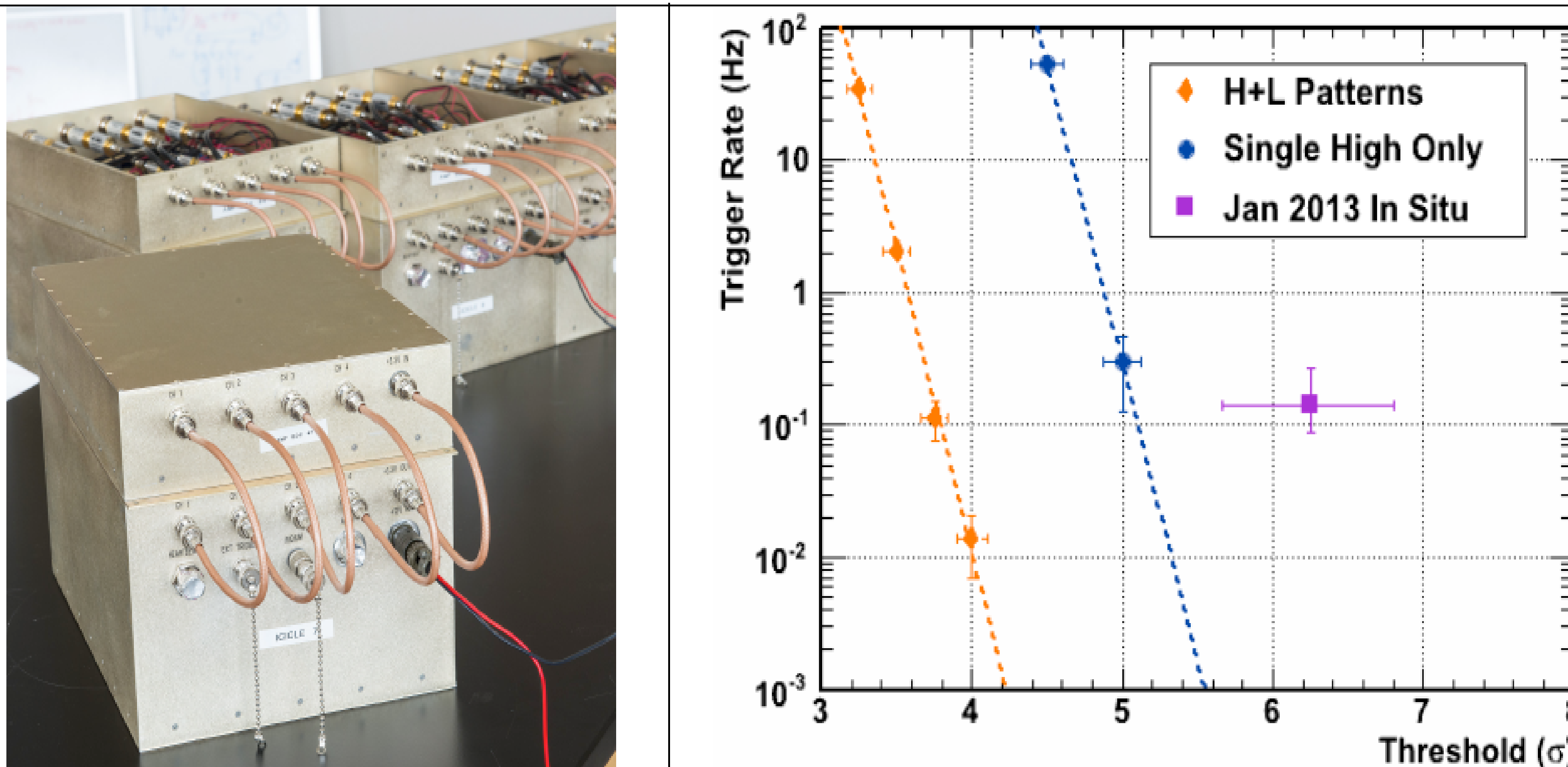


Fig. 6: (left) Assembled ARIANNA electronics within RF-right enclosures, ready for calibration and pre-deployment studies. Three systems were deployed in November 2012. Photos: S. Kleinfelder. **(right)** Two of four majority logic thermal trigger rates as a function of threshold (in units of $\sigma = V_{rms}$) for systems deployed in 2012 (purple square), for upgraded systems employing a simple positive threshold (blue circle) and pattern trigger (orange diamond).

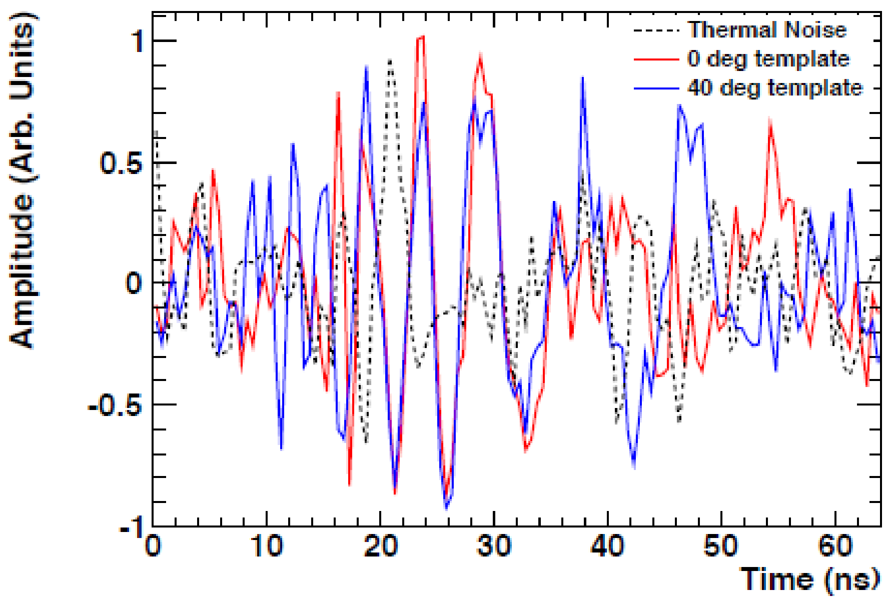


Fig.10: (left) Template waveforms for thermal noise (black dash) and neutrino signals arriving at zenith angles of 0 deg (red) and 40 deg (blue) with respect to the nose the LPDA receiver antenna.

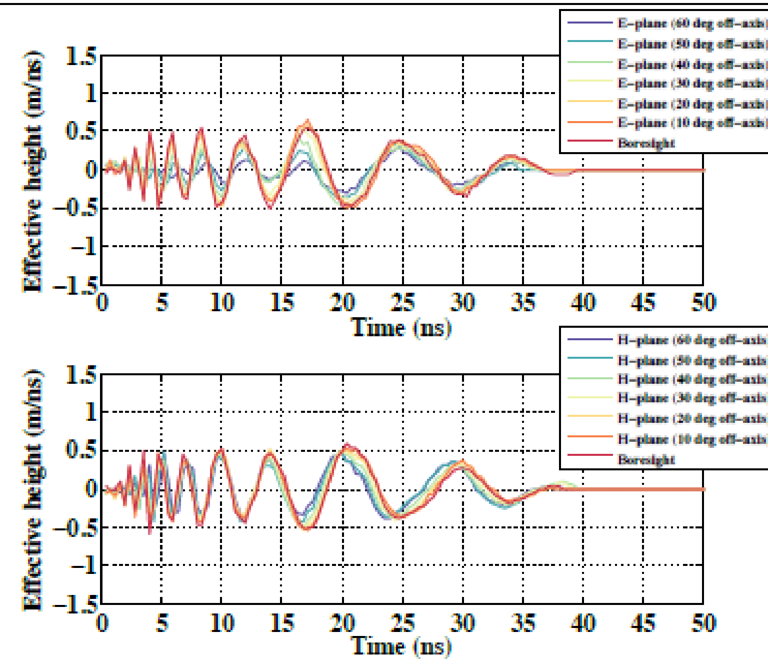
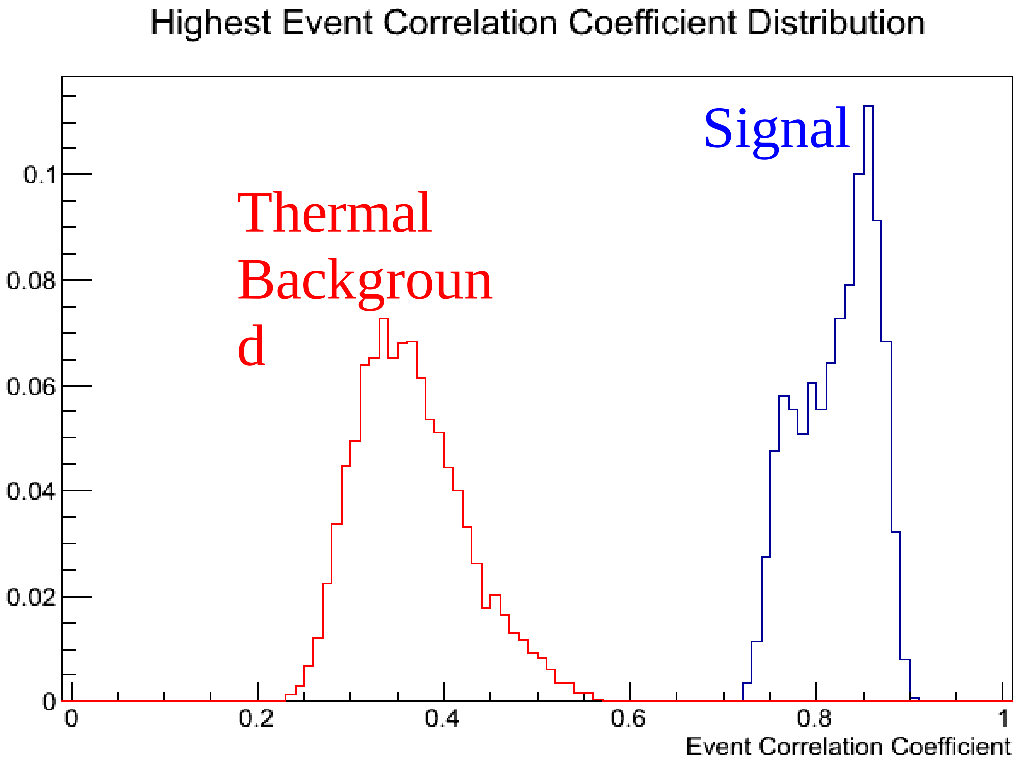


Fig 11: Representative sample of the time dependence of the effective height of LPDA receiver between 100MHz to 1 GHz for E-plane (top) and H-plane (bottom).

Waveform shape correlation



Select antenna channel with largest correlation coefficient in given event

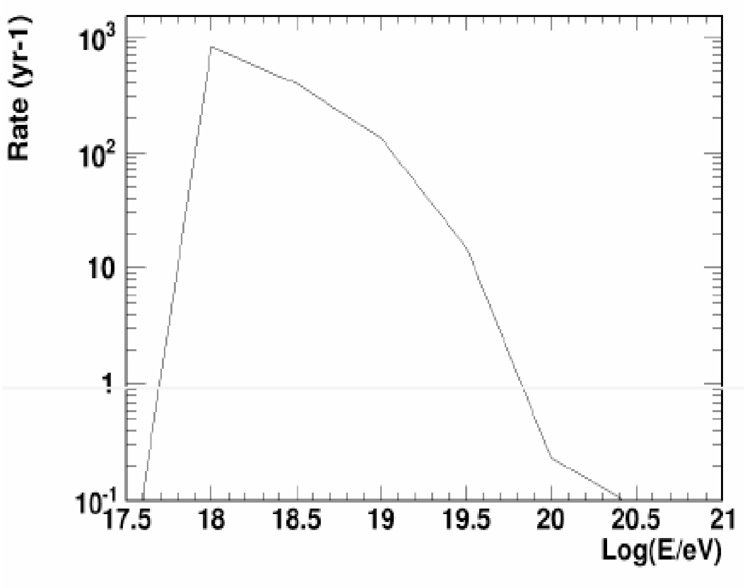
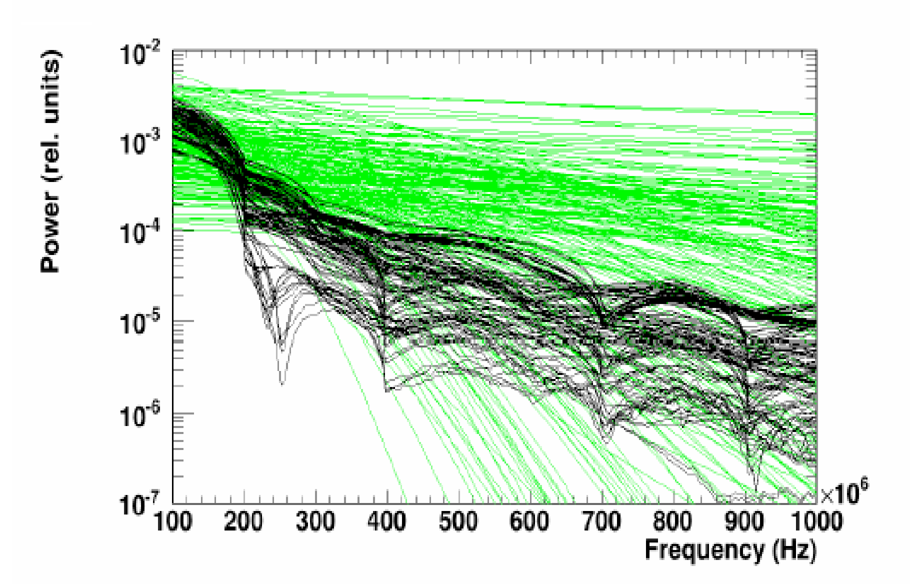
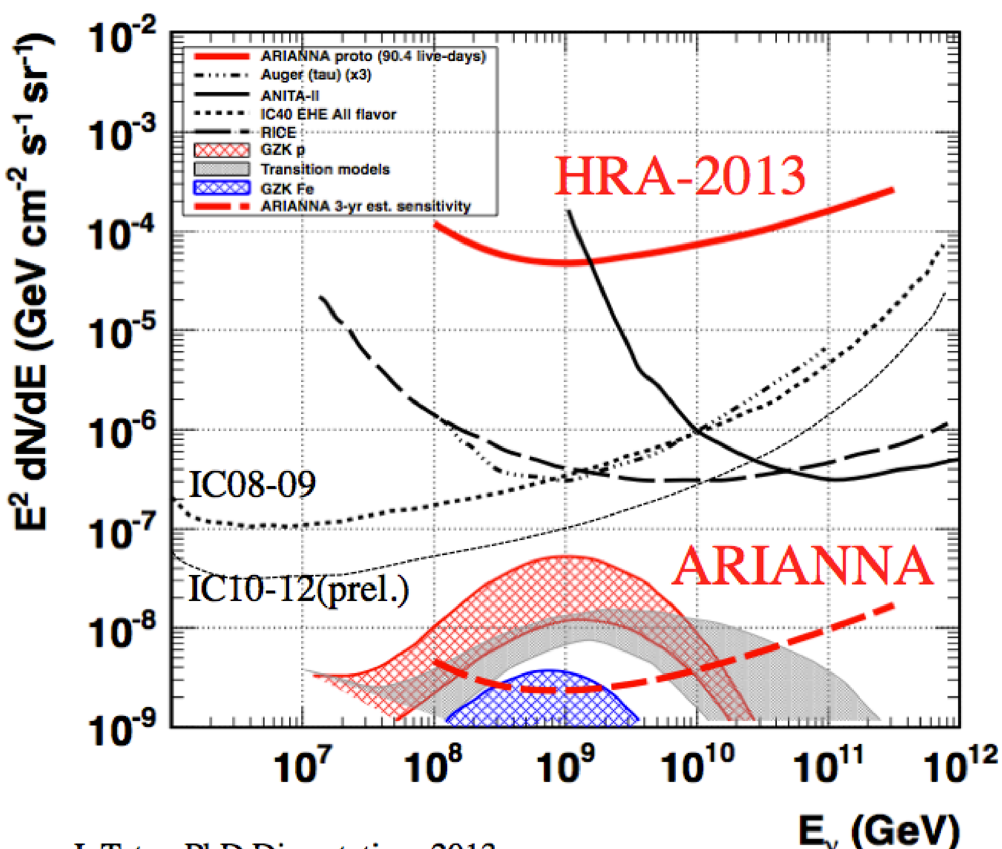
	

Fig.4: Preliminary estimate of yearly rate of cosmic ray events per half decade of energy for baseline array of 960 stations.	**Fig.5:** Spectral power (in relative units) for cosmic ray events (black) and neutrino events (green) for downward facing LPDA receiver antennas.

Limit from HRA-2013



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

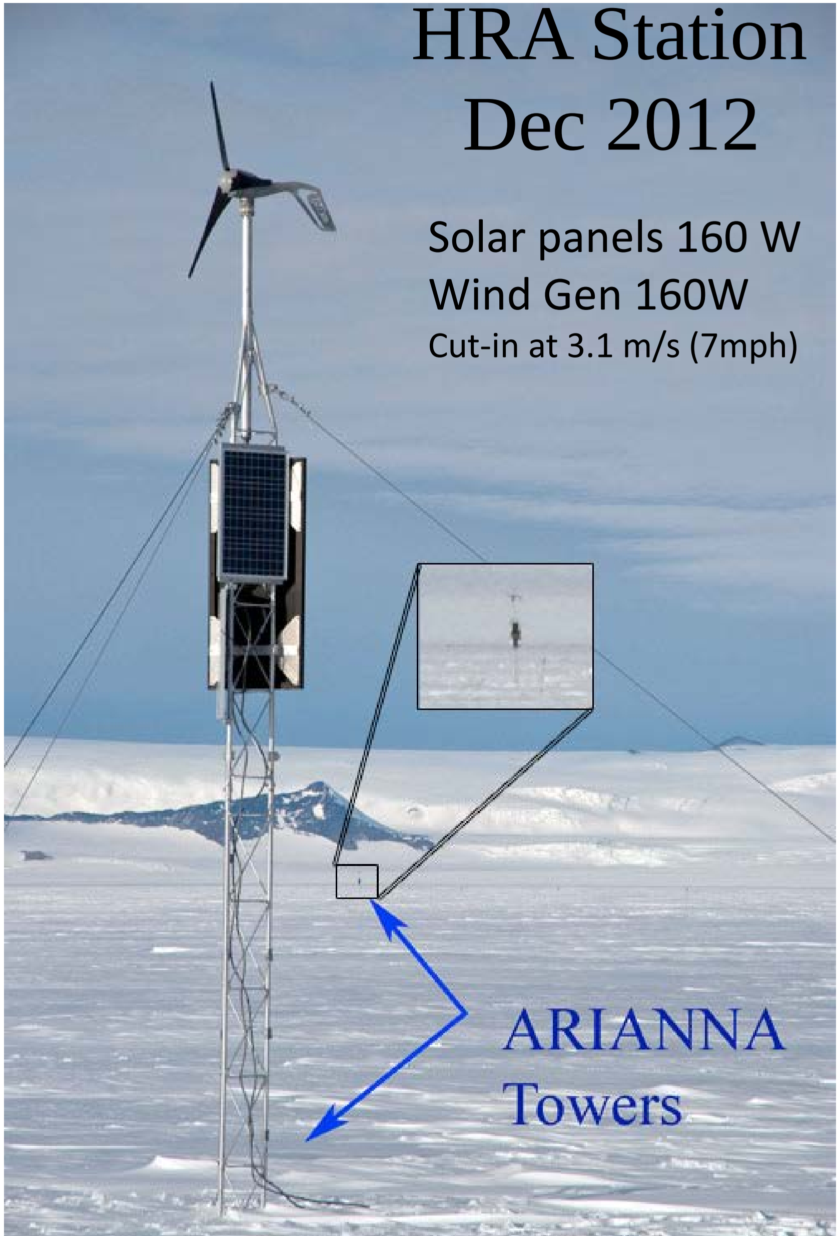
Data from one of the HRA stations for 71 days time (Jan-Mar, wireless link, this season will be much high live time fraction...].
Analysis efficiency 90%
(up from 60% for the protostation).
Half decade bin width

Power Budget: Total~12 W/8-ch station:

(accept hit in slightly higher threshold)

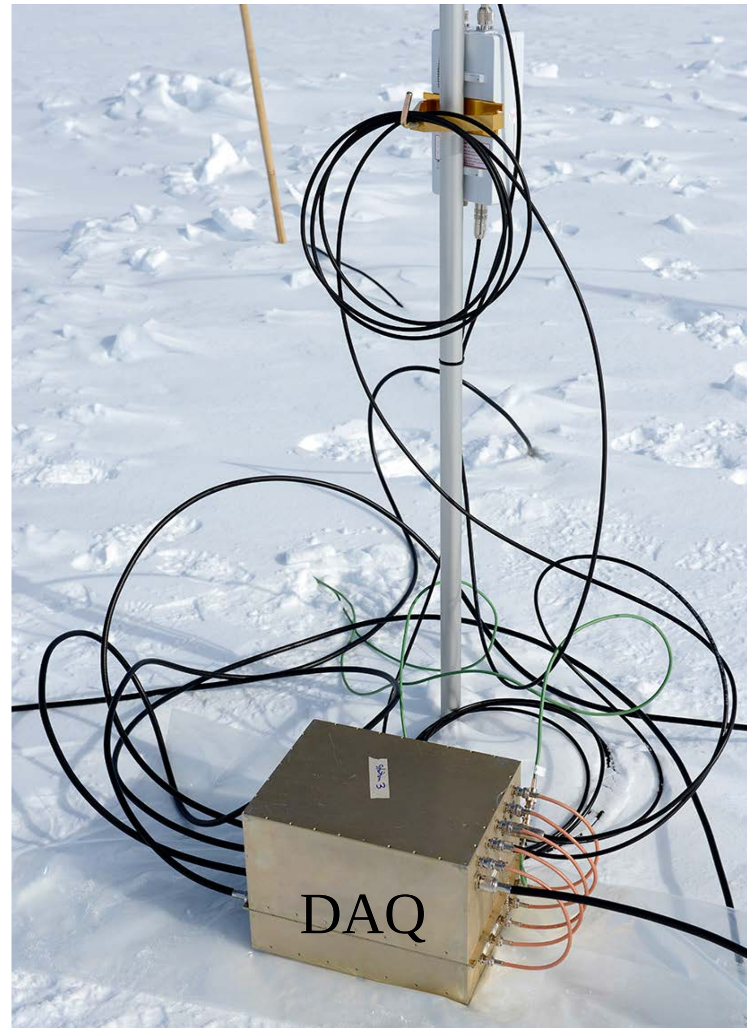
	Number	Total Power Draw
LNA's	8	1 W
Readout	8	3 W
Wireless comms	1	0.8 W
comms+GPS+ ”heartbeat”	1	3 W
Control+digitizer	1	4 W

Note: NO CPU: use on-board micro-controller only!



Electronics and base of
comms tower (AFAR+Irid)

(AFAR=high speed internet)



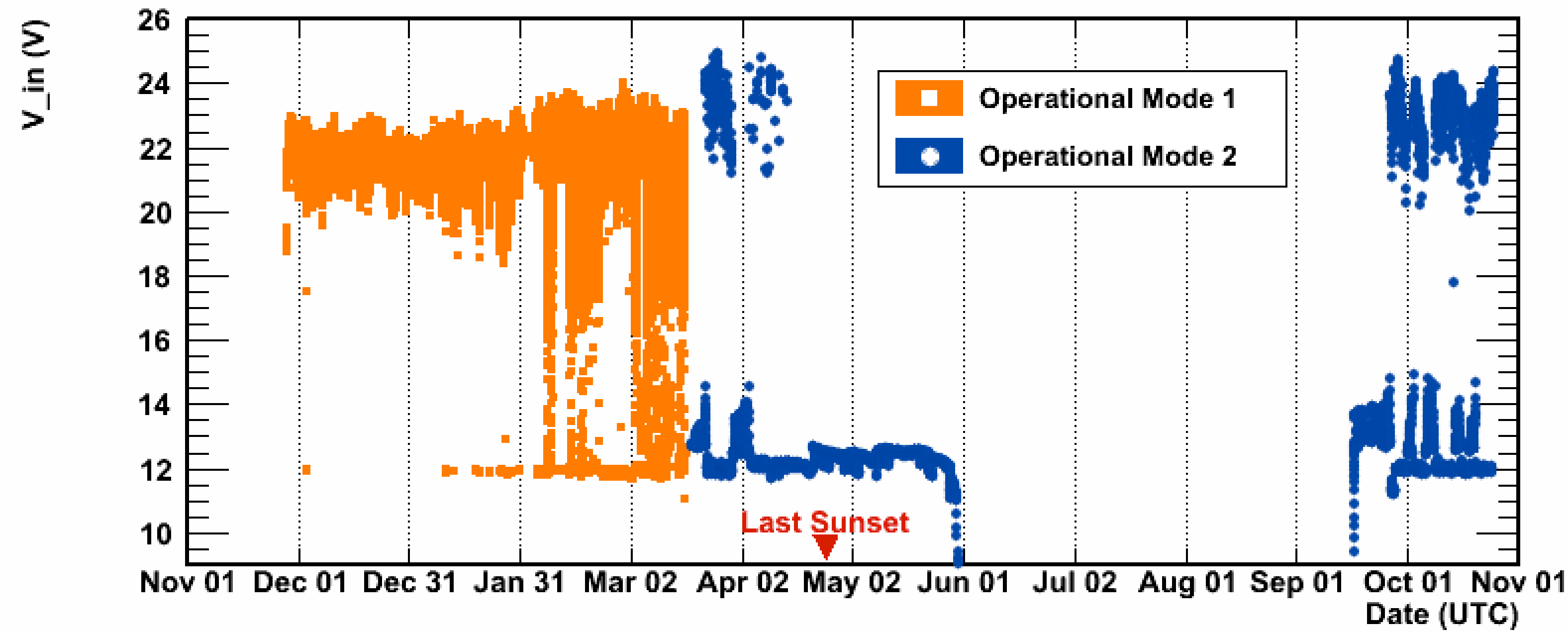
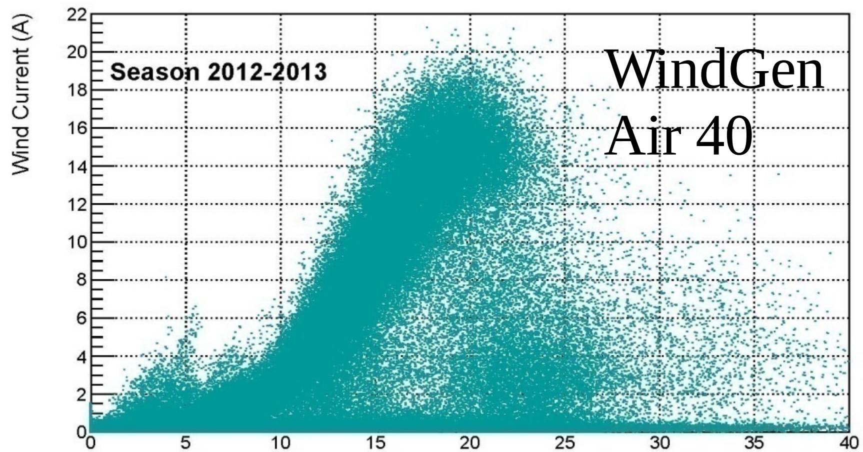


Fig. 8: Stripchart of supply voltage for ARIANNA station during past year. Higher voltages occur when the Lithium batteries are fully charged, and stations are powered by solar panels. Lower voltages when battery not fully charged. Operational mode 1 defines the period of wireless highspeed communication, whereas communications in operational mode 2 is by satellite modem only.

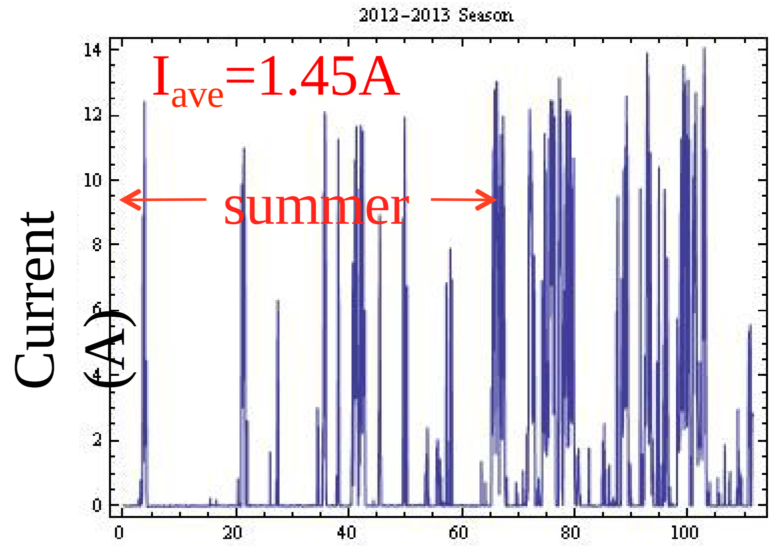
Wind Power is Sufficient!

(Southwest WindPower Air 40)

V_{ave}= 7.4 mph during summer



Wind Speed (mph)



Days after deployment

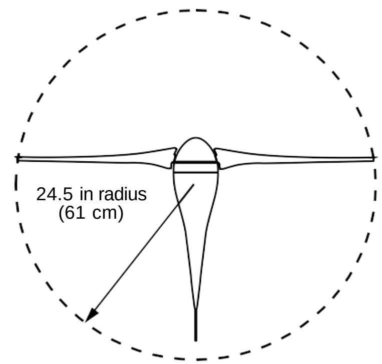
Require ~0.9A to operate station and station produced 1.45A

Wind expected to stronger in winter

However, low temps in winter lead to loss of efficiency

AIR 40 Technical Specifications

Model	AIR 40
Weight	13 lb / 6 kg
Rotor Diameter	46 in / 1.17 m
Start Up Wind Speed	7 mph / 3.1 m/s
Kilowatt hours/month	38 kWh/month @ 12 mph / 5.4 m/s avg. wind speed
Maximum Wind Speed	110 mph
Rated Power	160 watts @ 28 mph / 12.5 m/s wind speed
Certifications	CSA (certificate 1954979), CE
Operating Temperature Range	AIR 40 are certified under IEC requirements applying to the temperature range 14º F (-10º C) to 104º F (40º C)



12 volt, 24 volt and 48 volt AIR 40 wind turbines are eligible to bear the CSA mark with “C” and “US” indicators. The “C” and “US” indicators signify that the product has been evaluated to the applicable CSA and ANSI/ UL standards for use in Canada and the US.

Voltage Regulation Set Point (factory setting)

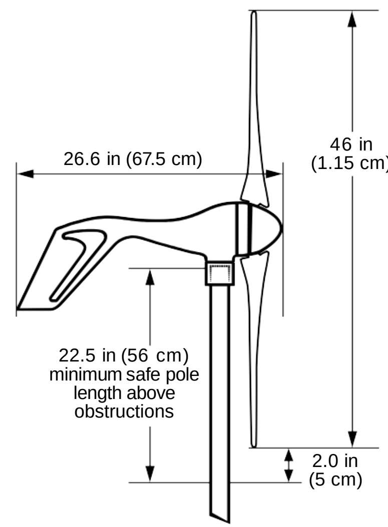
12 Volt Systems	14.1 Volts
24 Volt Systems	28.2 Volts
48 Volt Systems	56.4 Volts

Regulator Adjustment Range

12 Volt Systems	13.6 to 17.0 Volts (approximately)
24 Volt Systems	27.2 to 34.0 Volts (approximately)
48 Volt Systems	54.4 to 68.0 Volts (approximately)

Recommended fuse Size

12 Volt Systems	20 amp (slow blow)
24 Volt Systems	10 amp (slow blow)
48 Volt Systems	5 amp (slow blow)



Tower Loads

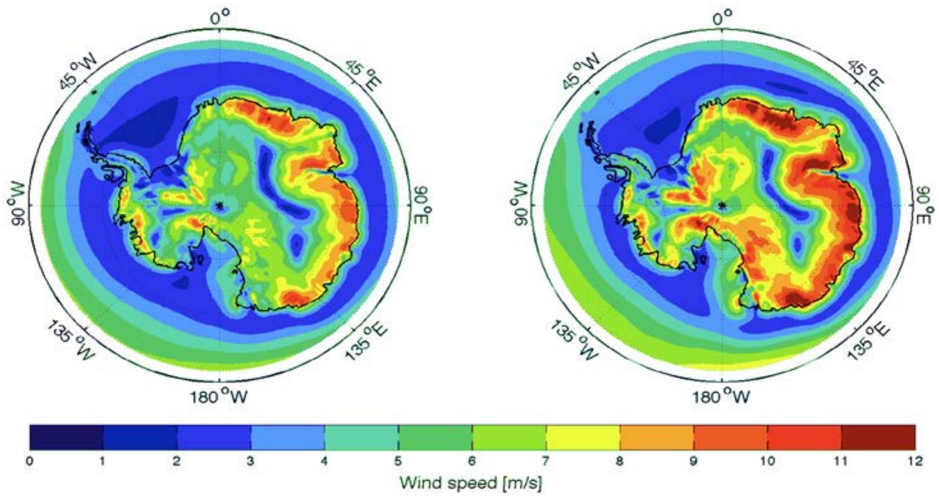
Shaft Thrust* 52 lb @ 100 mph wind speed (230 N @ 45 m/s)

*Value does not include safety factor. SWWP recommends safety factor of 1.5.

Assessment of green power production in Antarctica

Christoffer Hallgren

Figure 2: Average wind speed in Antarctica during summer (left) and winter (right).



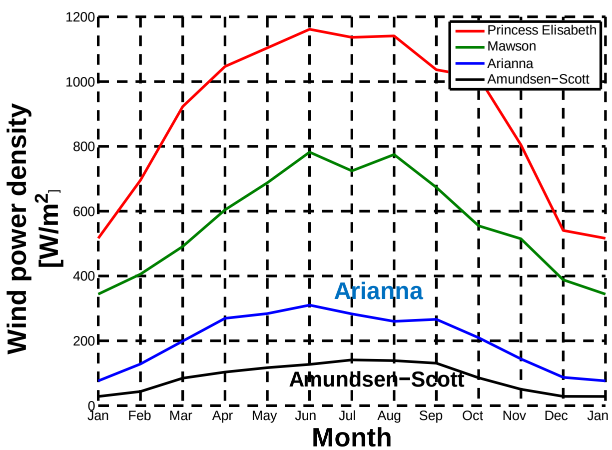


Figure 4: Monthly change of WPD for the research stations investigated.

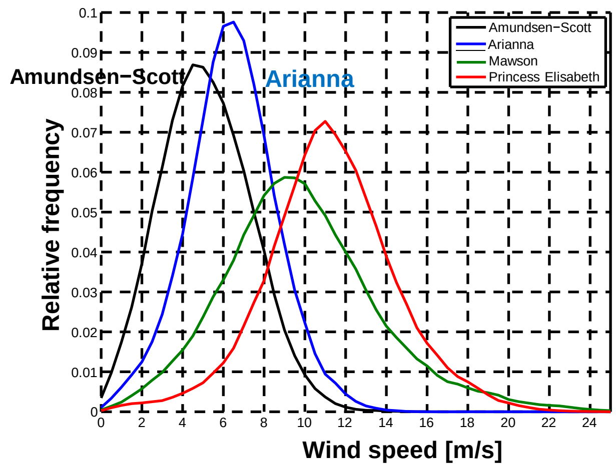
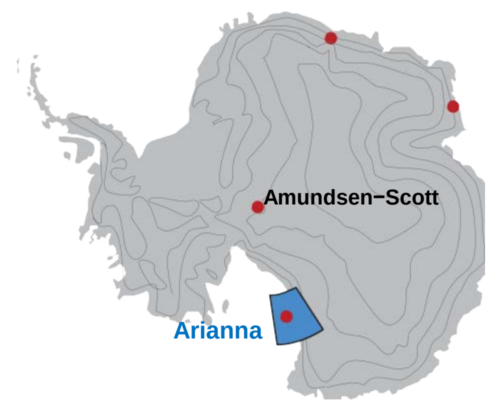


Figure 5: Distribution of wind speeds for the four research staions investigated.

3. The MERRA data set

To be able to study the Antarctic wind resource and compare the wind power potential at several scientific stations, reanalysis data from the Modern-Era Retrospective Analysis for Research and Applications (MERRA) (Rienecker et al. 2011) has been used for the calculations. The data set is provided by National Aeronautics and Space Administration (NASA) and covers the modern era, from 1979 and onwards, during which remote sensing has been dominant when collecting data about the atmosphere.

The reanalysis data is created by combining different types of measurements (such as (surface observations, radio soundings and satellite data) and using a numerical model to calculate a gridded data set in a consistent way.



Arianna	78.5	S	165.3	E
Amundsen-Scott	90.0	S	0.0	E
Mawson[1]	68.0	S	62.7	E
Princess Elisabeth	71.5	S	23.3	E

Assessment of green power production in Antarctica

Christoffer Hallgren

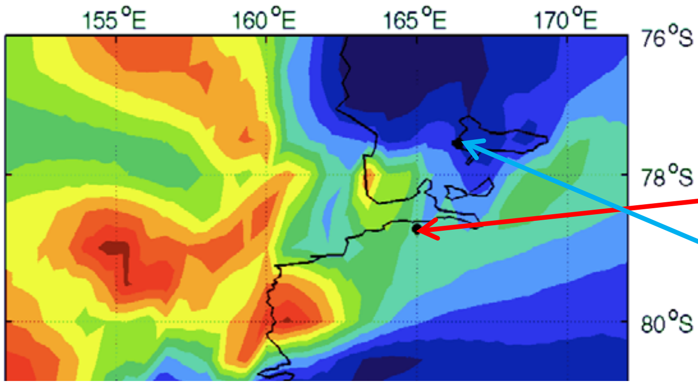


Figure 8: Median WPD in the Arianna area.

Arianna site

McMurdo Station

The resolution of the MERRA data is too low to accurately depict the wind conditions in the coastal zones. However, in combination with measurements from a weather station it should be possible to long time correct the results. It is also concluded that the extreme high wind speeds are underestimated in the MERRA data.

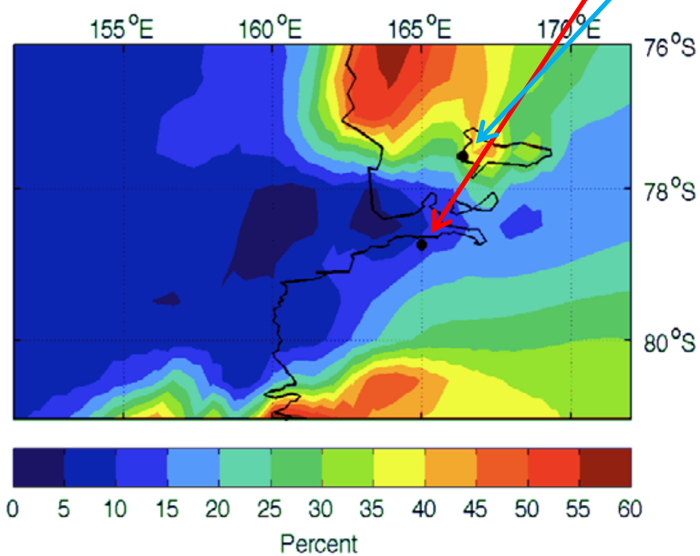


Figure 9: Percent of time that the wind speed is less than 4 m/s in the Arianna area.

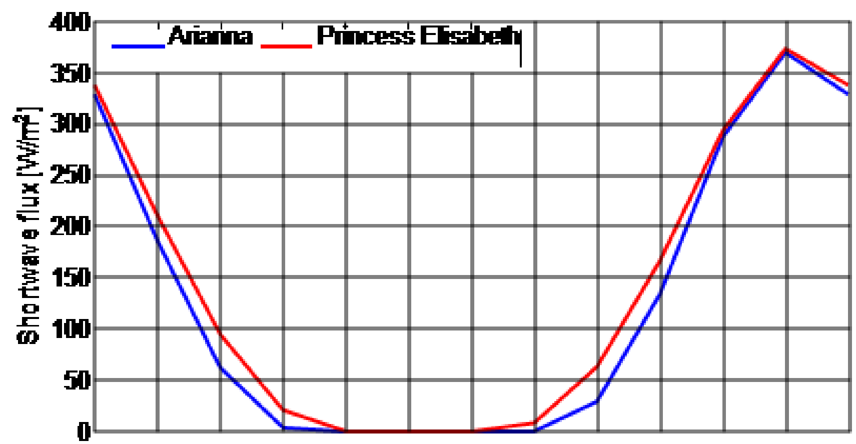
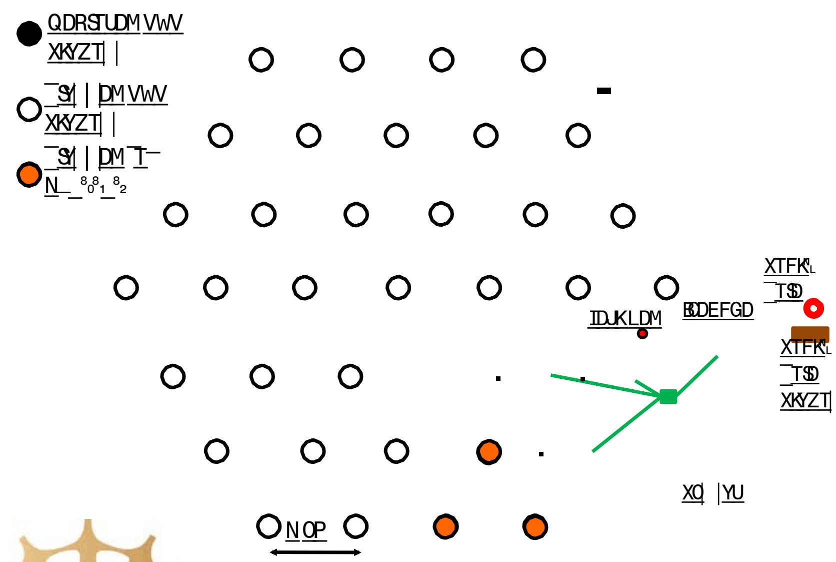


Figure 11: Average monthly incoming shortwave flux for Arianna and Princess Elisabeth.

Askaryan Radio Array (ARA)

University of Wisconsin, Ohio State University and CCAPP, University of Maryland and IceCube Research Center, University of Kansas and Instrumentation Design Laboratory, University of Bonn, National Taiwan University, University College London, University of Hawaii, Universite Libre de Bruxelles, Univ. of Wuppertal, Chiba Univ., Univ. of Delaware

- Radio array at the South Pole
  - Testbed station, Stations 1,2&3 deployed last 3 seasons
- Phase 1: 37 stations ~100 km^2
  - Establish flux
  - Begin astronomy/ particle physics exploitation



200 m depth
2 km separation

NSF has funded Testbed+3 Stations. Propose to deploy another 3 stations in 2014-2105 (ARA6)

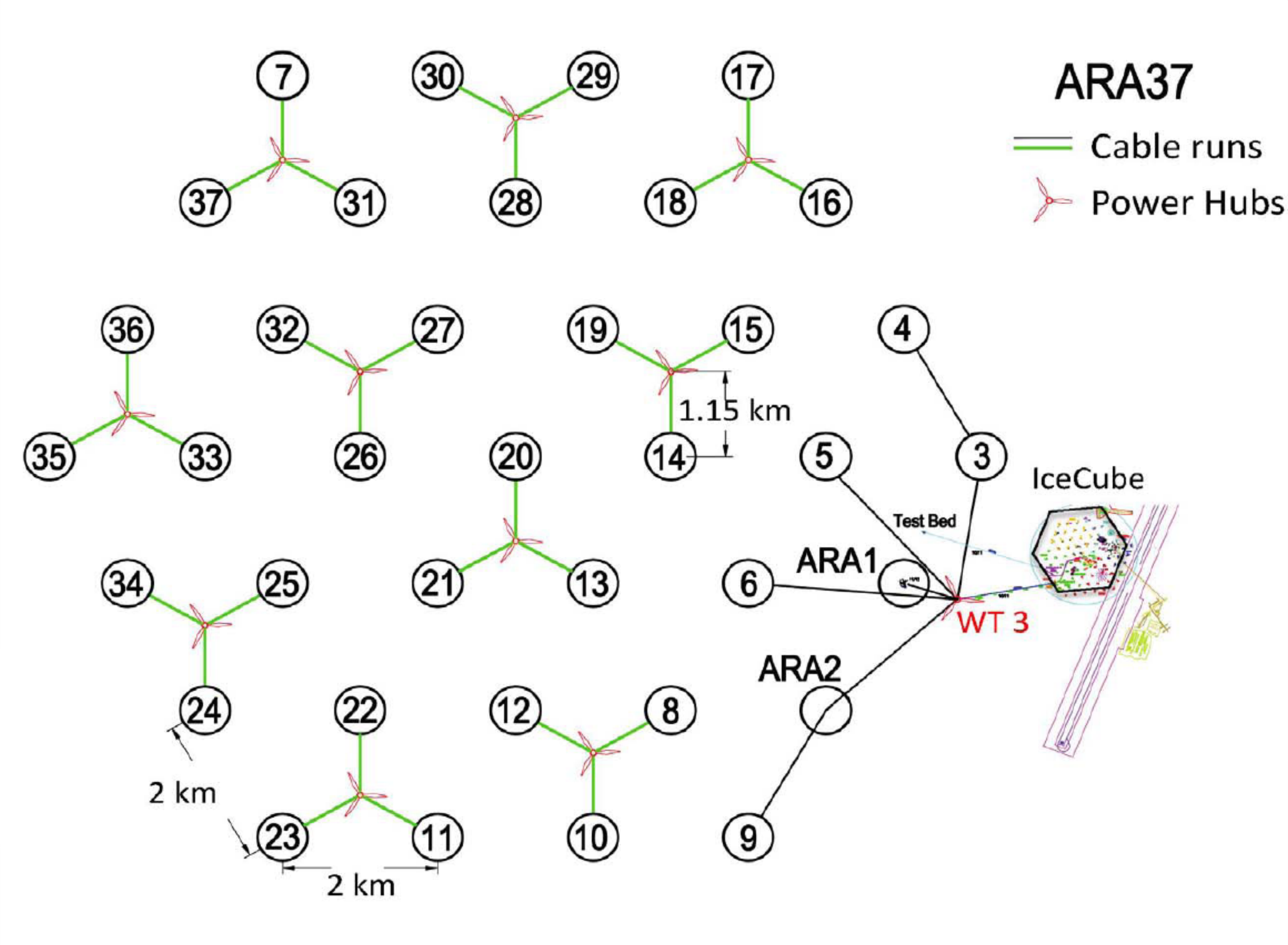
ARA

- **Australia (UNSW, Adelaide), Belgium (ULB), Germany (Wuppertal, Aachen, Bonn), Israel (Weizmann), Japan (Chiba), Taiwan (NTU), UK (UCL), US (Bartol, Hawaii, Maryland, OSU, Wisconsin, UNL, KU), France (Nancay/CODALEMA)**
  - ~$10 M USD
    - ($3M already committed from non-US participants; $7M proposal approved for science (12Oct11; logistics impact review/co-funding with EPP panel: Feb 2012)
- Phase 1: 2009-2016
  - 100 km^2 footprint
  - Establish cosmogenic flux, observe first GZK neutrinos
- Phase 2: 2017-2025
  - 1000 km^2 footprint: statistical studies of neutrinos

Station concept

- =4 vertical holes, 10 m apart laterally, 200 m deep
  - Each can independently image a neutrino event in-ice
  - 4 Rx (2 Hpol + 2 Vpol)/hole; 5-m vertical spacing
  - • •• resolution via 4 Gsa/s 2 GHz BW digitizer
  - 4 Hpol surface antennas-independent trigger
  - Prototype with testbed (2010-)
    - NOT ideal: only 20-30 meters deep;
    - Only 2 Hpol surface antennas
    - Only 4 in-ice Vpol have been fully calibrated & are useful for reconstruction
    - Limited bandwidth and throughput DAQ
    - Provide a lower limit for estimating individual station performance

Footprint (NB: local power=> >2km spacing!)



Arianna Collalboration expands:

UC Irvine (PI Steve Barwick)

LBL, Kansas, Washington Univ, SUNY Stony Brook in the US,

Sweden, Denmark, Netherlands (?), New Zealand (?).

Uppsala involvment:

Applied for KAW grant for 12 station addition to the 7 in HRA + personell giving possibility to see a few GZK neutrinos. Not granted.

Checked wind power conditions using MERRA data base.

New Postdoc Sebastian Euler will start to simulate and analyse experimental data

Leif Gustafsson (senior electronics engineer) will participate in new electronics design. Has already measured antenna response.

Participates with 15 k$ to new run of integrated circuit