

Performance of the ARIANNA Neutrino Telescope

Corey Reed
UC Irvine

<http://arianna.ps.uci.edu/>

UHE Neutrinos

CRs have $E > 10^{18}$ eV

Origin?

No nearby sources known

Space too hazy for distant sources

UHE CRs \rightarrow UHE ν 's

Can arrive from far away

Not bent by magnetic fields

Imply hadrons at source

UHE Neutrinos

UHE ν measurements could

Confirm GZK

Help describe CR sources

Evolution, E_{max} , CR composition

Reveal new sources

CR sources, EM hidden sources

And more!

ν x-scn measurement



UHE Neutrinos

What kind of telescope?

BIG

Flux tiny, x-scen tiny

Cost efficient

So it can be big

Low background

Don't lose rare signal

ARIANNA

Detect ν with radio

Radio pulse from
hadronic shower

See Amy Connolly's
talk Tue at 10am

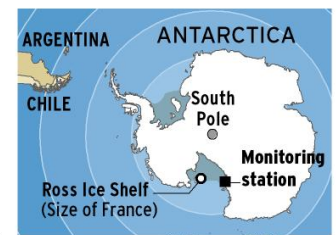
Exploit properties of
Ross Ice Shelf

All thanks to NSF!

MRI, OPP, MEP

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:



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.

Source: UCI Professor Steven Barwick

Graphic by Scott Brown / The Register

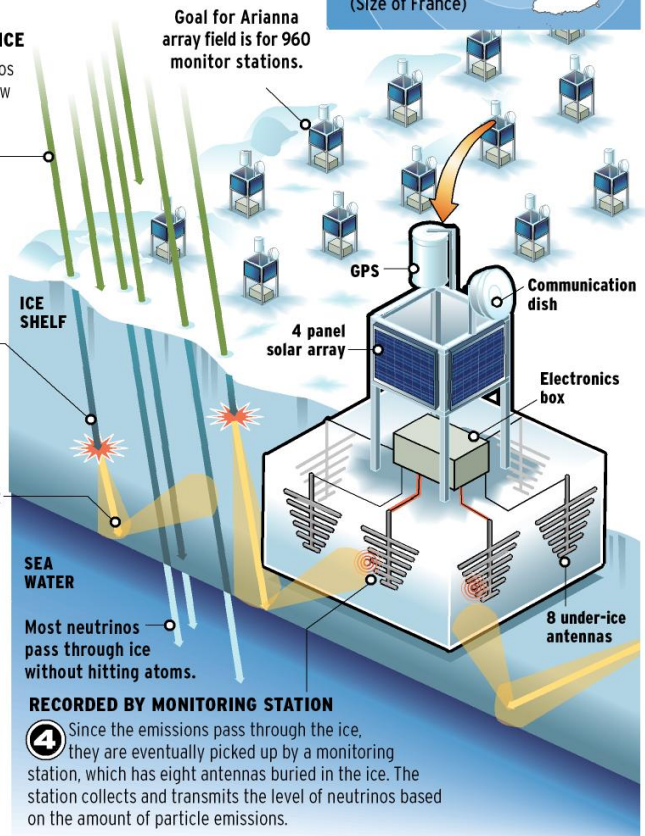
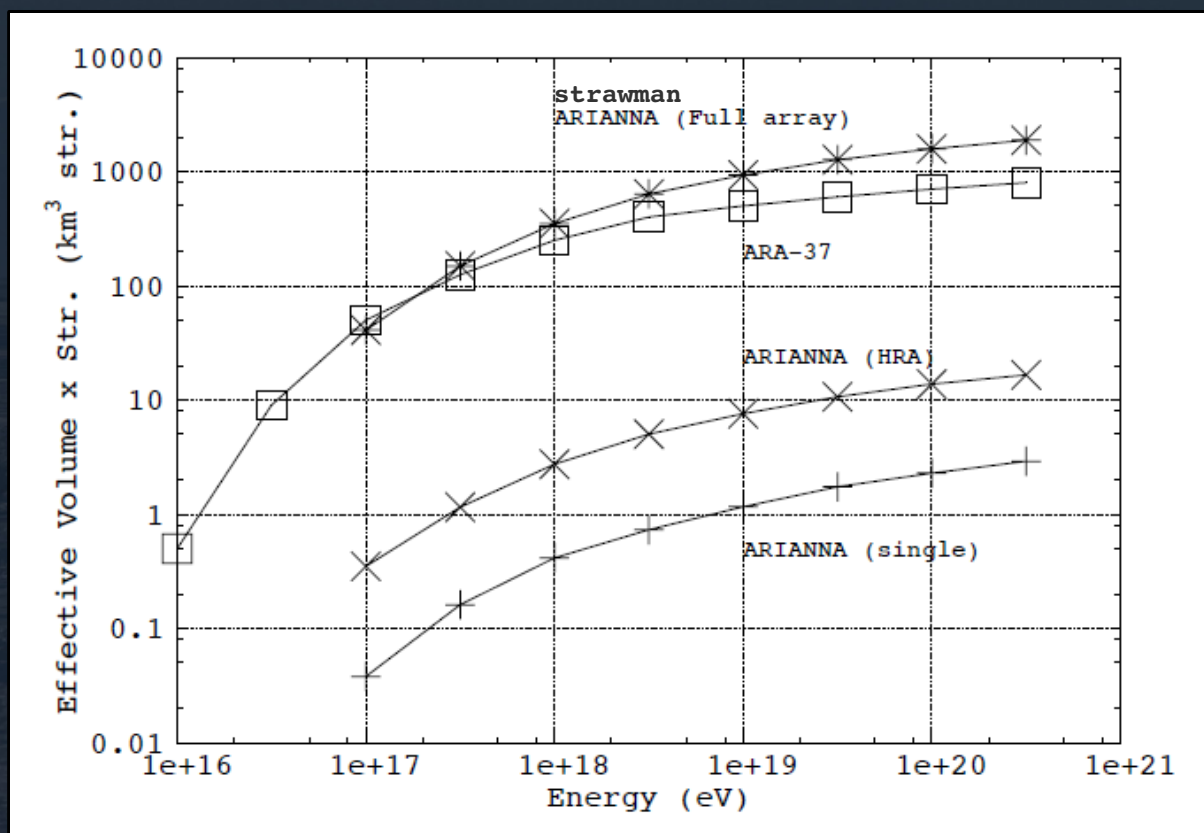


Image from O.C. Register

ARIANNA

Sensitivity comparable to ARA



J. Hanson PhD Thesis, 2013. ARA-37 from Astroparticle Physics, 35:457-477, 2012

Flux Sensitivity

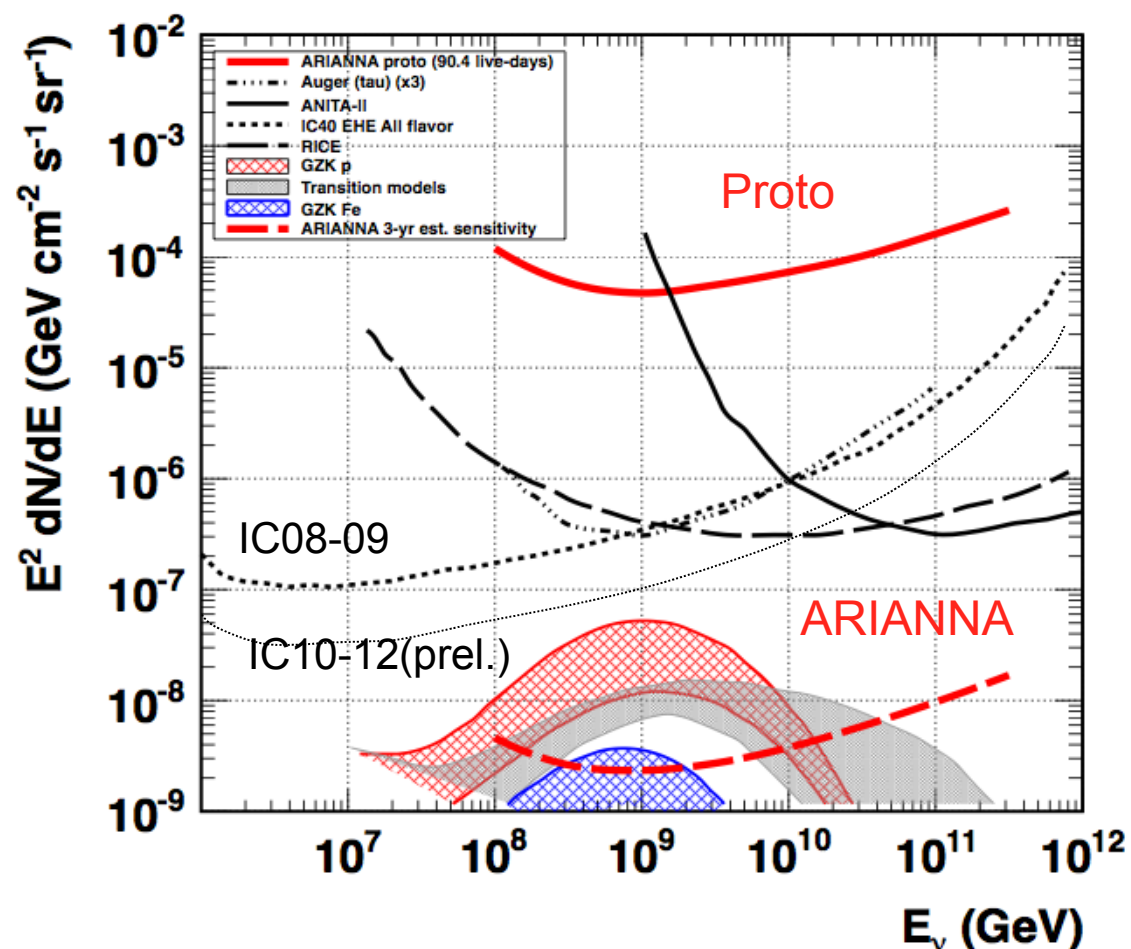
ARIANNA

30 km² grid

3 yrs (shown)

“low” E thresh

Expect ~40 ν /yr
from reasonable
models

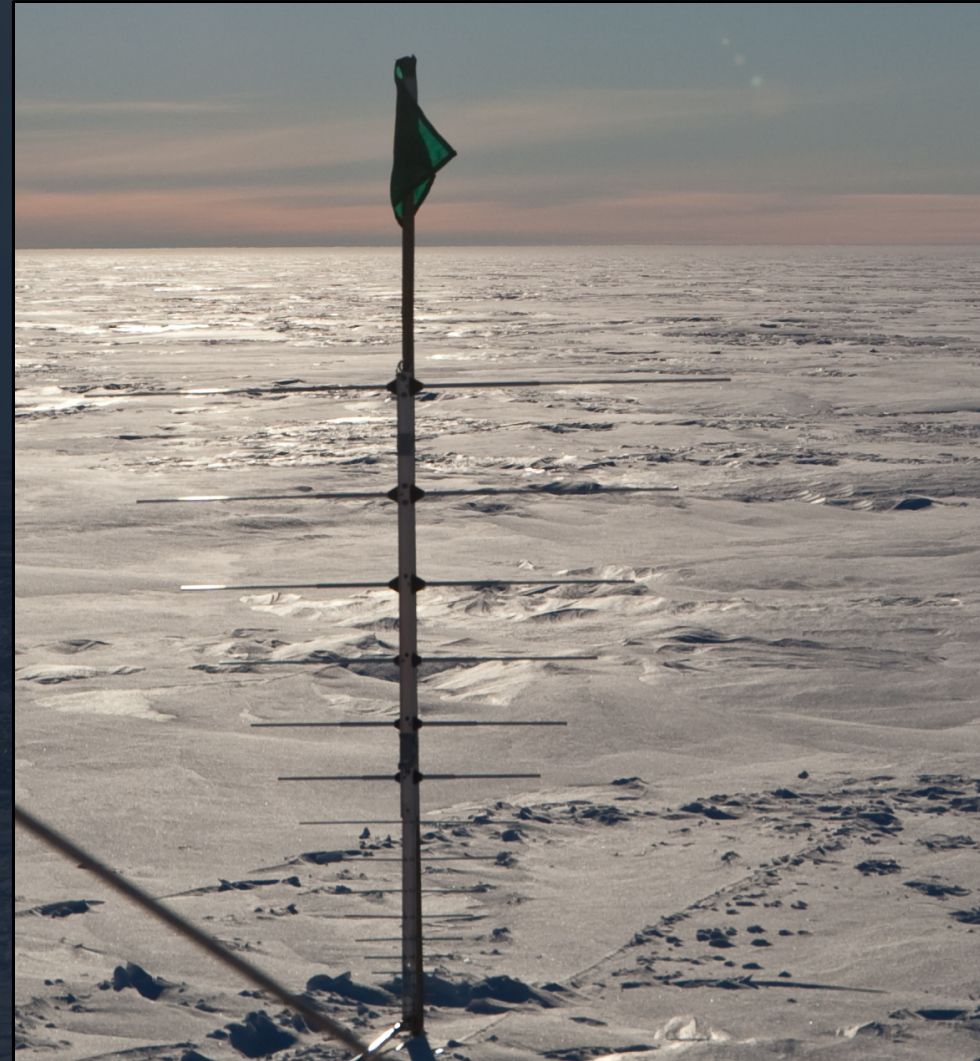


J. Hanson, PhD Dissertation, 2013. Half-decade E bins.
Fig. adapted from Kampert & Unger

ARIANNA HRA Stations

4 LPDA Antennae

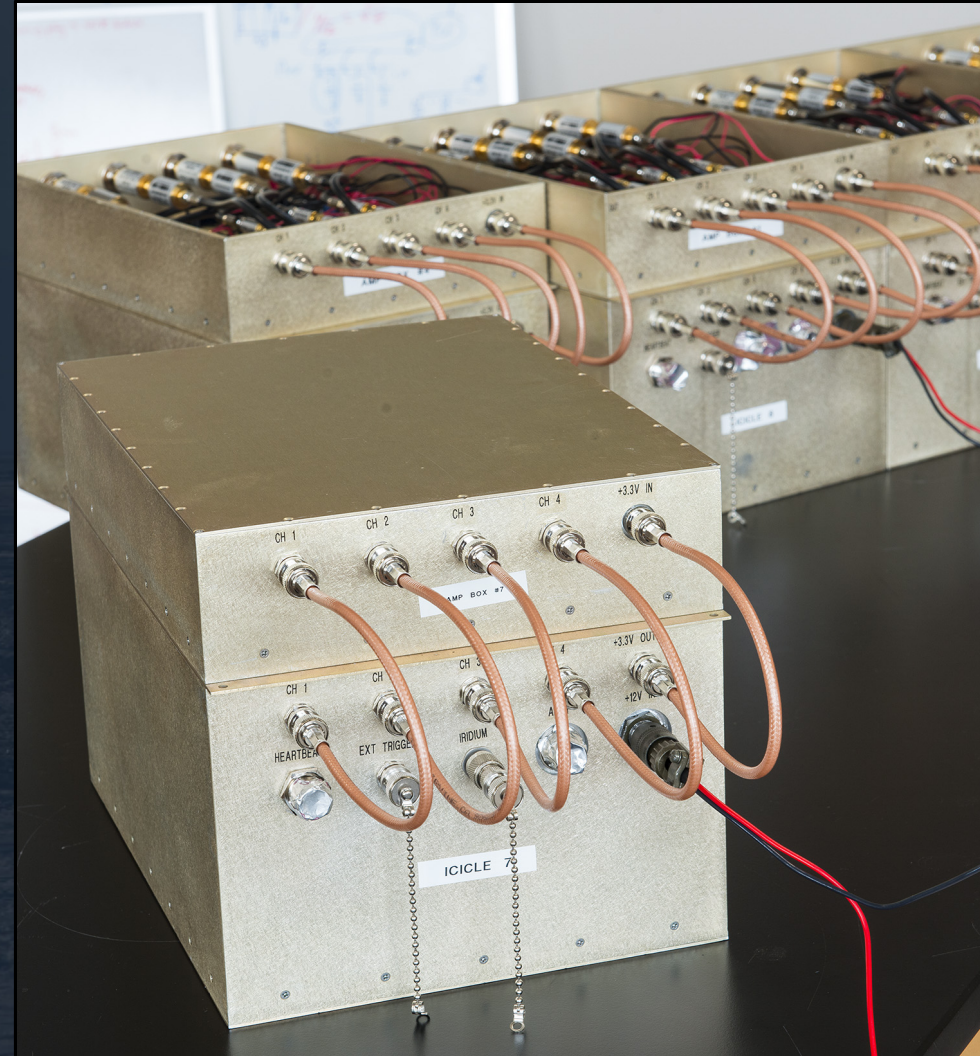
Log Periodic Dipole Array



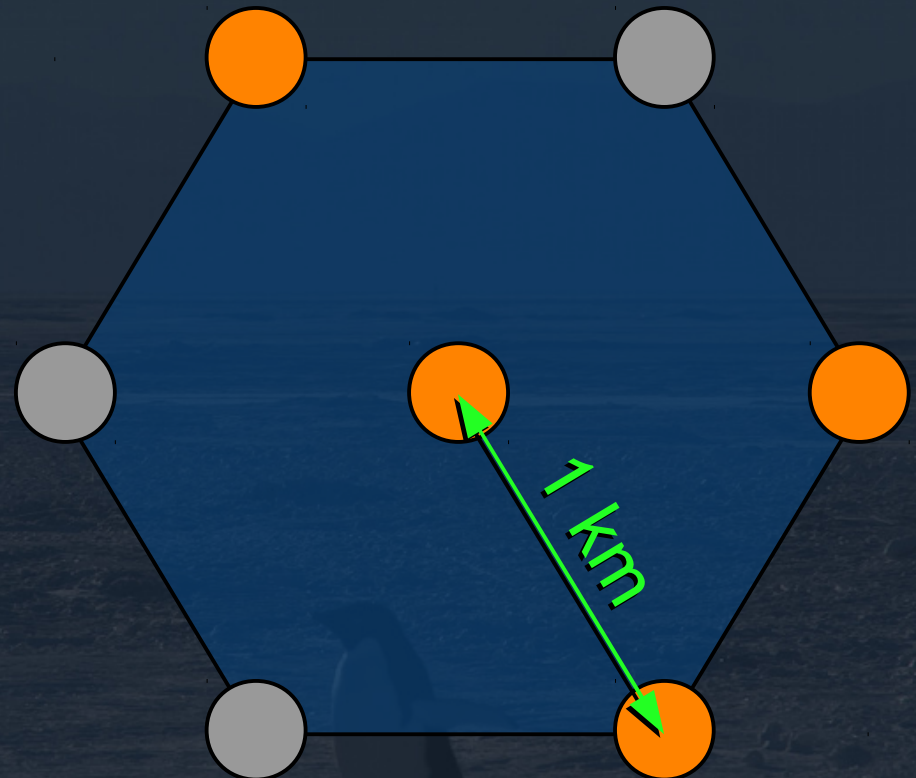
ARIANNA HRA Stations

Local DAQ

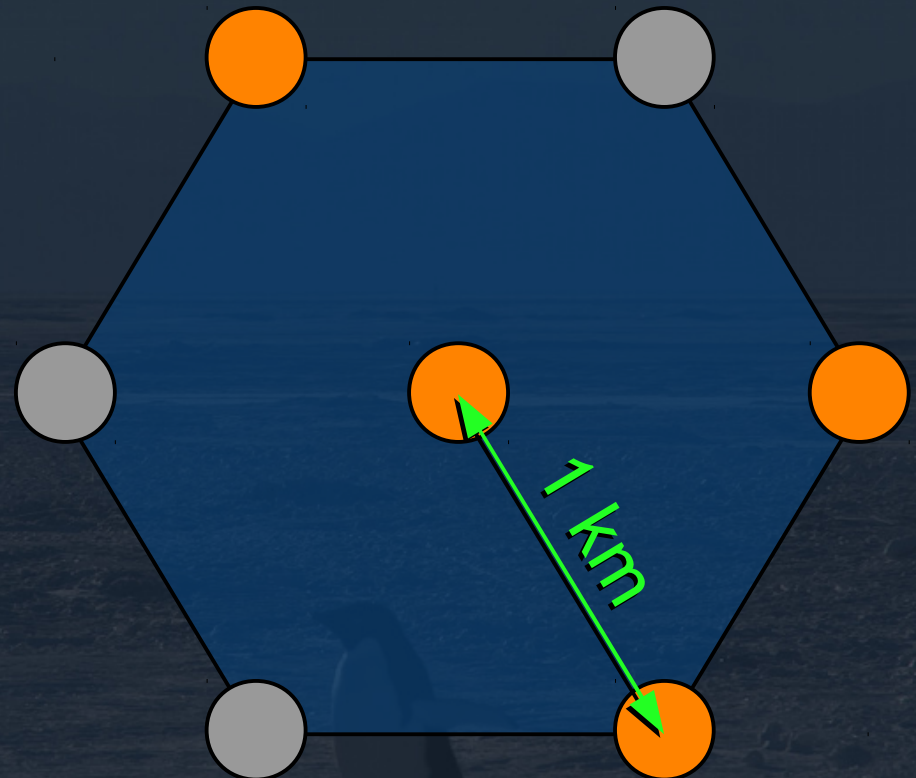
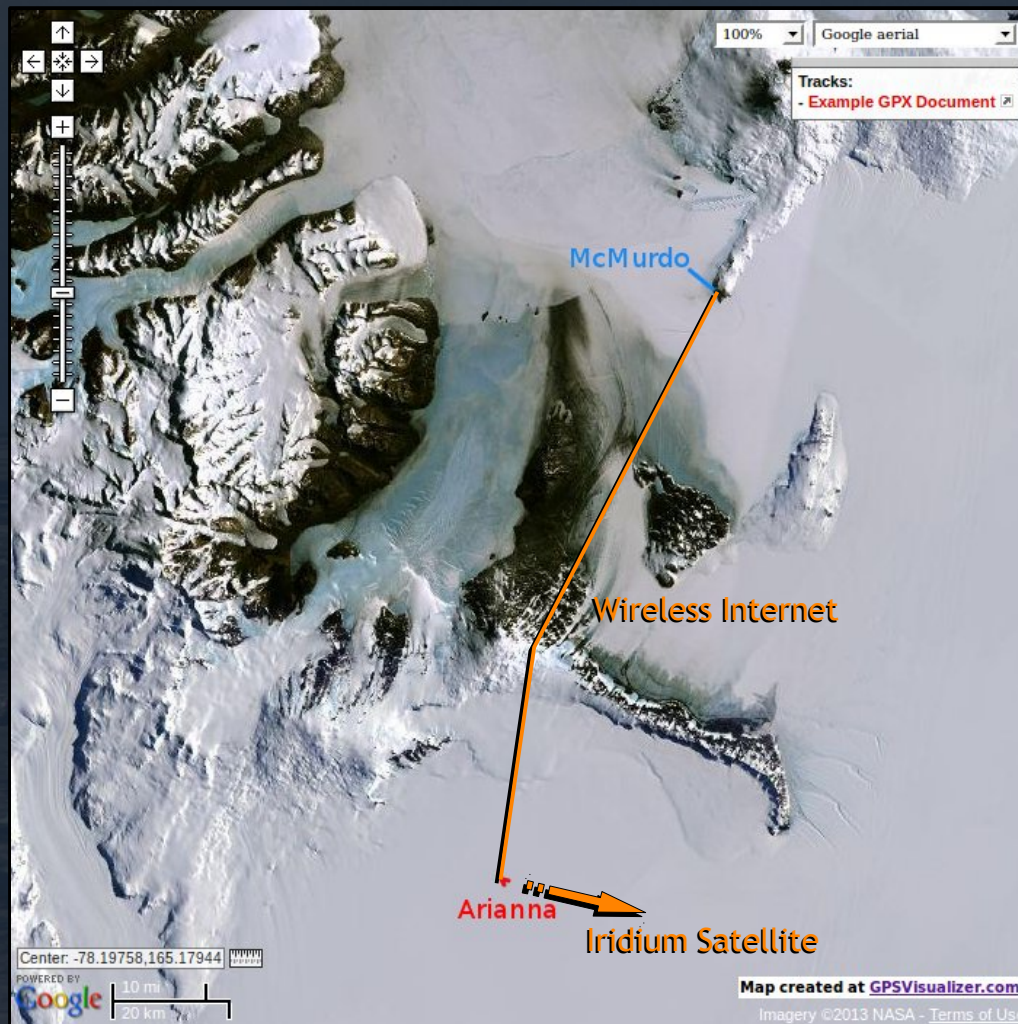
1.92 Giga-samples/sec



ARIANNA HRA Stations



ARIANNA HRA Stations



ARIANNA HRA Stations

Local power

Solar

Wind

Li Batteries

Station needs ≤ 10 watts



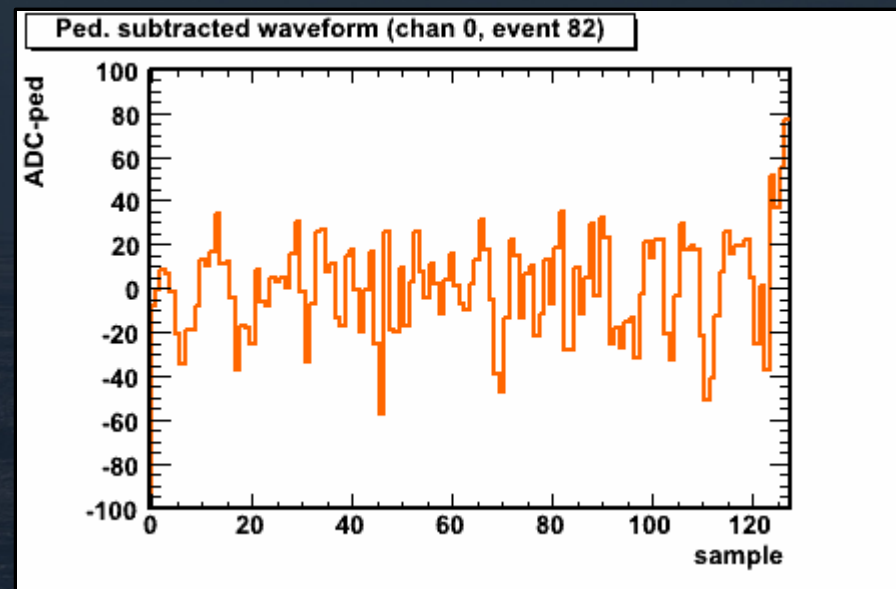
Data From Site

Stations taking data

Simple trigger:

1+ sample high
on 2+ antennae

Mix in min-bias

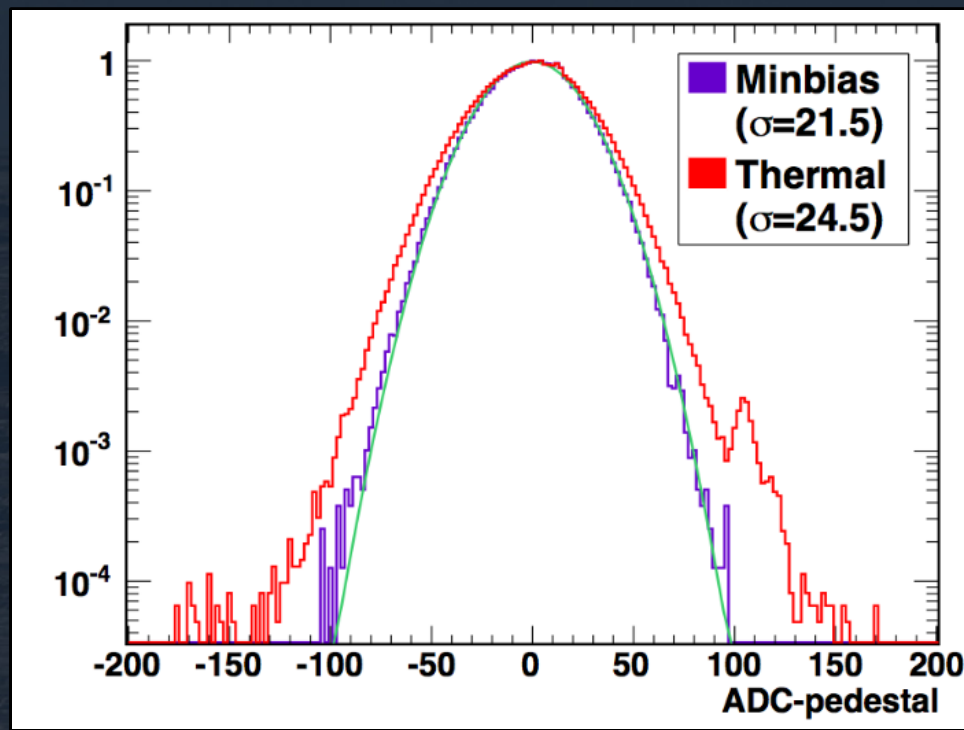


Jan 16, 2013 at 13:57:06 UTC. NW station. N channel.

Data From Site

Environment is radio quiet

White noise from amps is Gaussian

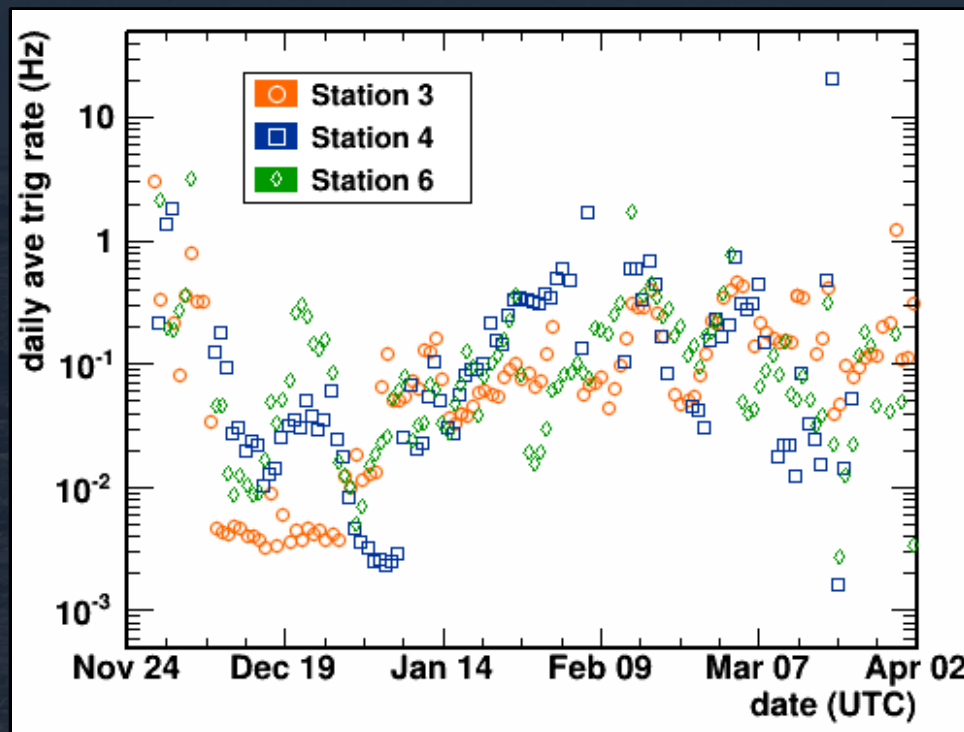


NW station (3). N channel.

Data From Site

Rates low with reasonable thresholds

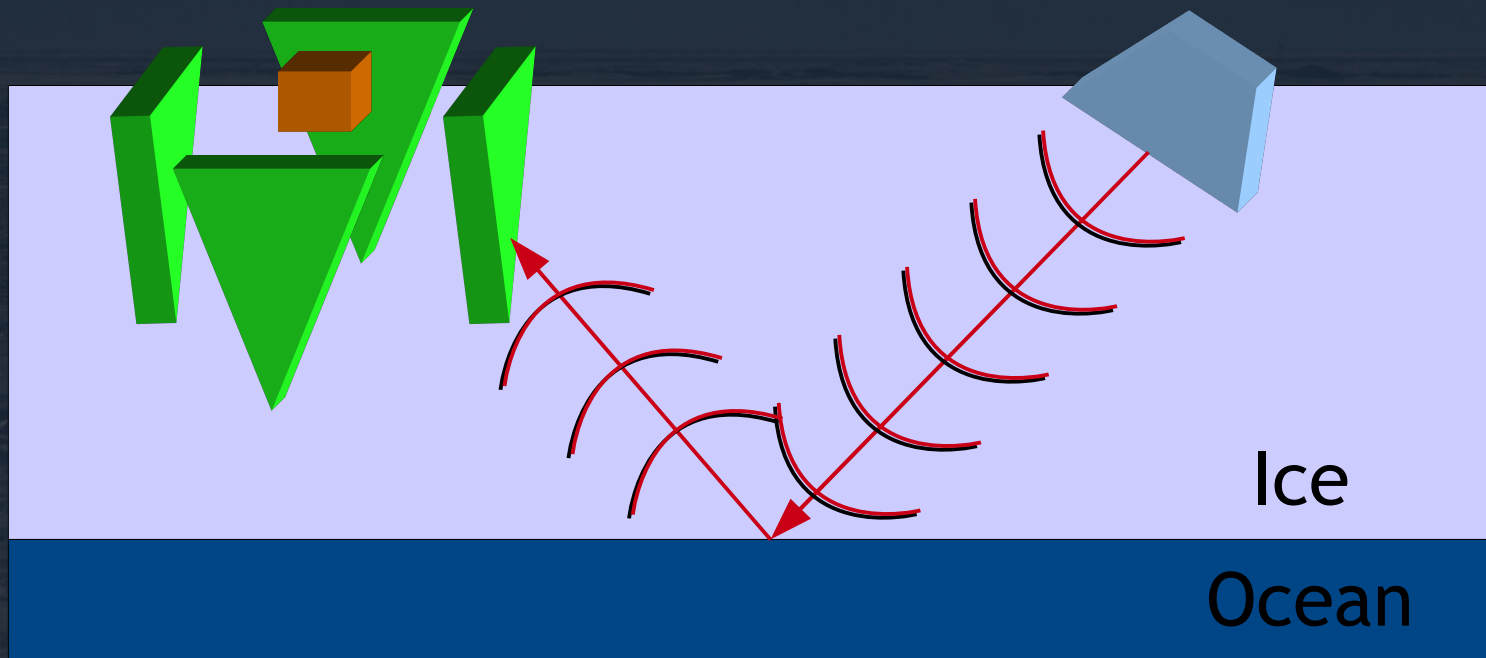
System can go much faster (>100 's Hz)



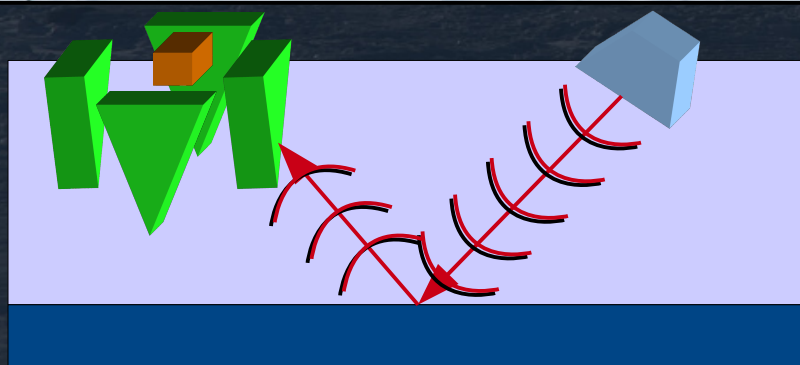
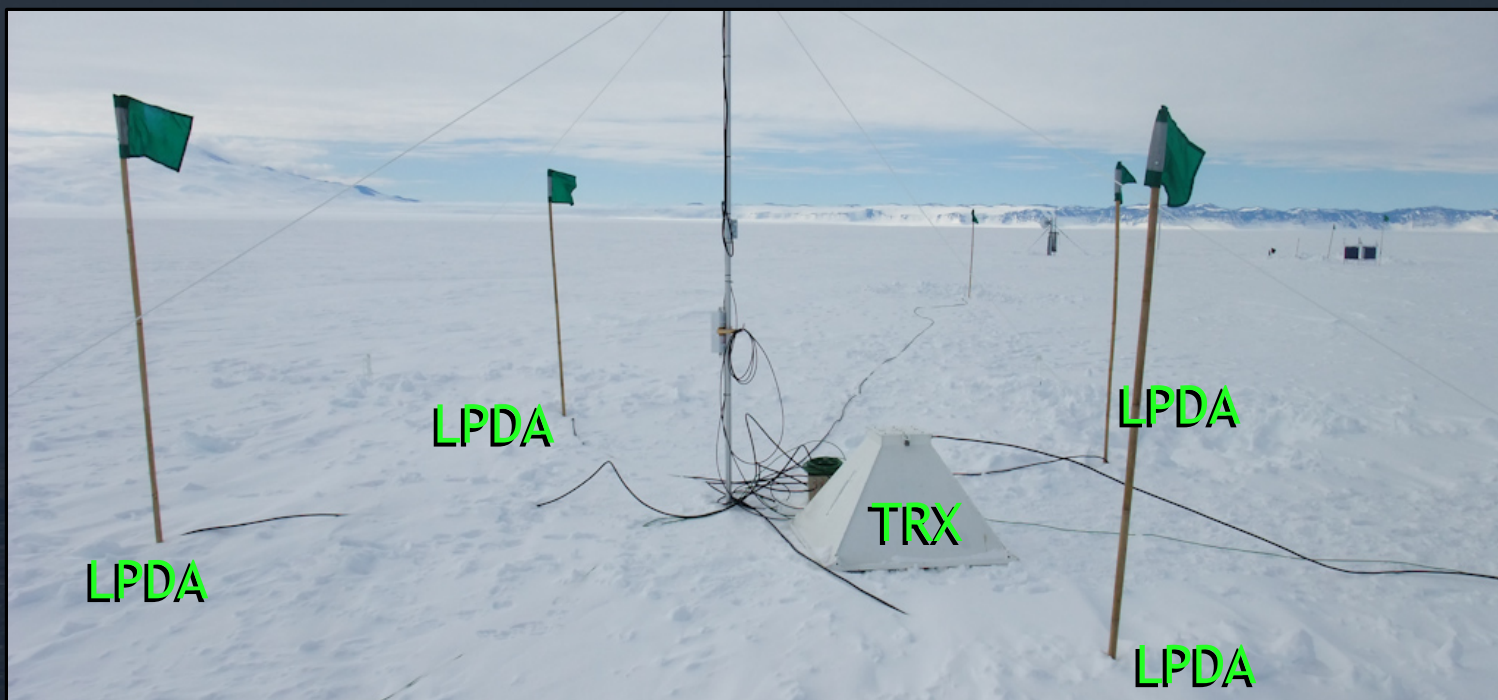
Signal Studies

Send a very short pulse down

Measure reflection with station

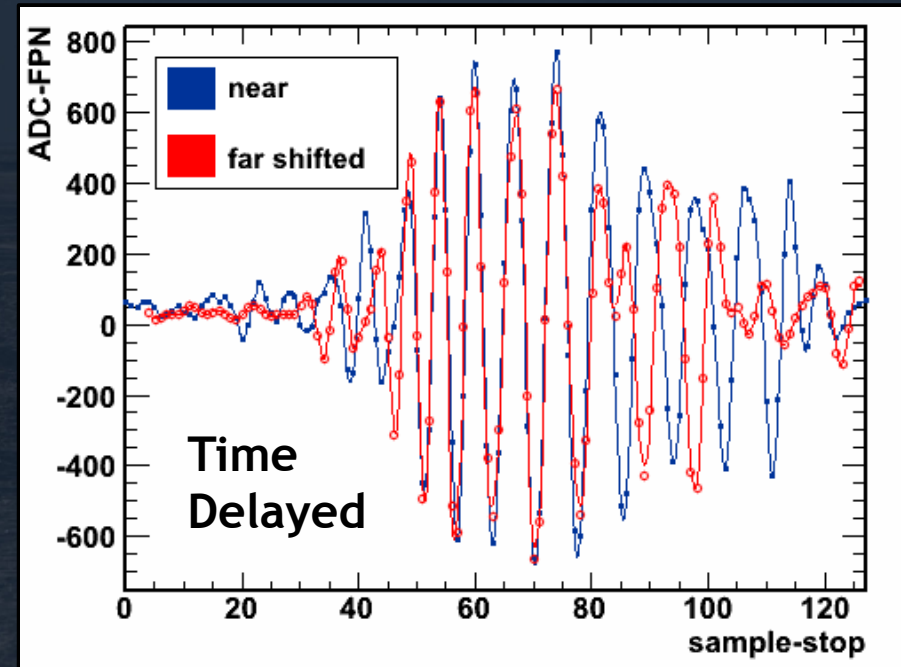
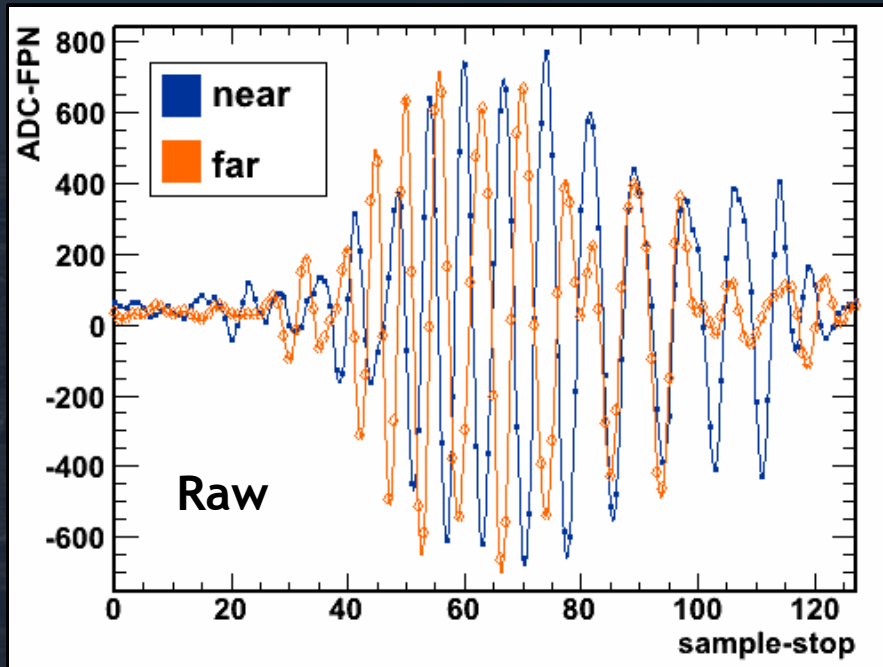


Signal Studies



Signal Studies

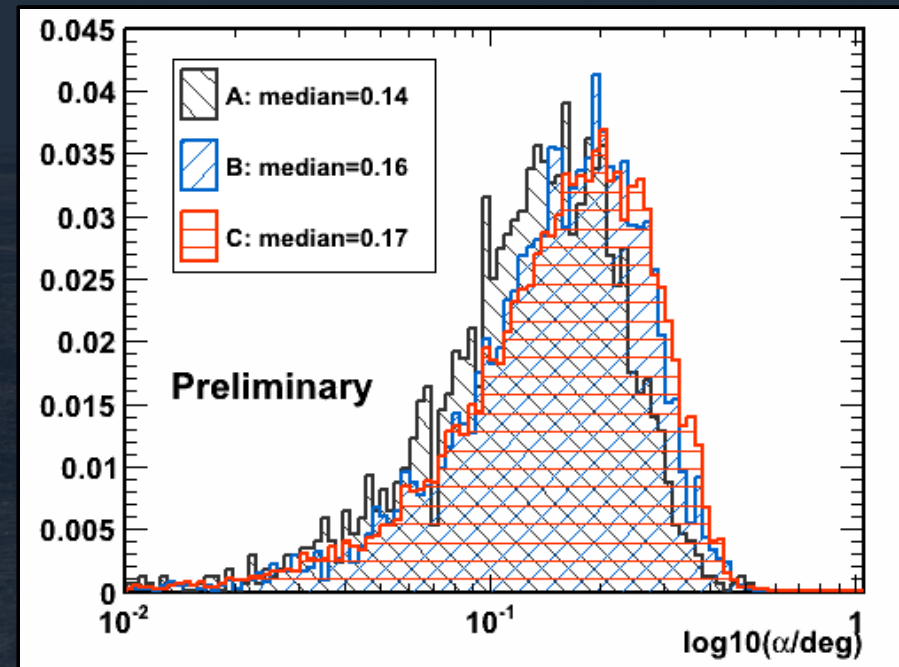
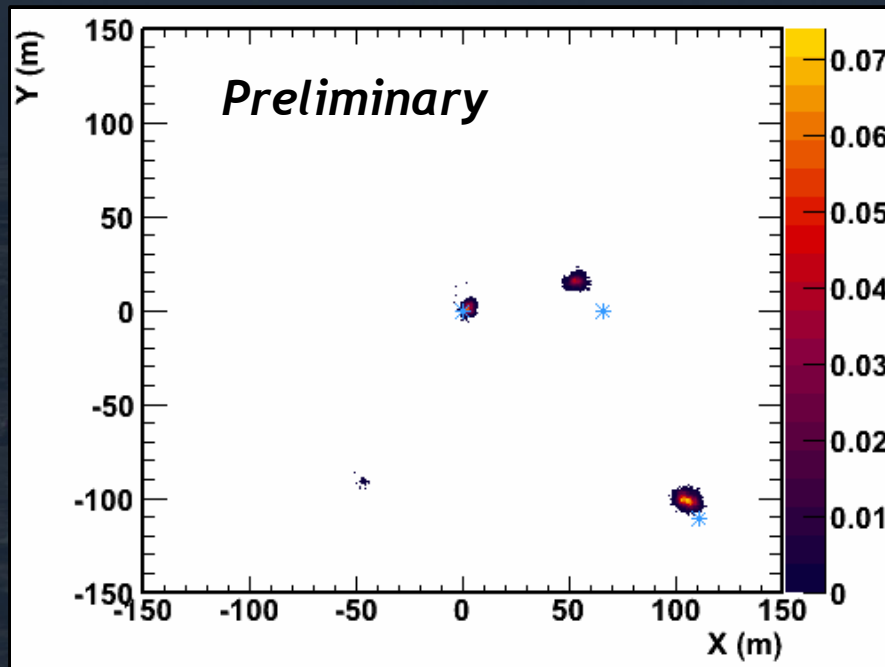
Align recorded pulses by shifting in time



Signal Studies

Require delays to be consistent with plane wave

Inherent angular precision $\sim 0.16^\circ$



Background Studies

First look at 2012-2013 data

Look at waveforms in frequency domain

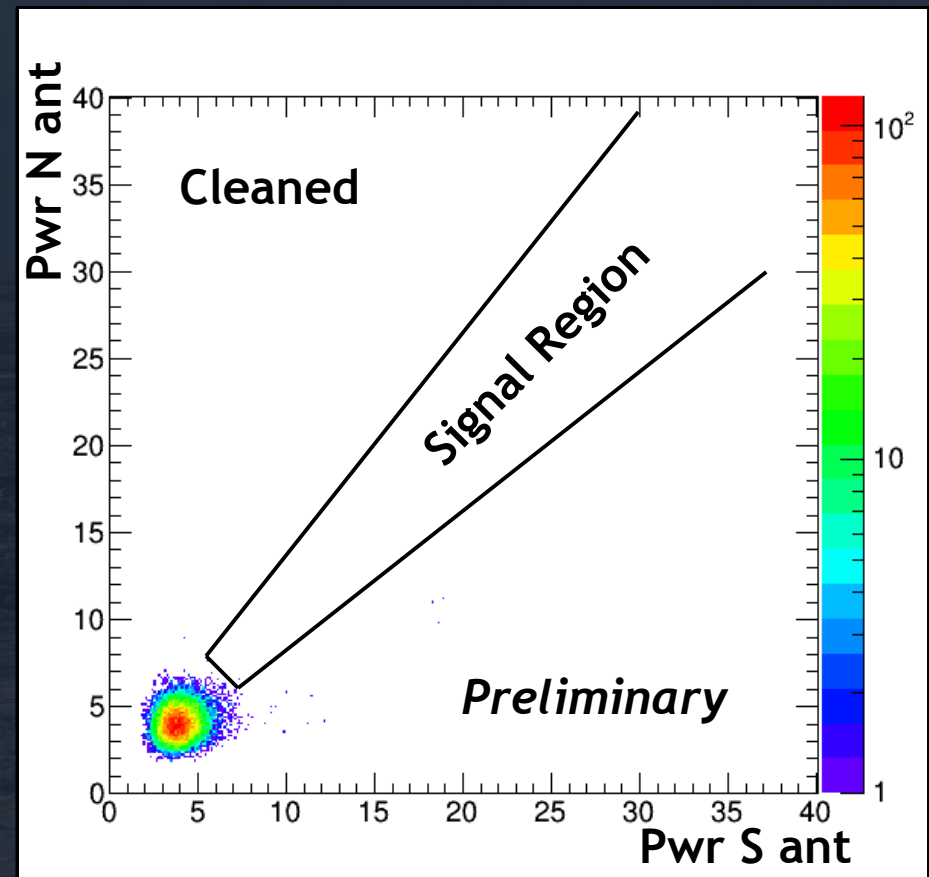
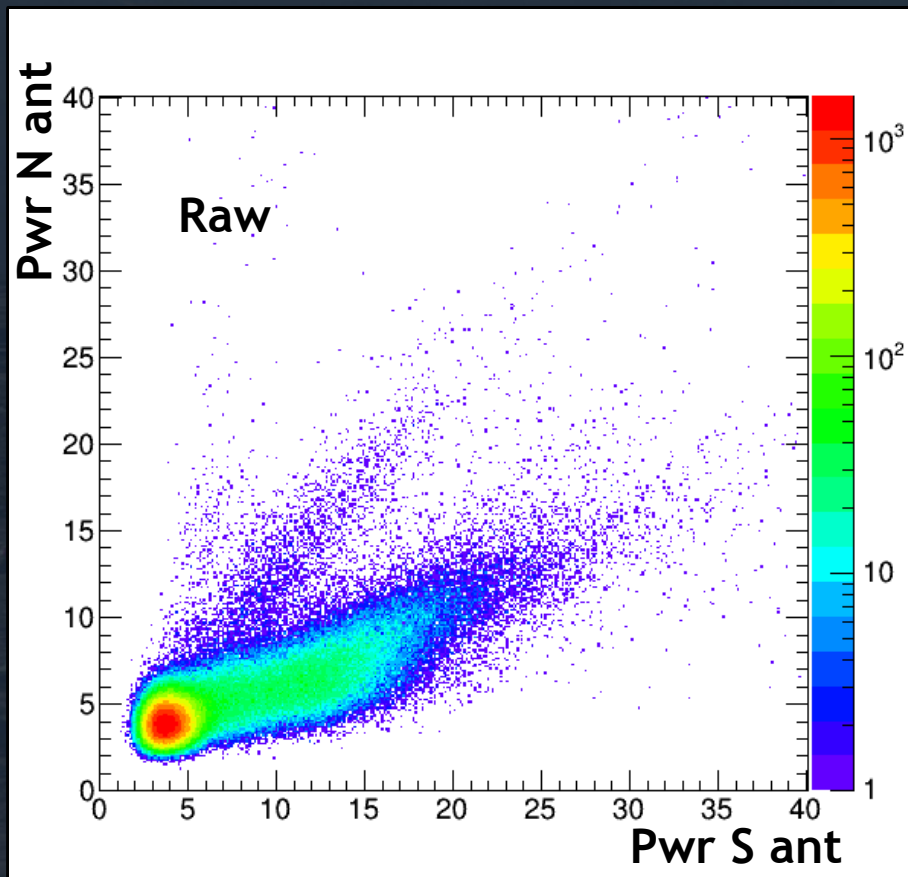
Take pulser as reasonable signal reference

Reject events with freq profiles far from signal

- ✗ lots of power at low freq
- ✗ strong peak at higher freq
- ✗ parallel antennae have very different low freq power

Background Studies

Excellent rejection - before timing or reco cuts!



Background Studies

Could we see CRs?

Currently under study

Antenna response,
time domain signals

See talk by Jordan Hanson after this!

Could be interesting background!

Many ways to separate from signal

Power down by 10db at back of LPDA

CR vertical, v horizontal

Freq spectrum different



Completing R&D

Next step for HRA

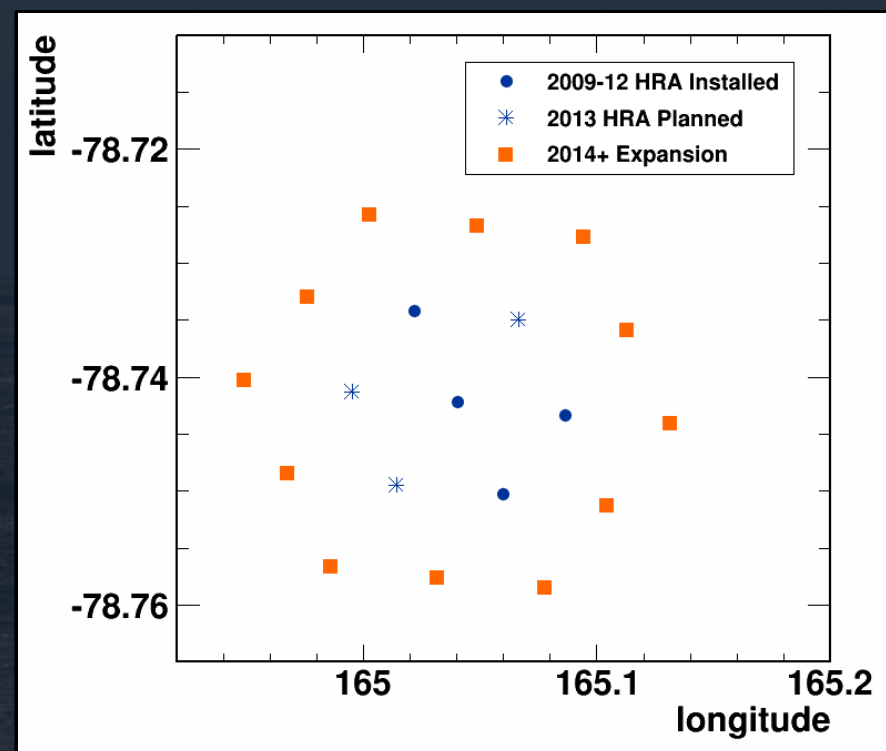
Sweden + USA

U. Uppsala

Winter power R&D

Further DAQ R&D

Potential to observe ν



Summary

New stations installed Dec 2012

Took data and communicated until end of May

RF quiet environment

Excellent angular precision

Background rejection straight forward

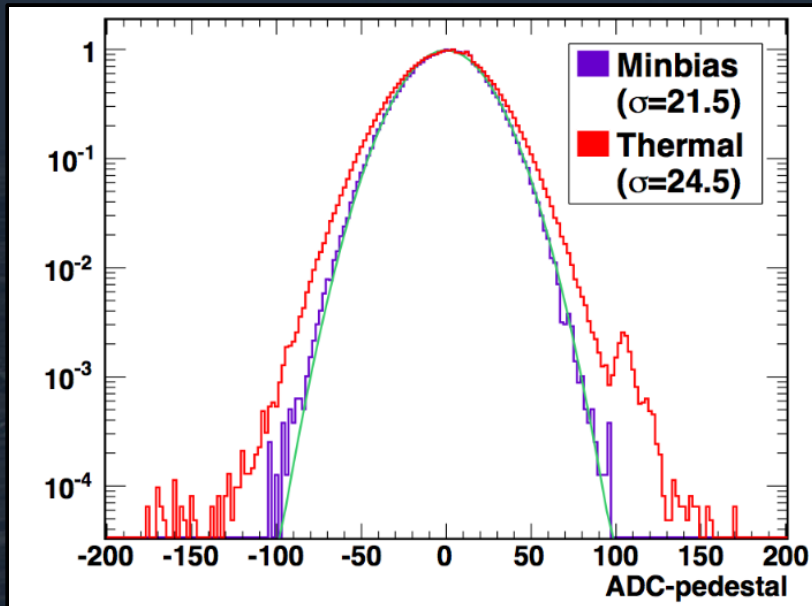
Proposal for full ARIANNA in the works!

960 station ν telescope

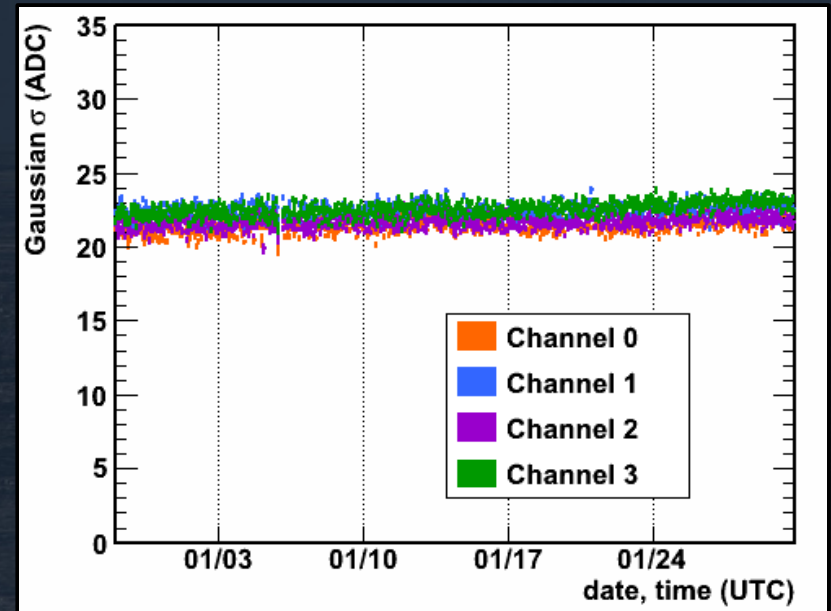
Backup Slides

Environment

RF quiet & stable



NW station. N channel.



NW station. Minbias events.

Rate Fluctuations

DAQ sensitive to temperature

Put station on roof

No antennae

Trigger 2/2 channels

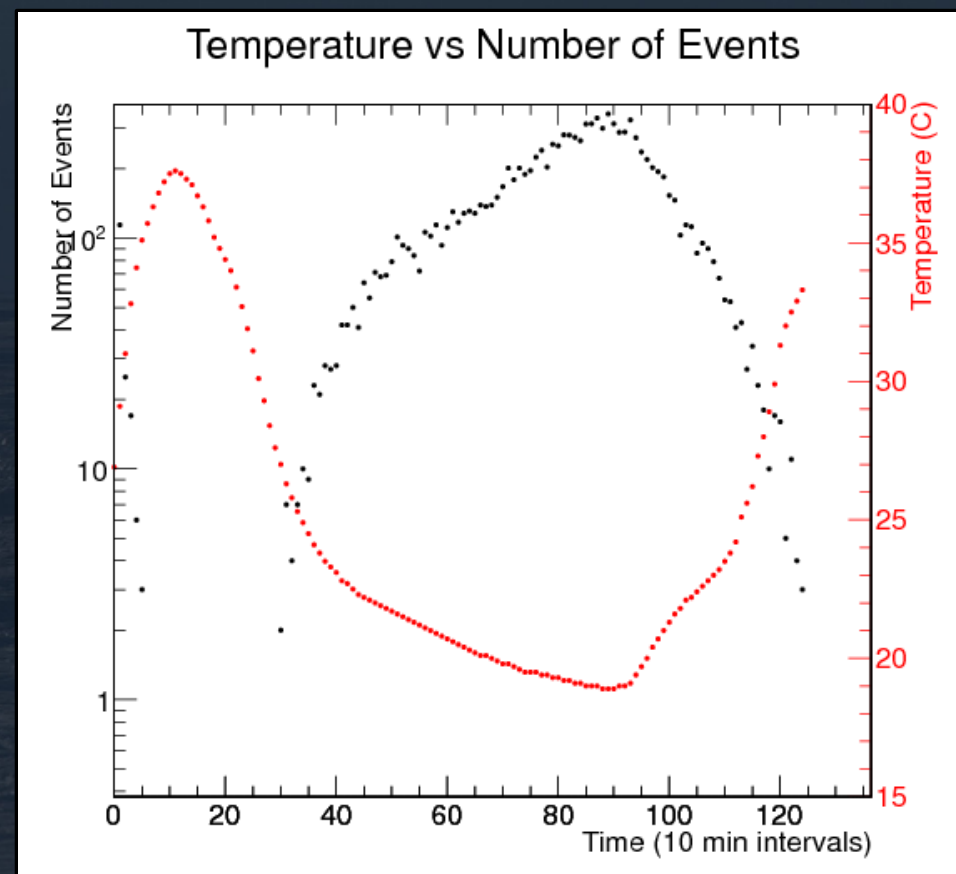
Amp noise

Doesn't affect ν sens!

No significant dead time

Can reduce with trigger

High + low thresholds



Background Studies

Origin of background?

Wind gen in strong winds

Increases power, but not rates!

Power at very low frequencies

Rare transients in summer

Dur. ~hour

Thermal noise of amps

Trivial

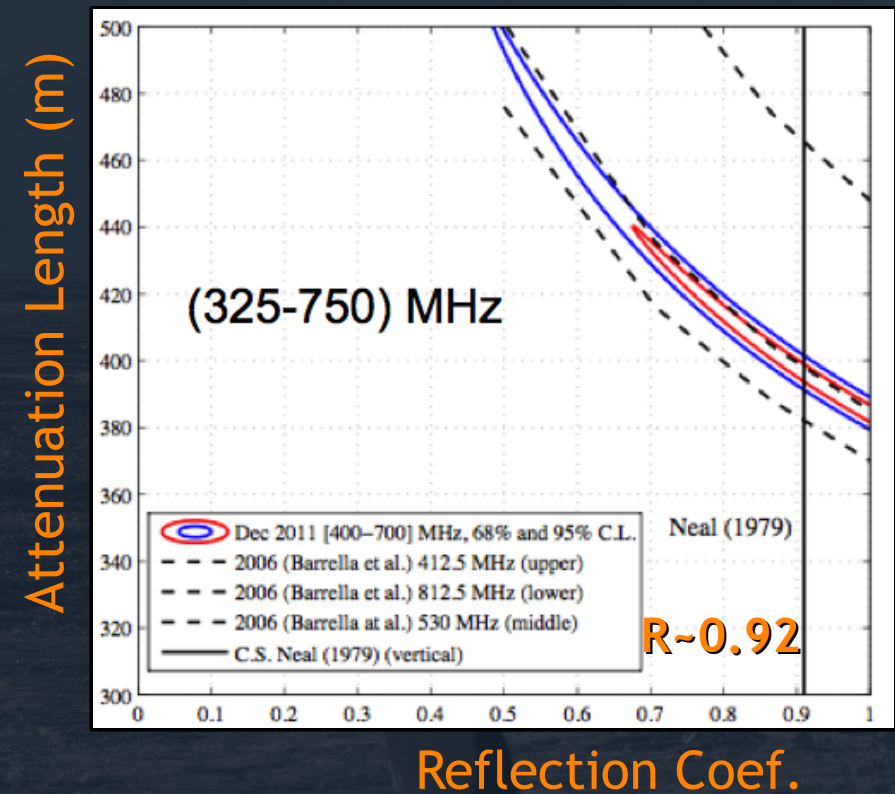
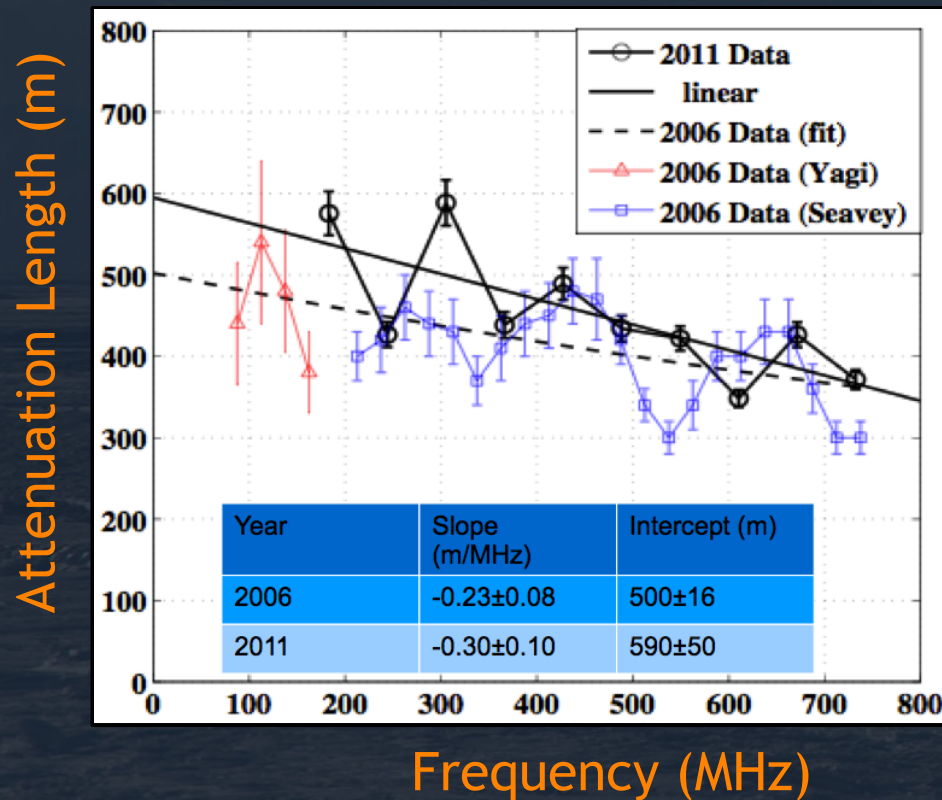


Models

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,
PhD Dissertation, 2013

Ice Properties



Costs

Should wait for proposal

Design plan (& costs) changing frequently

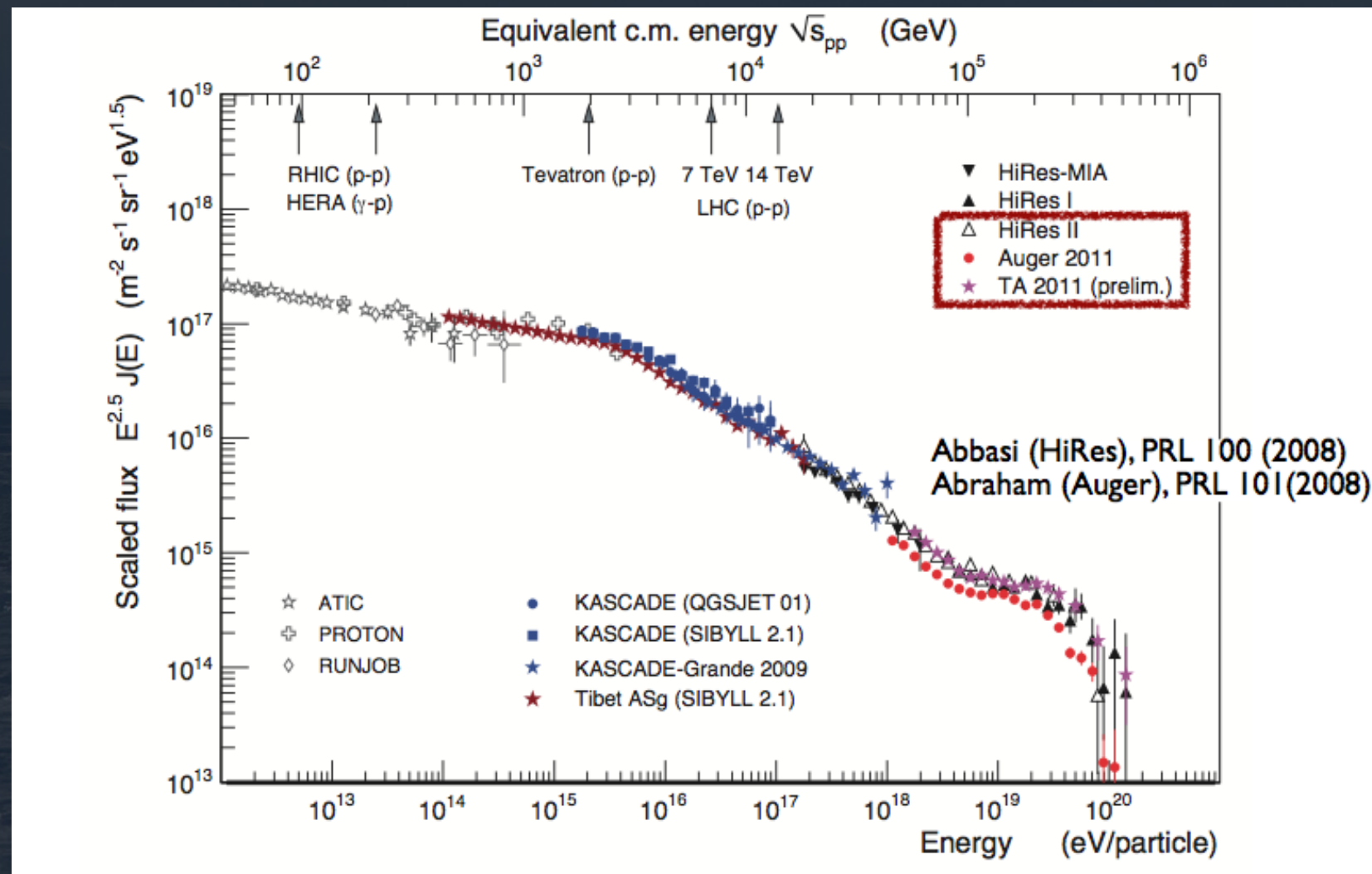
Hardware ~ 10k / station ~ \$9.6 M

Personnel ~ \$10 M

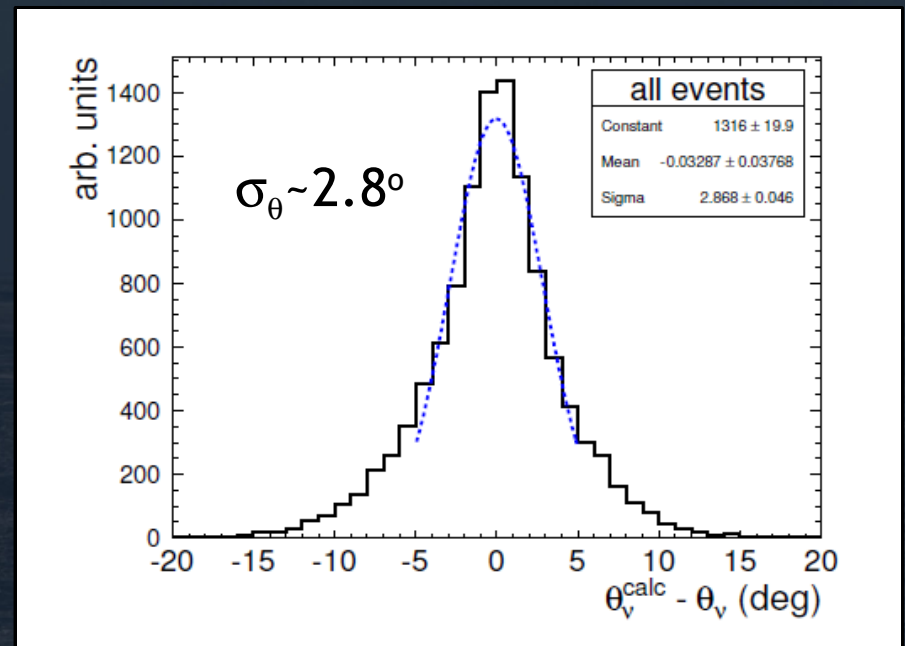
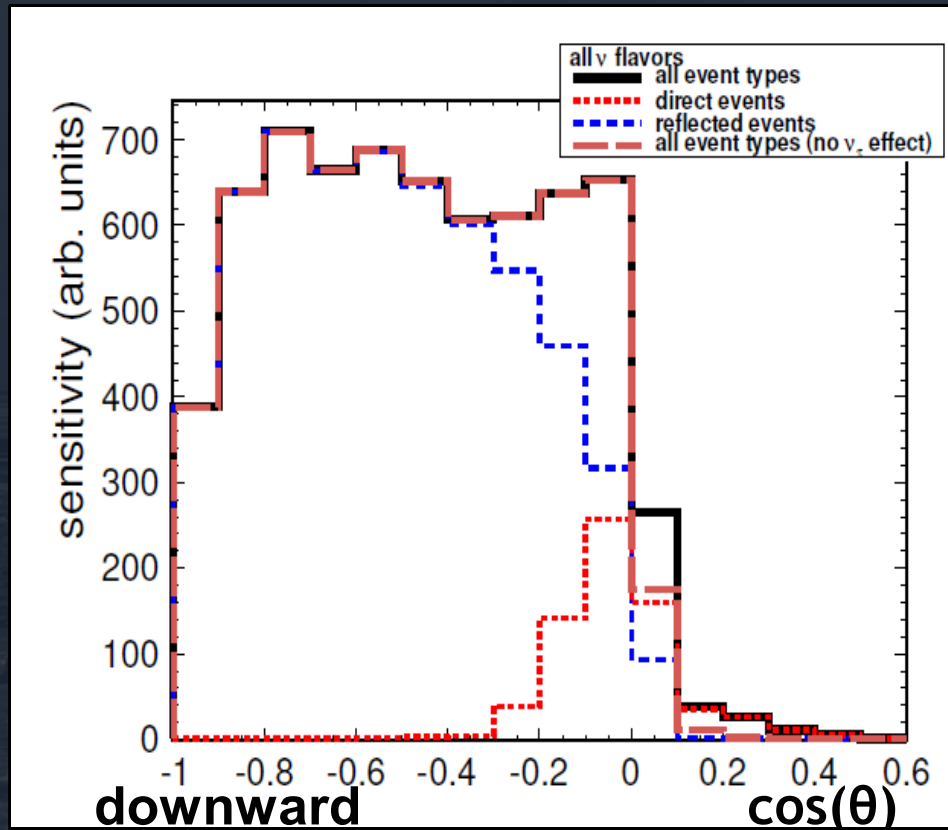
Logistics (3 yr install) ~ \$5 M



Cosmic Ray Spectrum

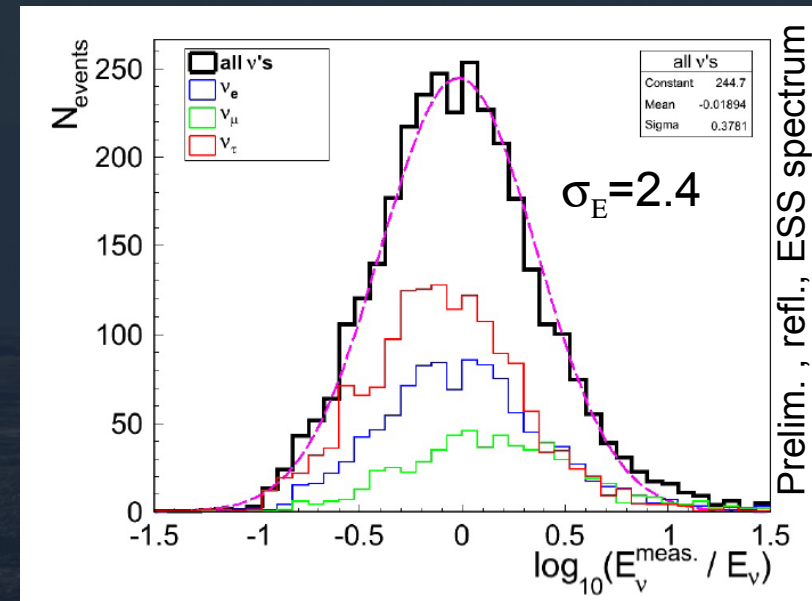
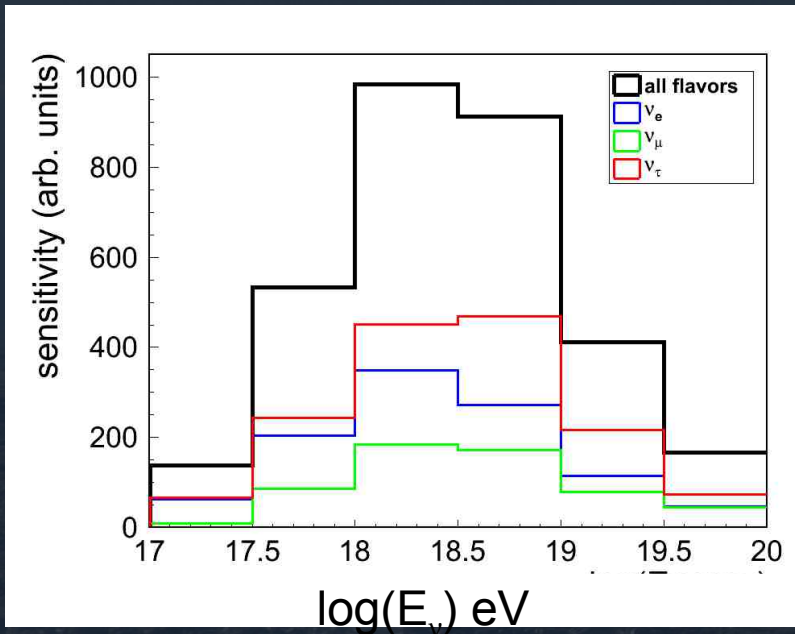


Neutrino Detection



K. Dookayka, UCI PhD dissertation, 2011

Neutrino Detection



K. Dookayka, UCI PhD dissertation, 2011