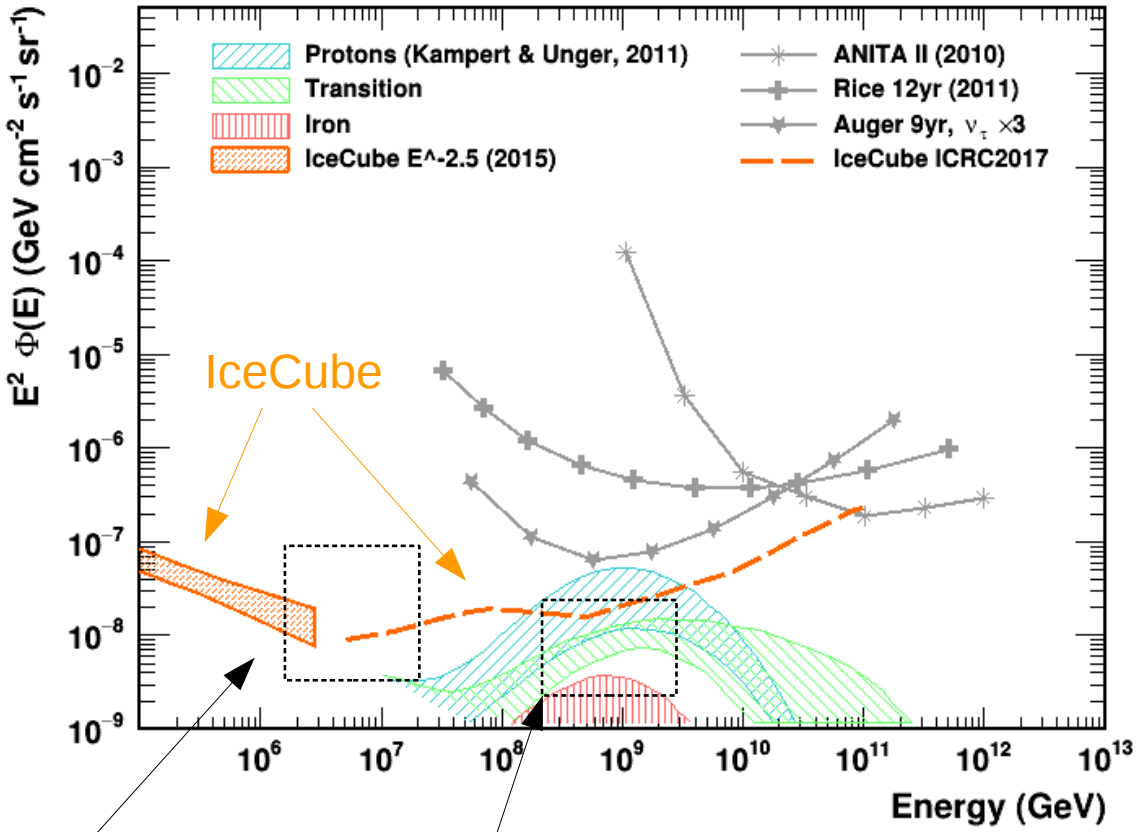
The ARIANNA Detector

Chris Persichilli
University of California, Irvine

TEVPA 2017
Columbus, Ohio

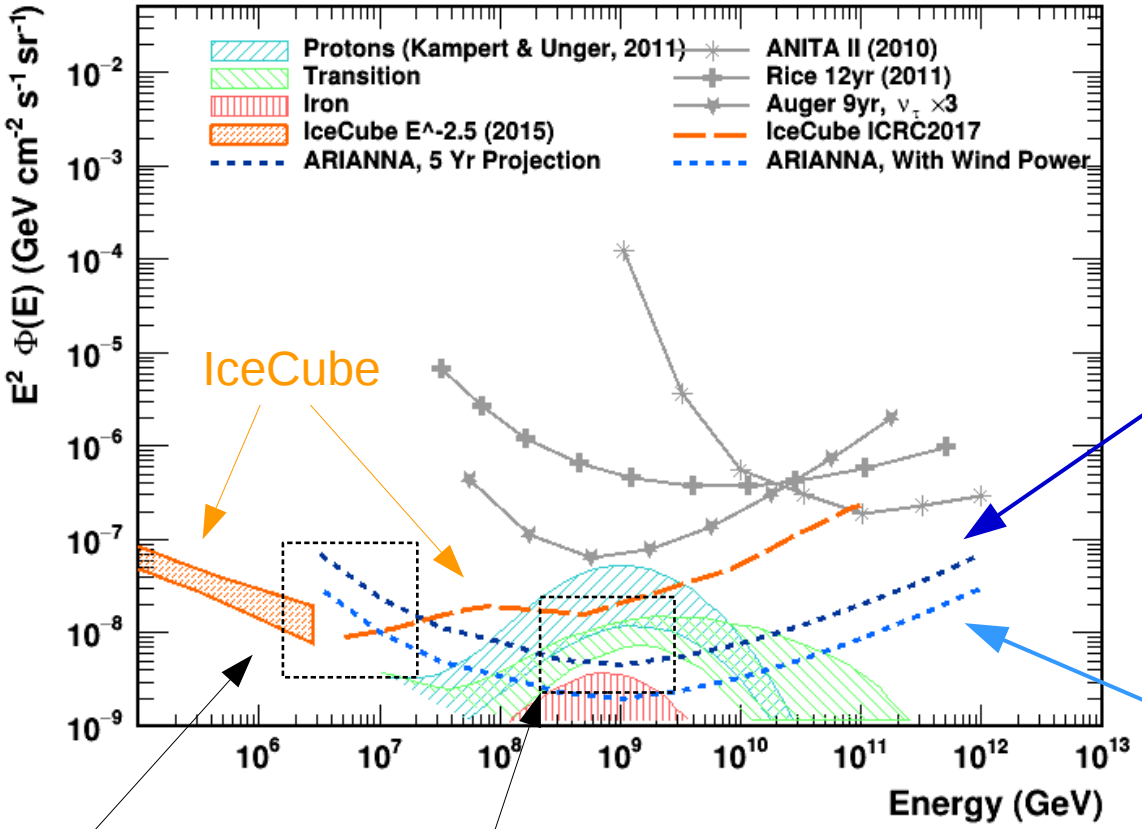
Science Goals of the ARIANNA Array



Extend IceCube Flux to higher energies

Probe pessimistic iron-only GZK flux predictions

Science Goals of the ARIANNA Array



Extend IceCube Flux to higher energies

Probe pessimistic iron-only GZK flux predictions

Baseline ARIANNA

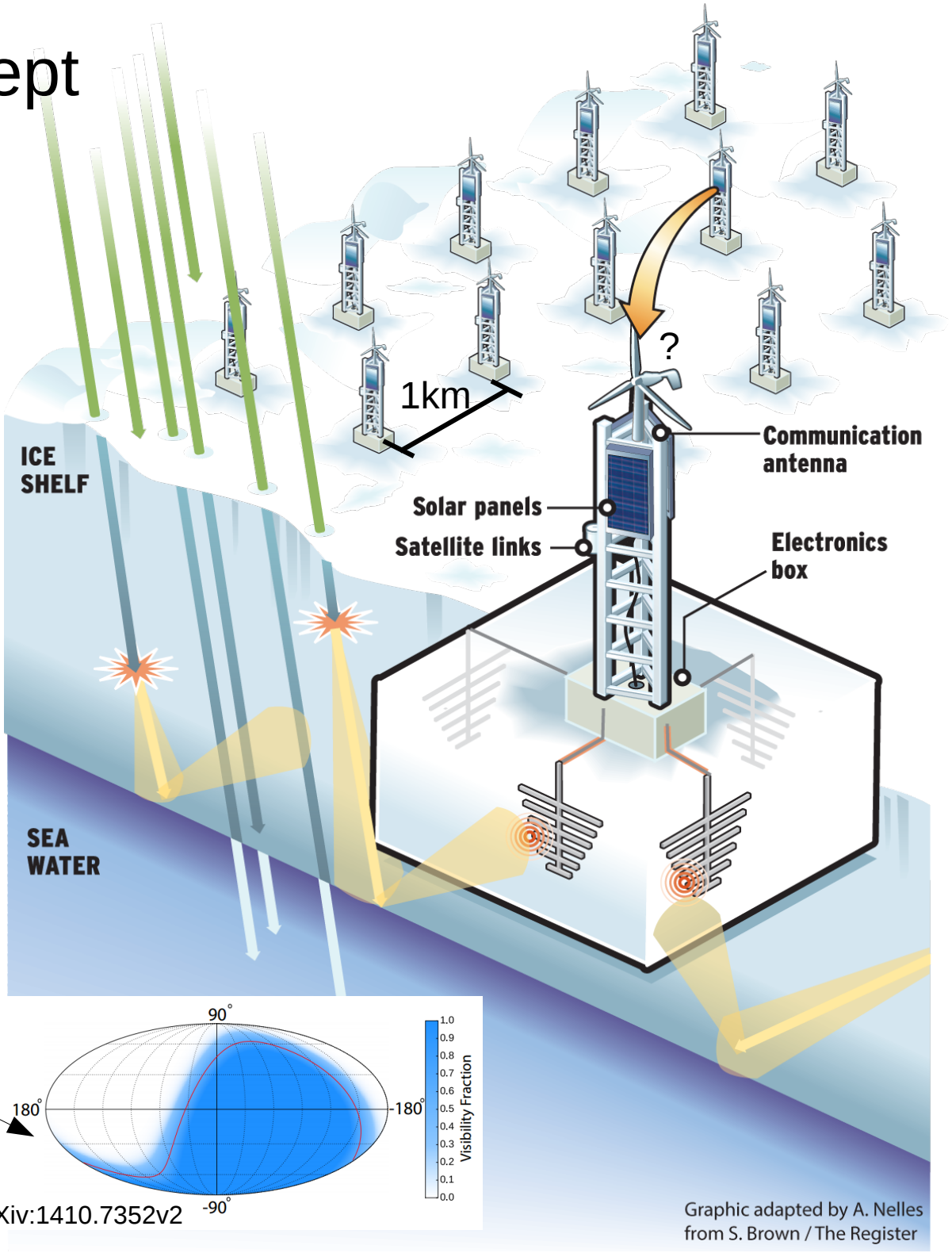
- 1296 Stations
- 1km separation
- 5 years of run-time
- Assume 90% analysis efficiency
- Average livetime fraction of current pilot stations

With wind power

- Extends operation through Antarctic Winter
- Currently being tested

The ARIANNA Concept

- Signal reflection at ice/water interface allows for surface installation and better sky coverage
- Low power requirements (4-10W) allow for self-contained power system, autonomous operation
- Radio-quiet environment means low trigger rate, allowing real-time wireless data transfer
- Off-the-shelf LPDA antennas are cheap (~$100), well understood and provide directionality
- Proximity to McMurdo Station provides excellent logistical support, and reduces construction costs

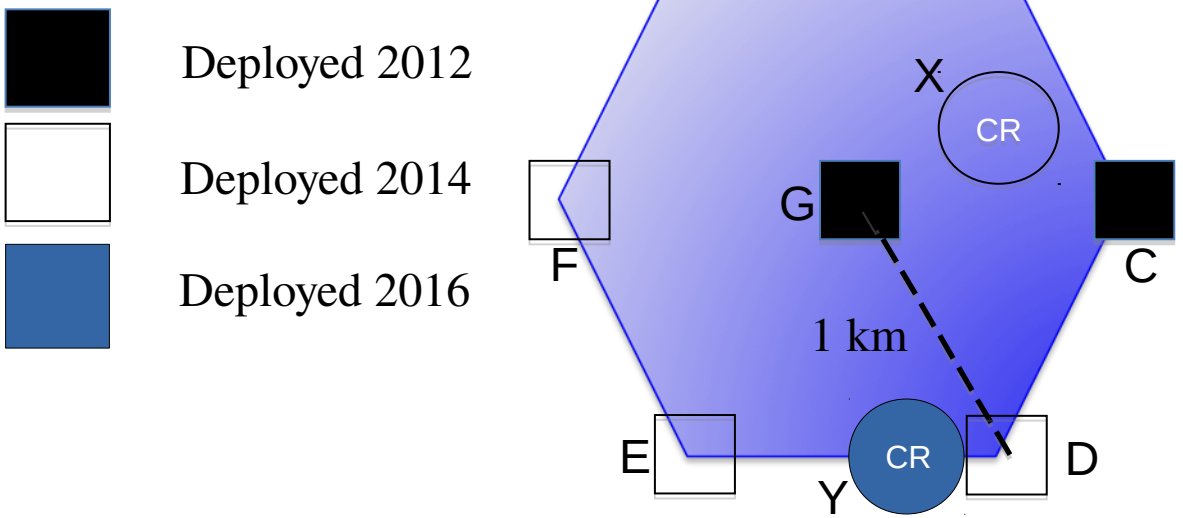


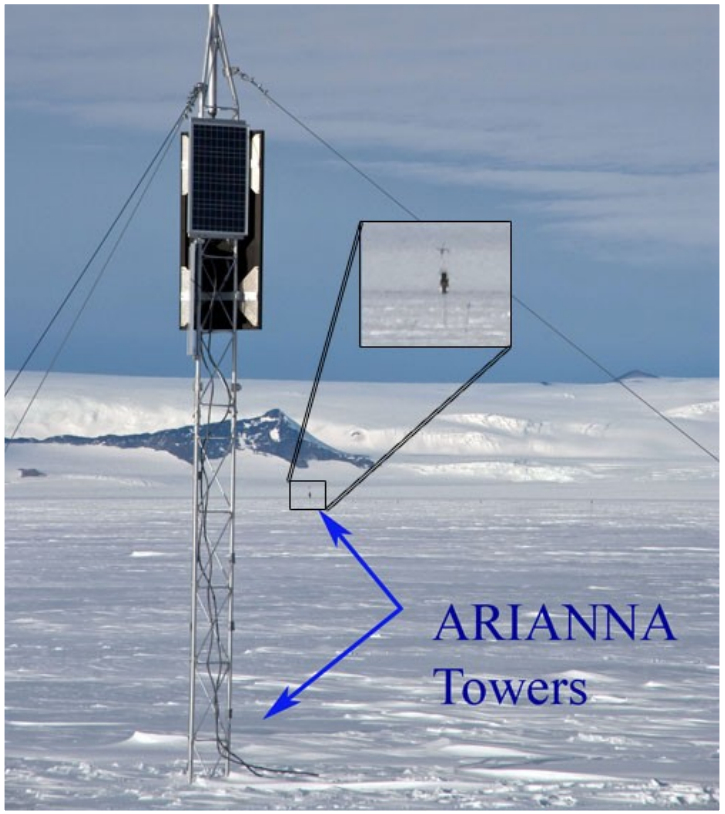
Neutrino Sky Coverage
(Galactic Coordinates)

C. Reed, arXiv:1410.7352v2

Graphic adapted by A. Nelles
from S. Brown / The Register

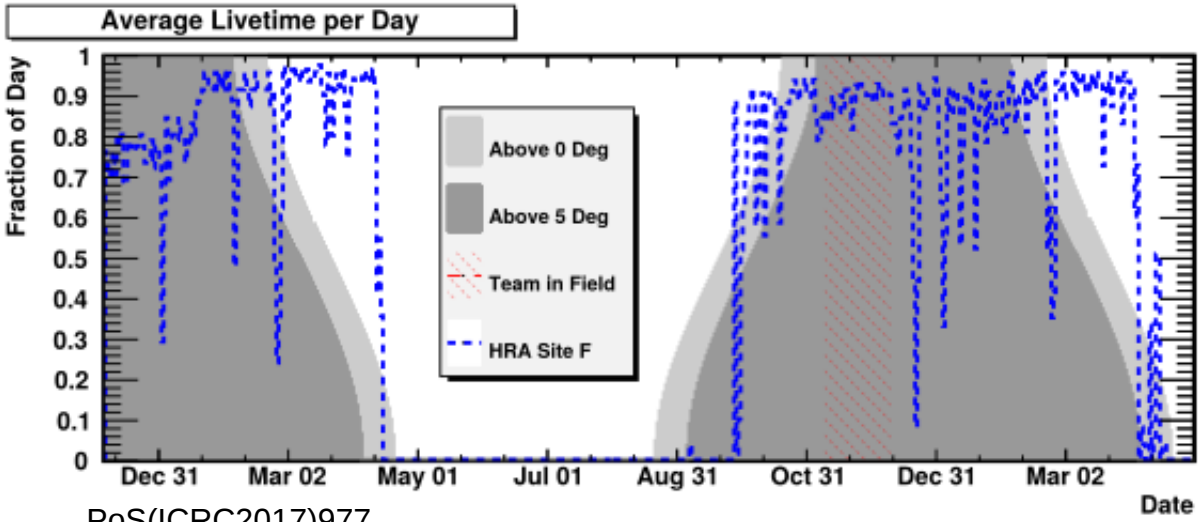
Current State of ARIANNA: The HRA





Useful Livetime for analysis, adjusted for DAq deadtime, and data transmission

- System survives the Antarctic winter and function correctly in the spring
- 90% livetime is typical during normal operation
- Dips in livetime due to bulk data transfers and storm periods
- Average Livetime of 149 days per HRA Station in 2016-2017 seaso



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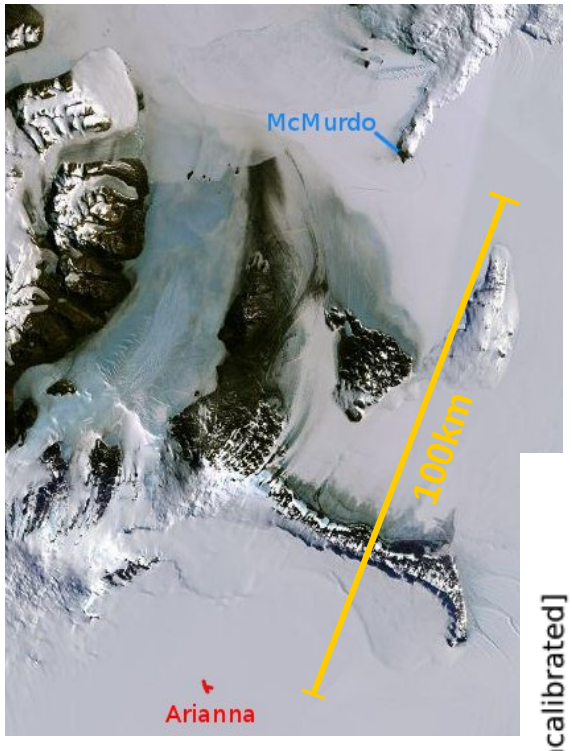
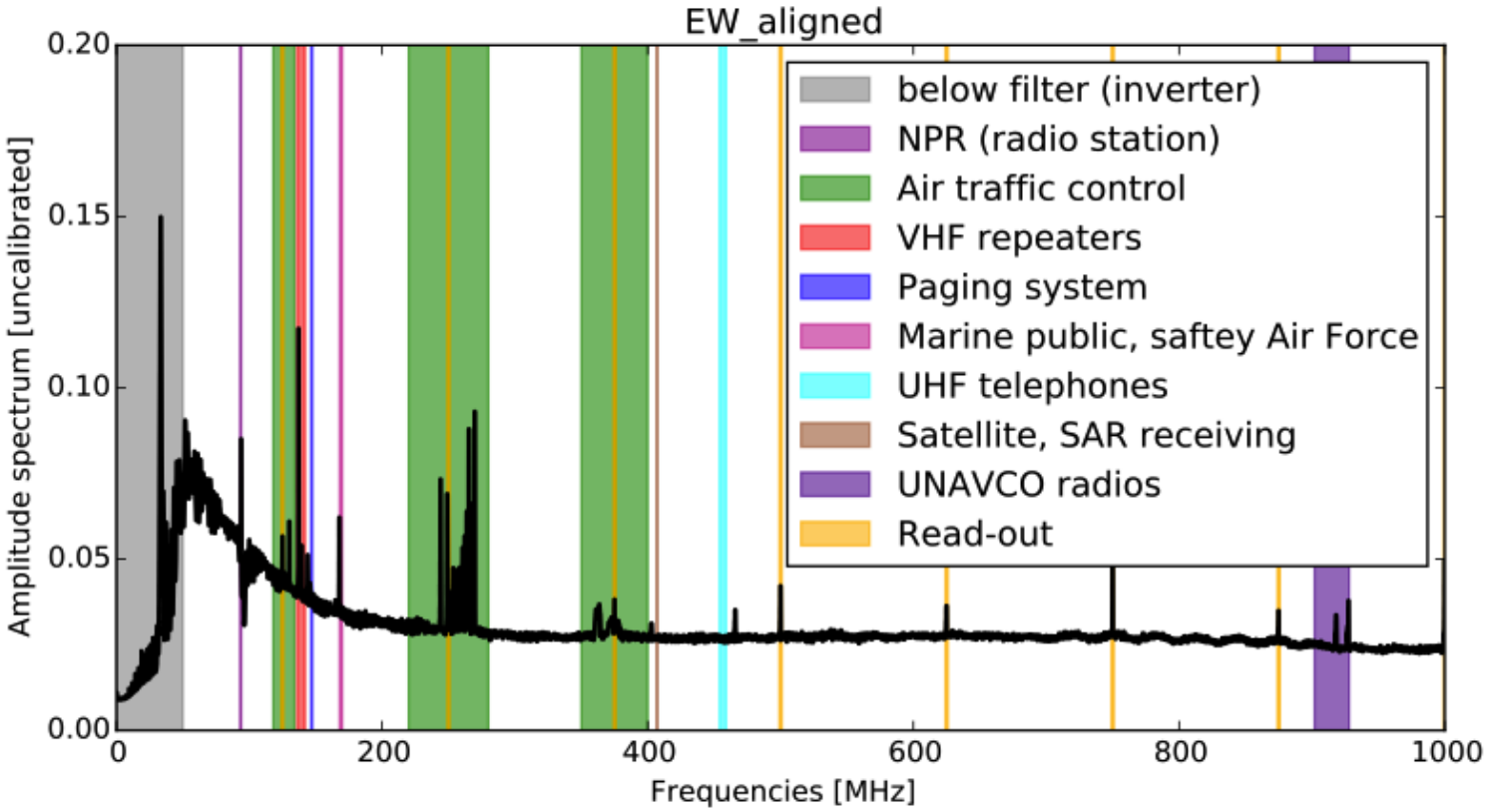
Radio Environment at the ARIANNA Site



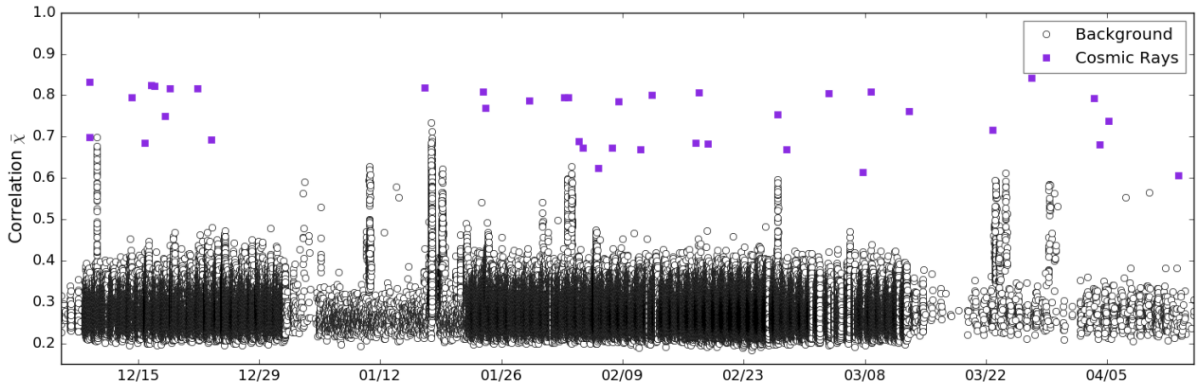
- Shielding by Minna Bluff creates <u>extremely quiet</u> environment
- Base spectrum limited by galactic noise
- Narrow bandwidth noise is transient, low power, and identifiable

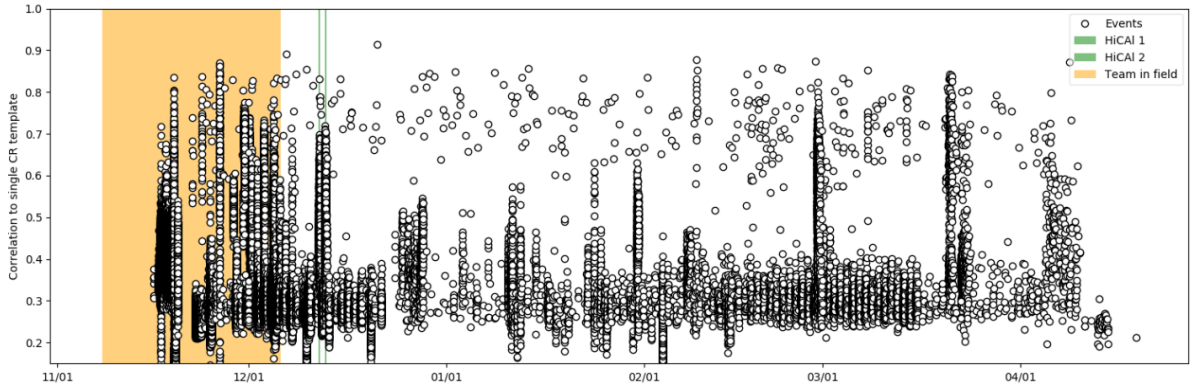
Forced triggers taken on oscilloscope with 50MHz LPDA →



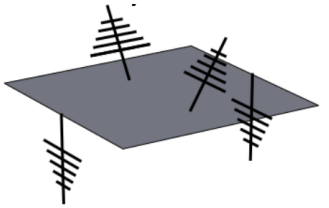
Radio Triggered Cosmic Rays

Correlation to Cosmic Ray Template

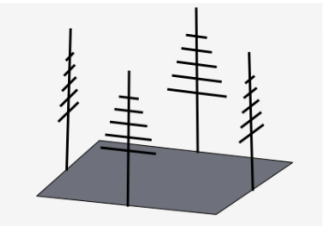




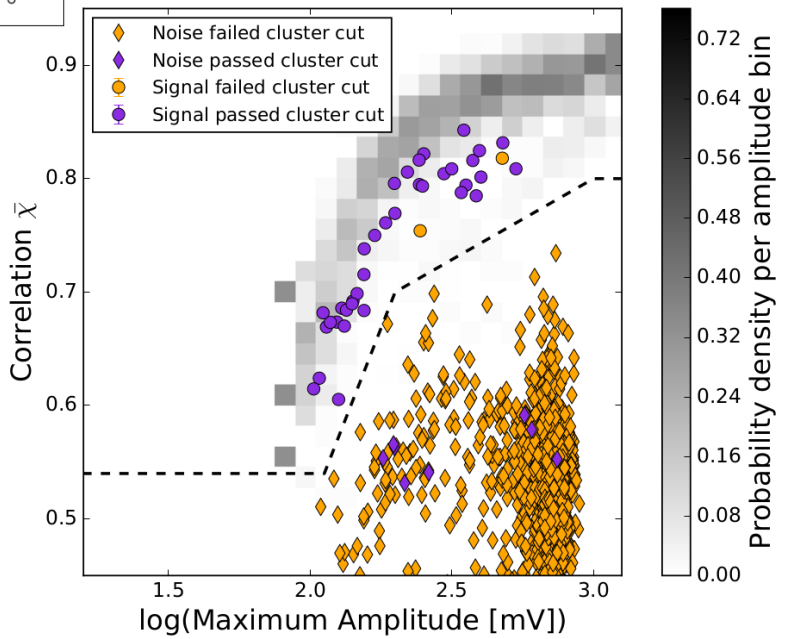
Site X
2015-2016



Site Y
2016-2017



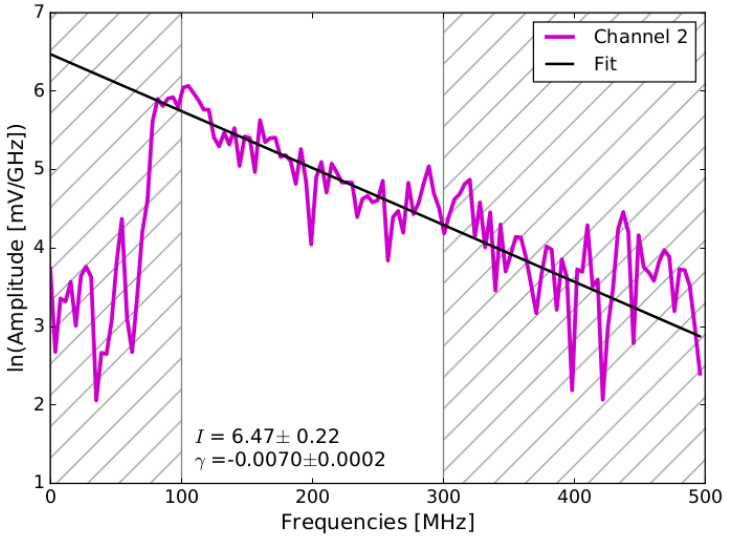
- Cosmic Rays abound, and are readily distinguishable from background based on waveform properties (Signal amplitude and correlation to CoREAS templates)
- Air shower and neutrino signals look similar in detector, so upward facing antennas are needed for CR tagging
- This serves as a calibration for ARIANNA, and a validation for our template matching analysis

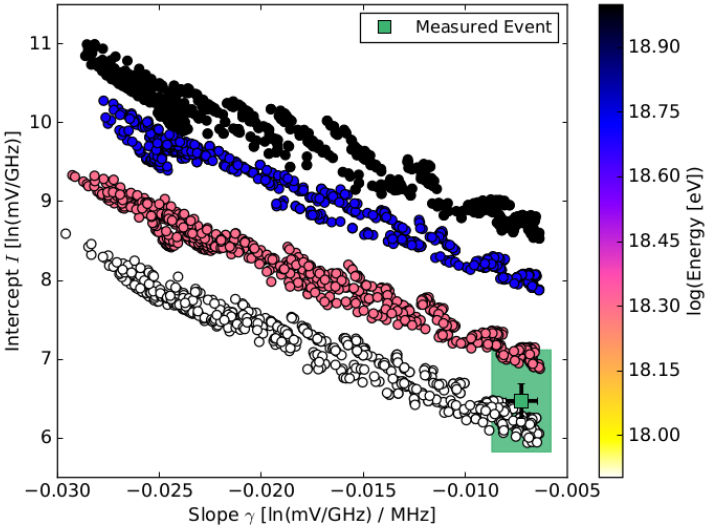


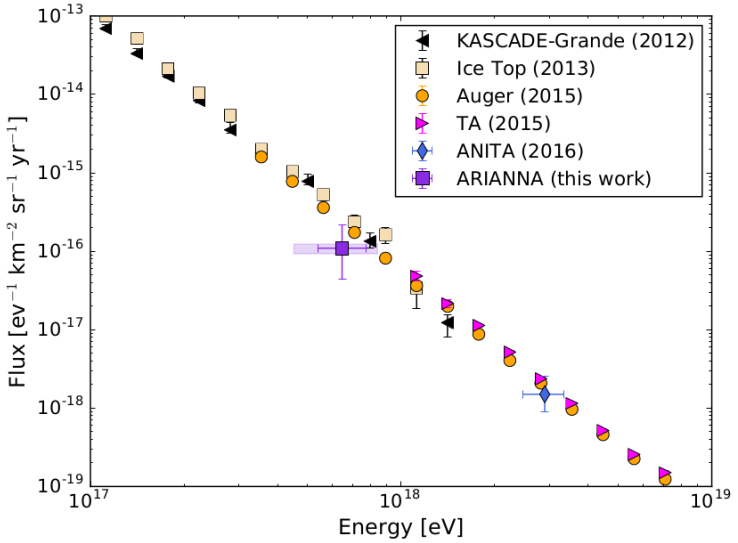
A. Nelles,
PoS(ICRC2017)399 & arXiv:1612.04473

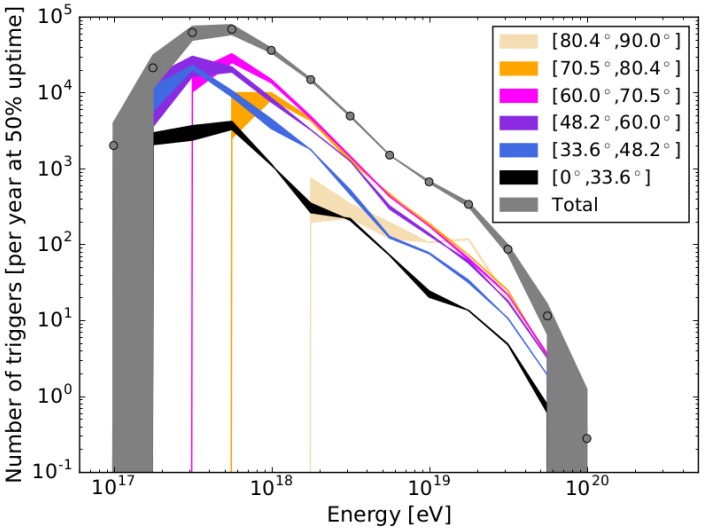
CR Capabilities of a full ARIANNA Array

- Wide bandwidth measurement → better energy reconstruction with slope/intercept analysis





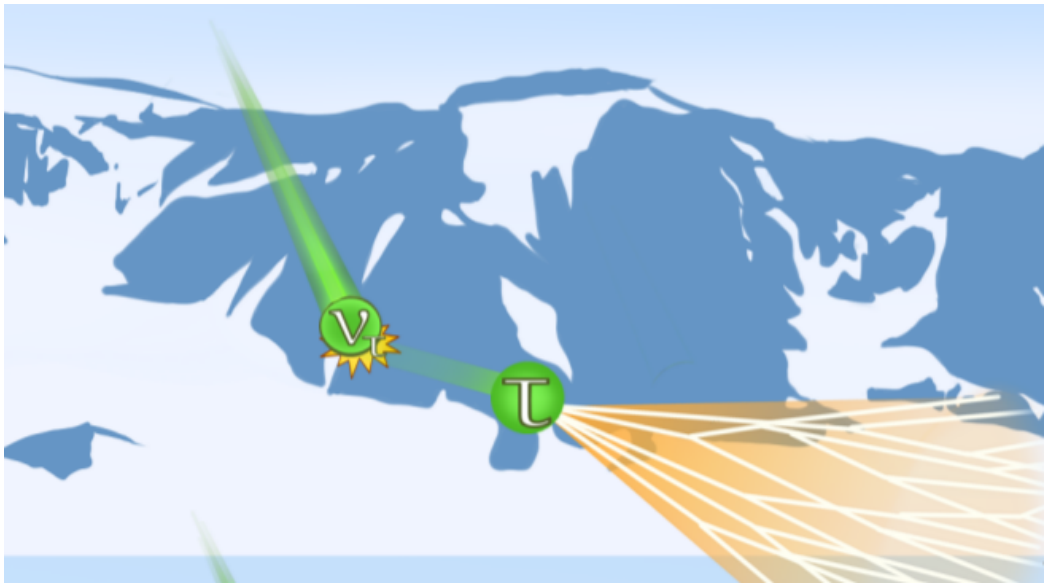


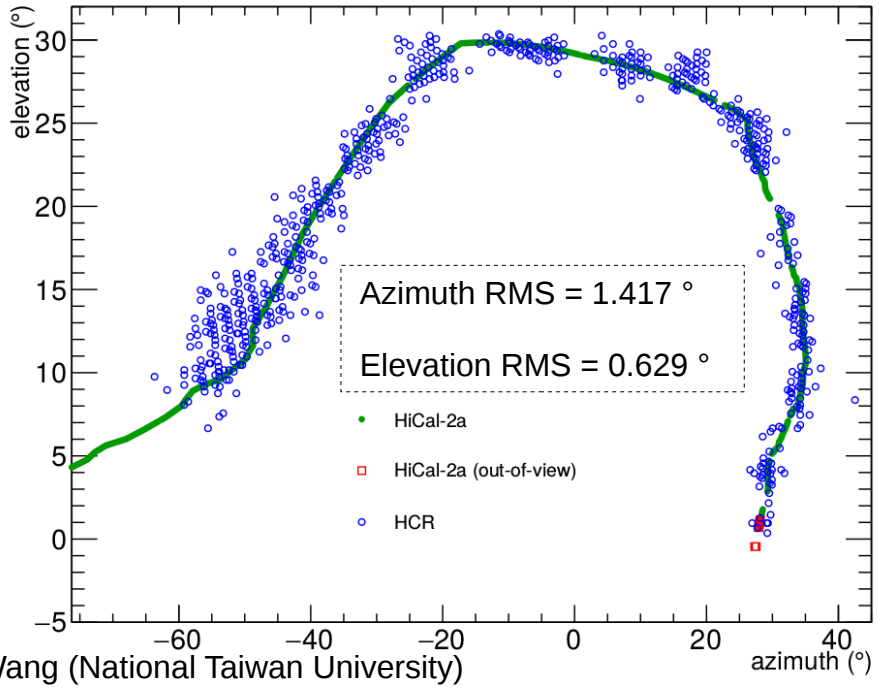


- Flux measurement consistent with other experiments
- Expect nearly 100k CR's after 5 years of full ARIANNA

A. Nelles,
PoS(ICRC2017)399 & arXiv:1612.04473

ν_τ detection In Radio





- Sucesfully identified and tracked pulses from HiCal
- Same ARIANNA electronics, with different antennas and layout
- 68 CR air-shower candidates in preliminary search

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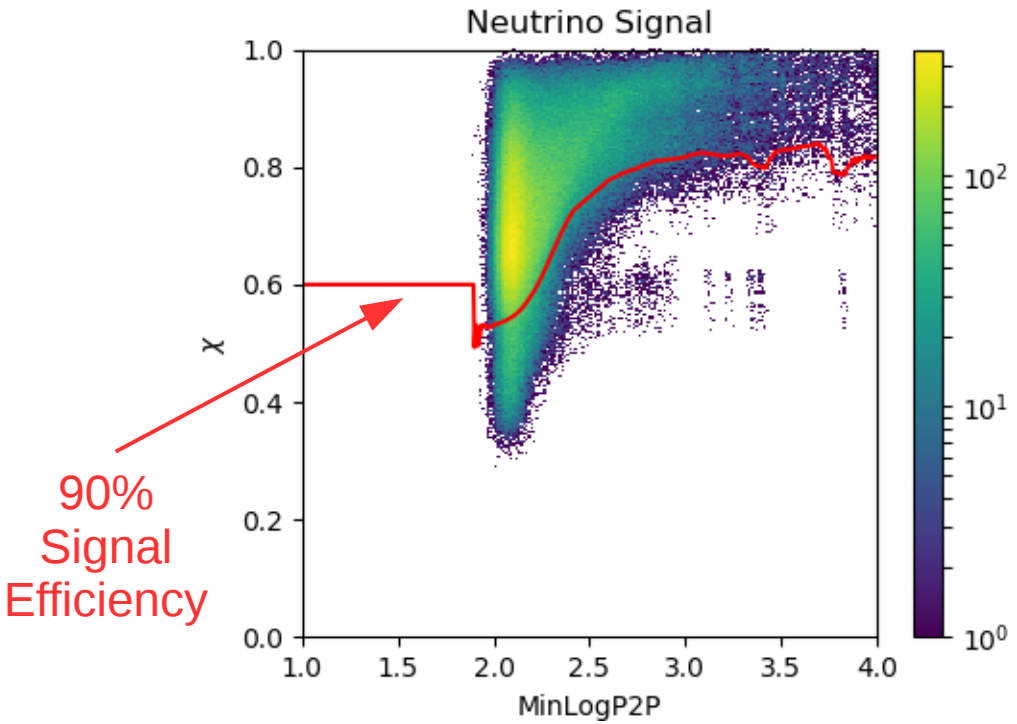
HRA Neutrino Search Efficiency



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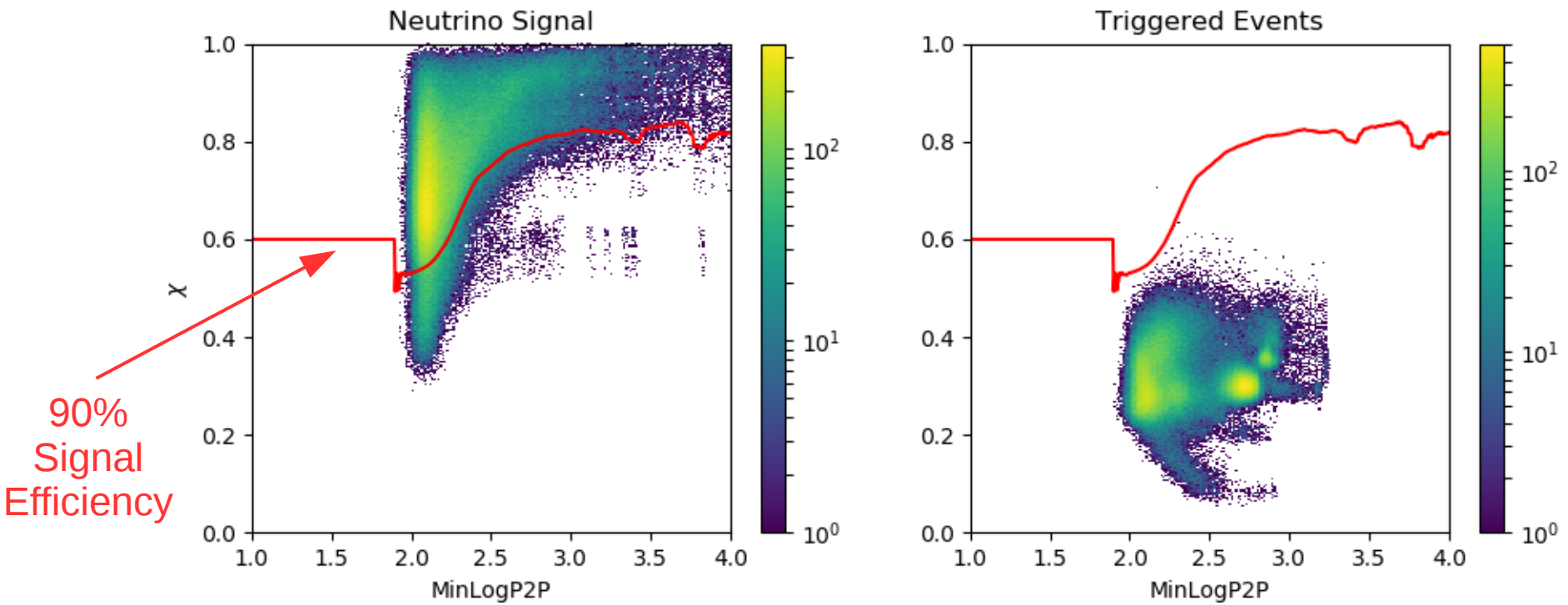
HRA Neutrino Search Efficiency

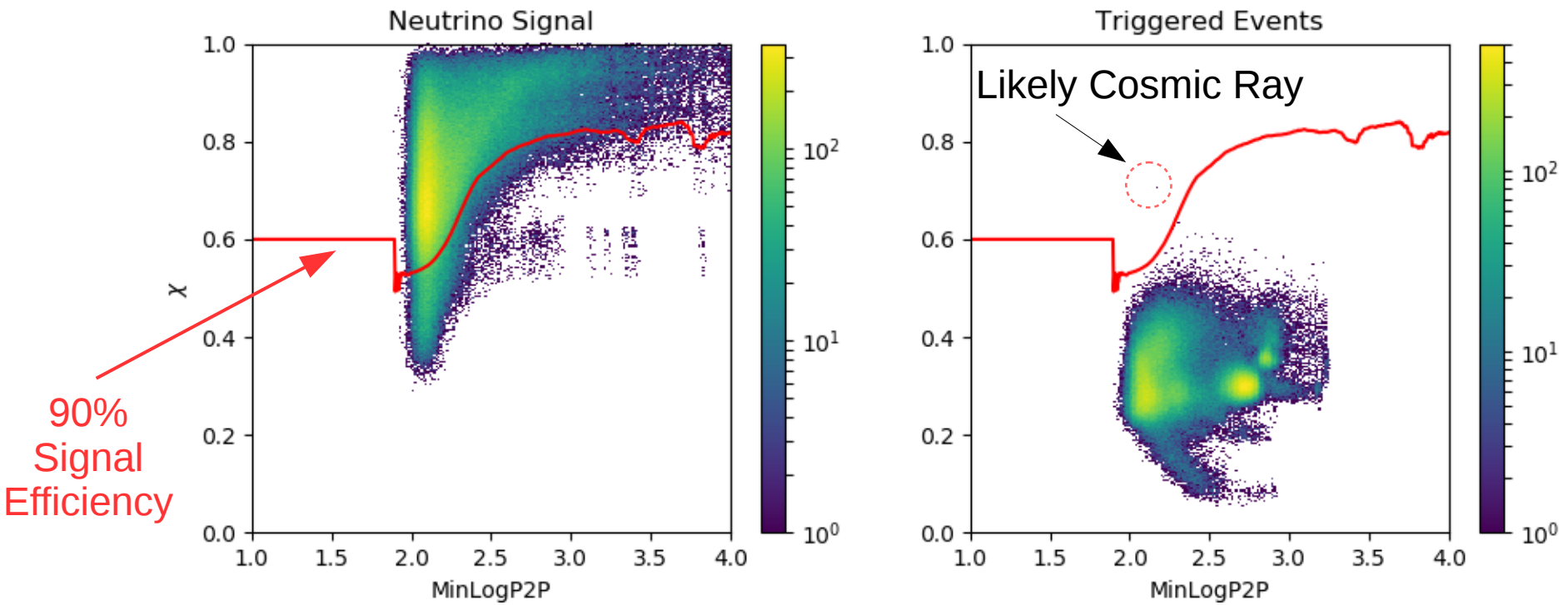
All HRA Triggered Events* from Dec 2015 to Mid April 2017



*Some stations have different model amplifiers, and are not shown for simplicity. See backup slides for details

HRA Neutrino Search Efficiency

All Triggered Events from
Dec 2015 to Mid April 2017

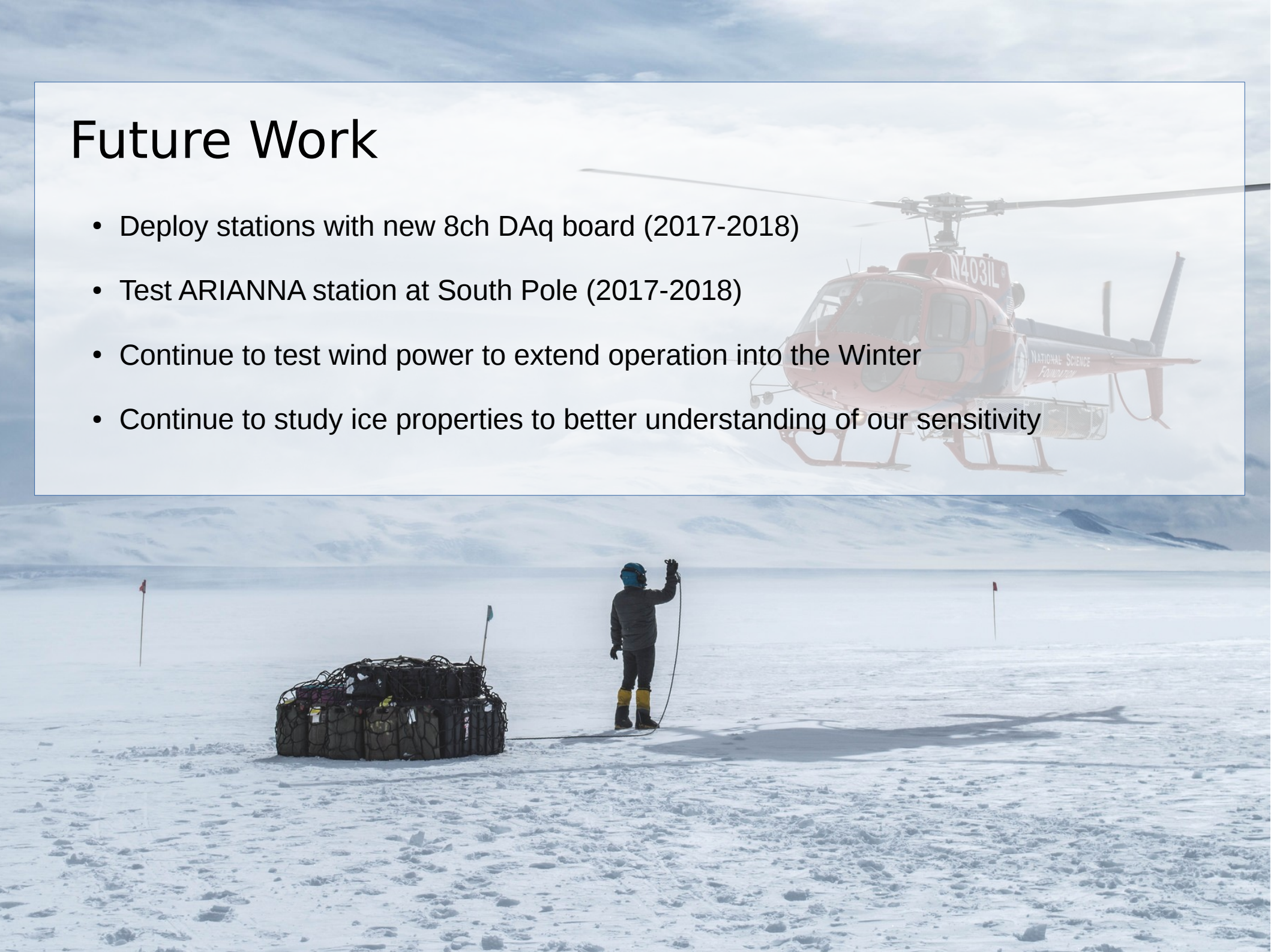


- Upward facing antennas will be necessary to tag cosmic rays (already planned)
- 90% signal efficiency is achievable with a simple analysis, and a plausible projection for a full ARIANNA deployment

*Some stations have different model amplifiers, and are not shown for simplicity. See backup slides for details

Future Work

- Deploy stations with new 8ch DAq board (2017-2018)
- Test ARIANNA station at South Pole (2017-2018)
- Continue to test wind power to extend operation into the Winter
- Continue to study ice properties to better understanding of our sensitivity



Conclusions

- The detectors of the HRA are now running robustly, with a typical livetime of 90%
- Moore's Bay' is a world-class location for radio based neutrino searches
- Our cosmic ray tag from upward antennas is necessary to distinguish neutrino signal, and has the potential to measure CR fluxes up to 10^20 eV with an independent technique
- A full deployment of ARIANNA should be able to probe all but the most conservative iron-only GZK spectra, even without any further livetime or sensitivity improvements

Backup Slides

The Outlying Event from Slide 12

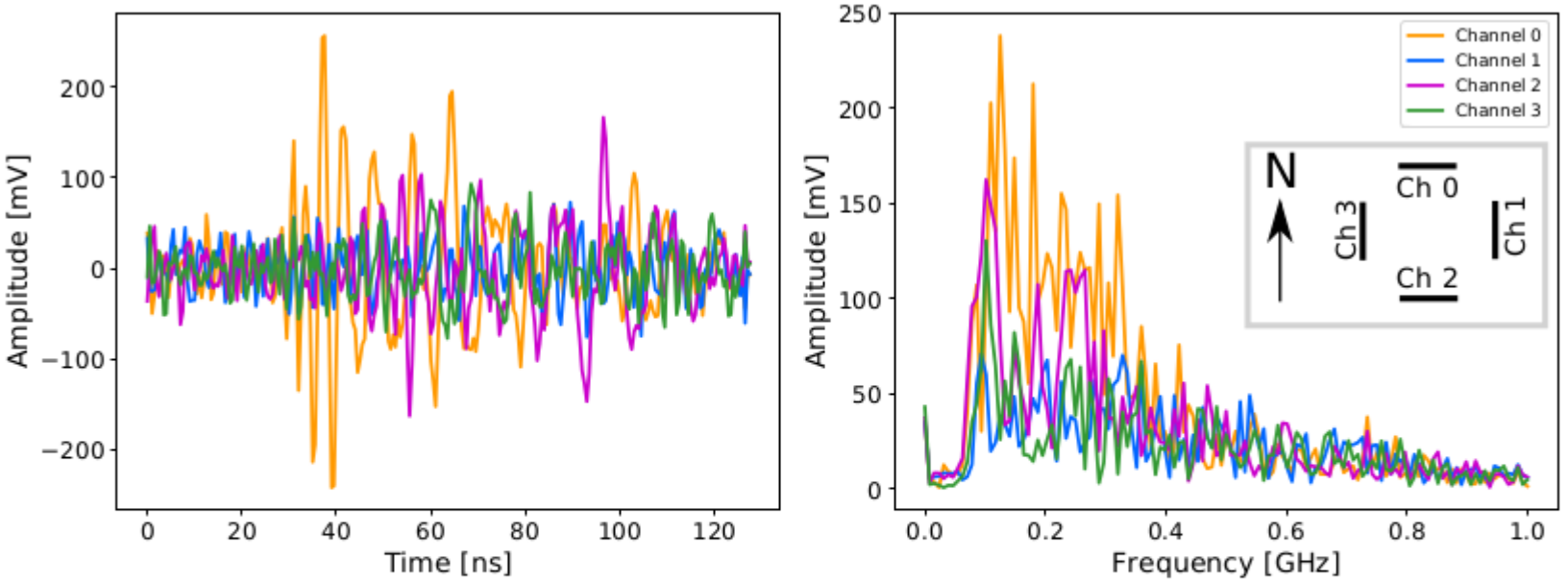
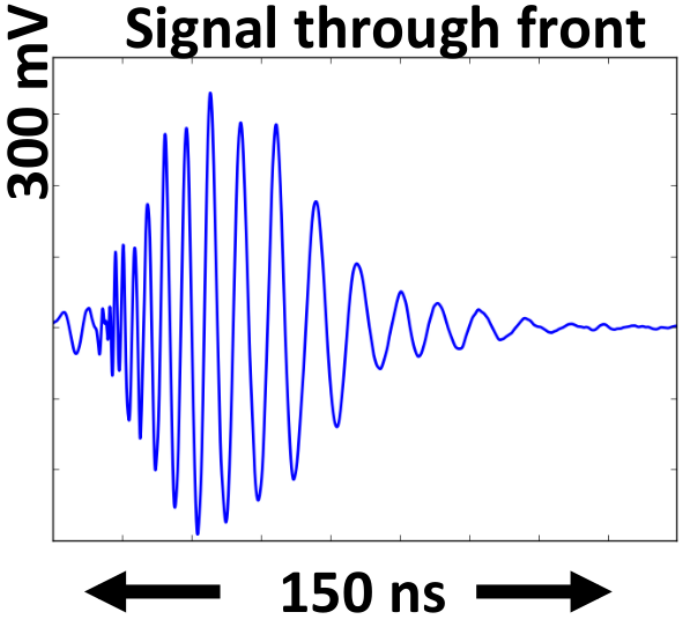
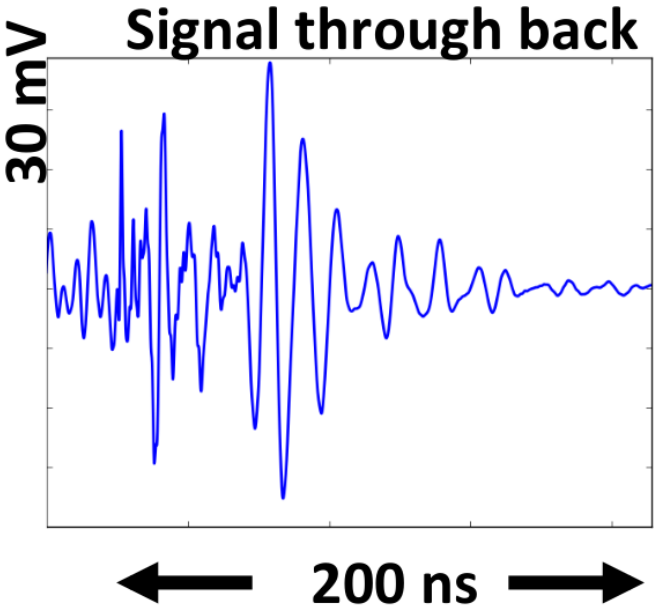
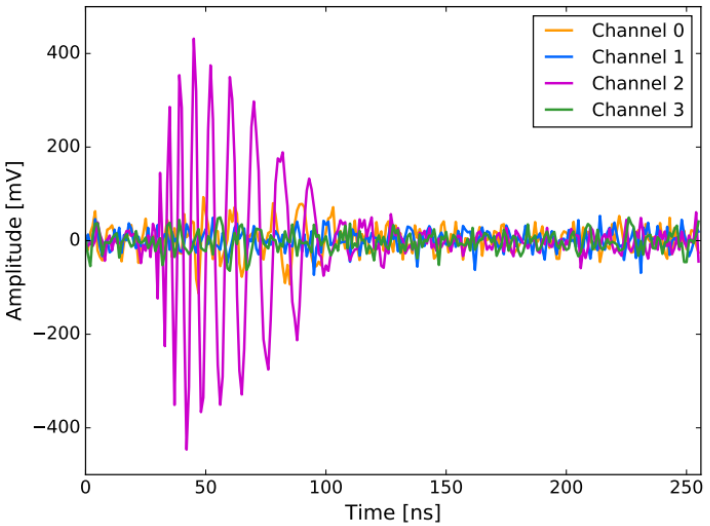


Figure 5: Waveform and FFT of the outlying event in Figure 4. This event has a correlation value of $\chi = 0.71$, and was recorded at ARIANNA Site A at 10:25:03 UTC on March 27th, 2017. The inset shows the positions and polarizations of the LPDA's for each DAq channel.

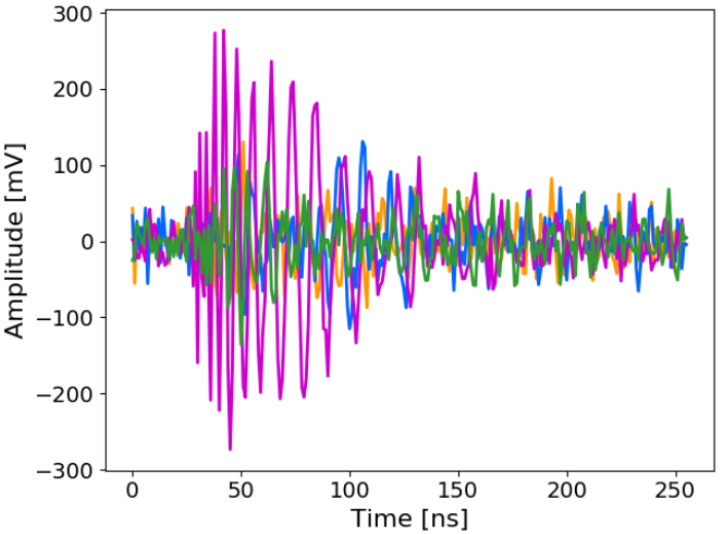
Cosmic Ray Templates







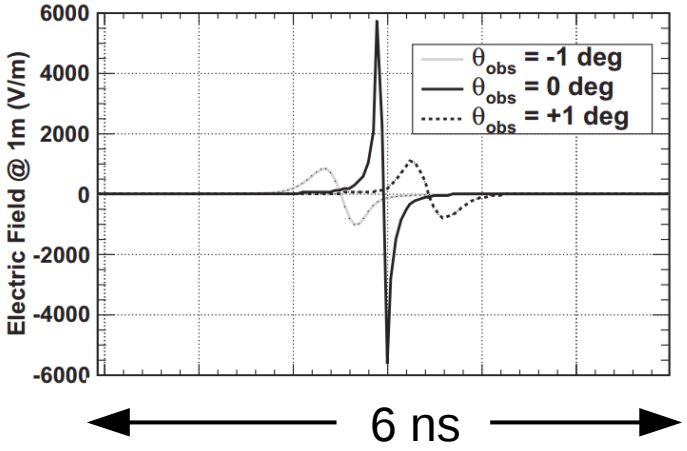
Template Event



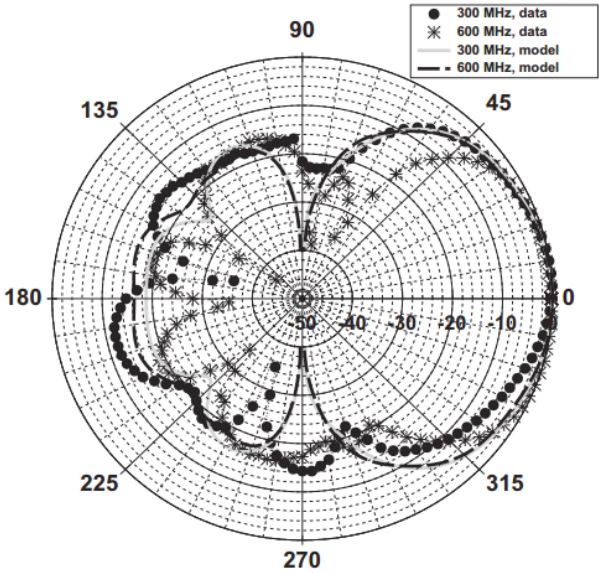
Measured Air Shower

Neutrino Template Matching

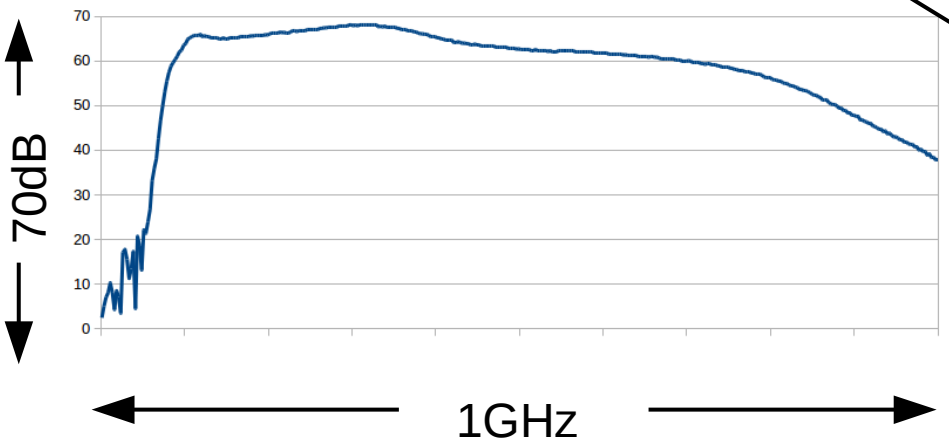
Simulated Neutrino Signal (ZHS)



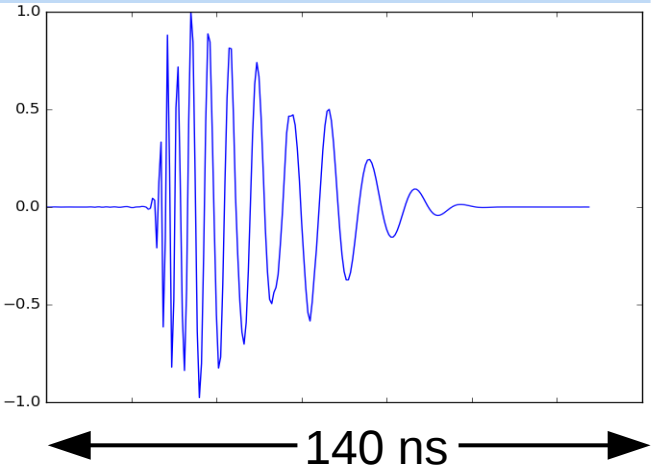
Antenna Response



Amplifier Response



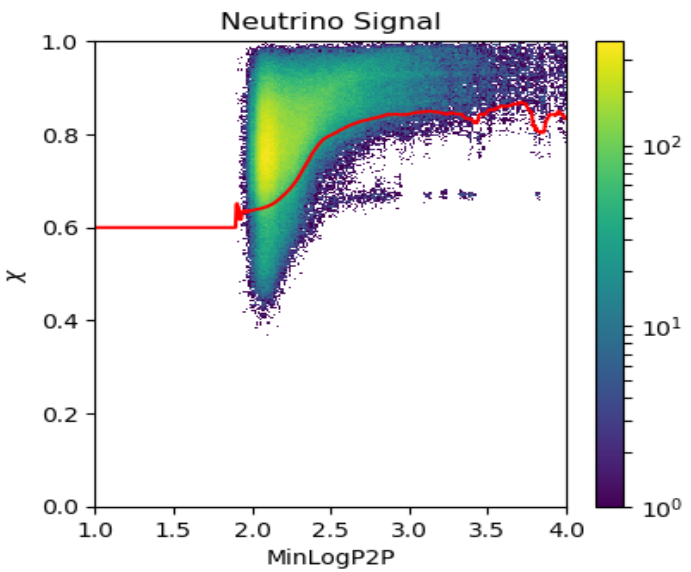
Neutrino Template

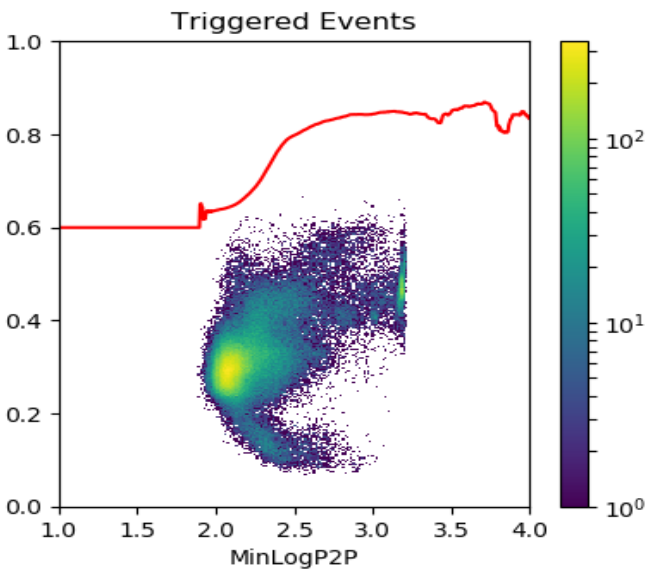


Time-domain Response of the ARIANNA Detector,
Astroparticle Physics,Volume 62, March 2015, Pages 139–151

Effect of Amp Response on Signal Region

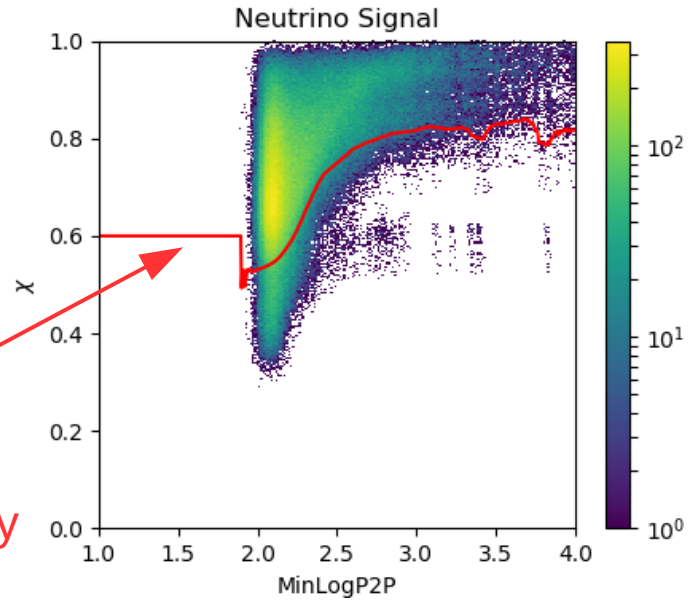
Series 100 Amps

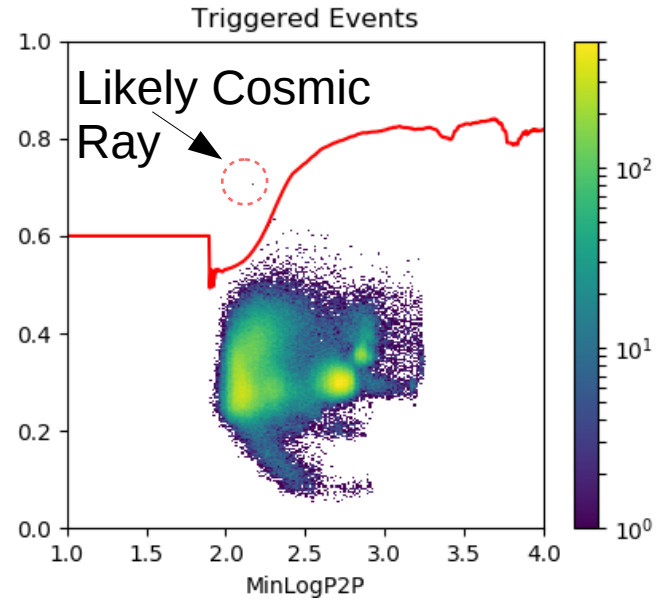




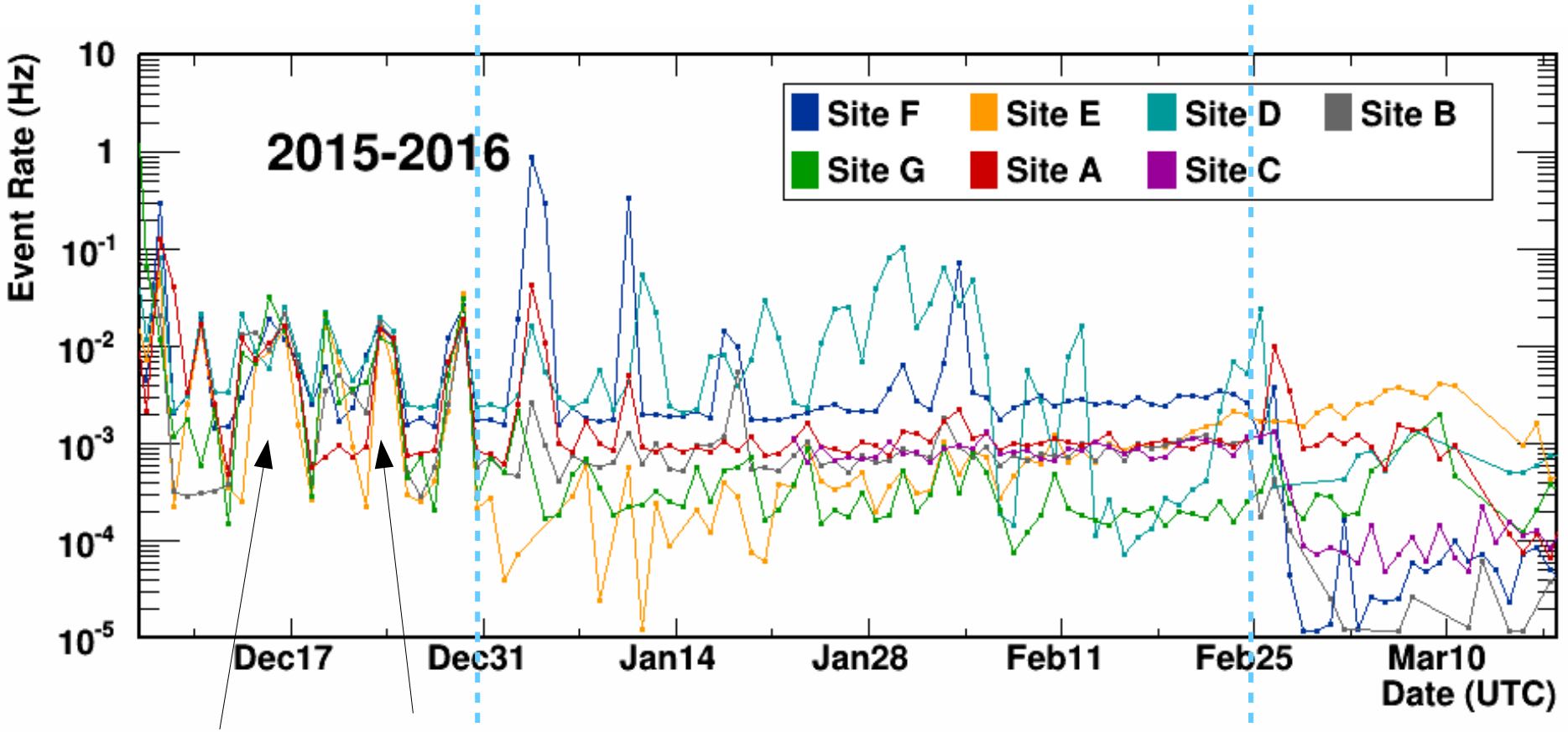
Series 200 Amps

90% Signal Efficiency





Event Rates

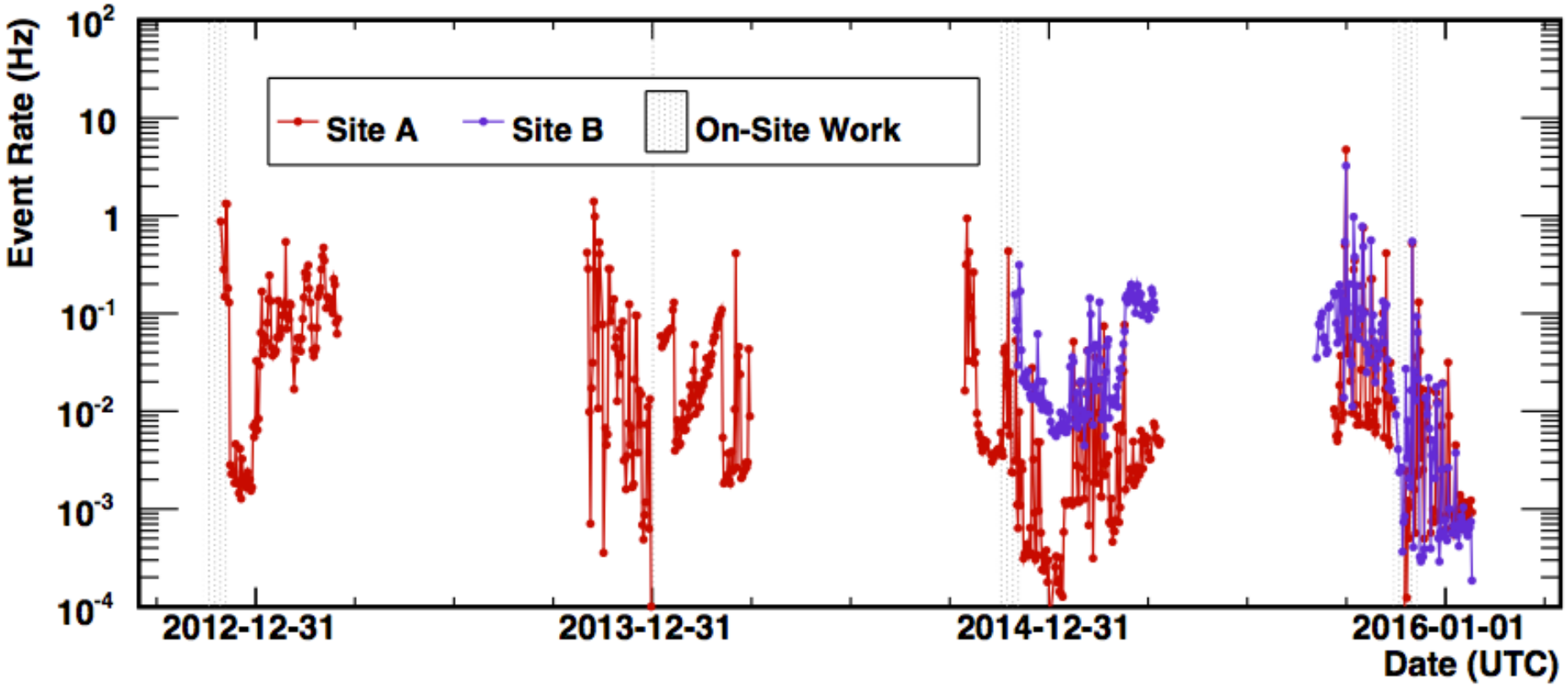


Thermal rate spikes from narrow-band noise

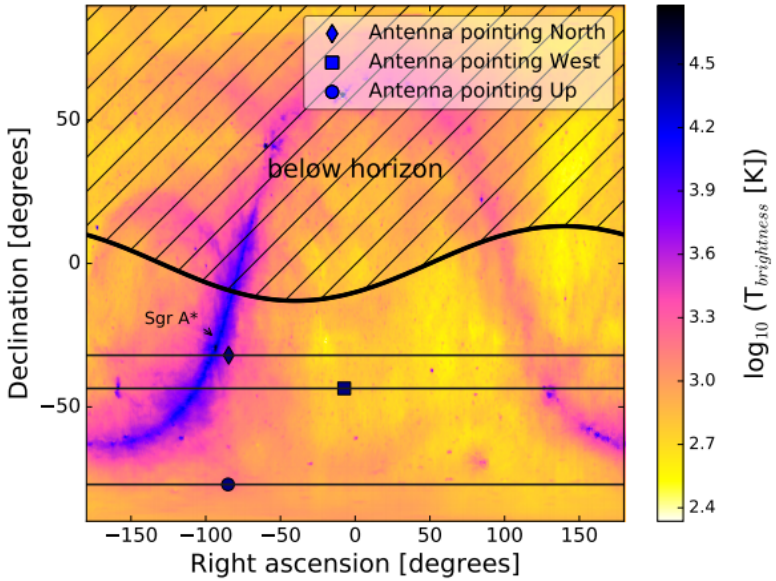
L1 Trigger Enabled

Thresholds optimized for satellite coms only mode

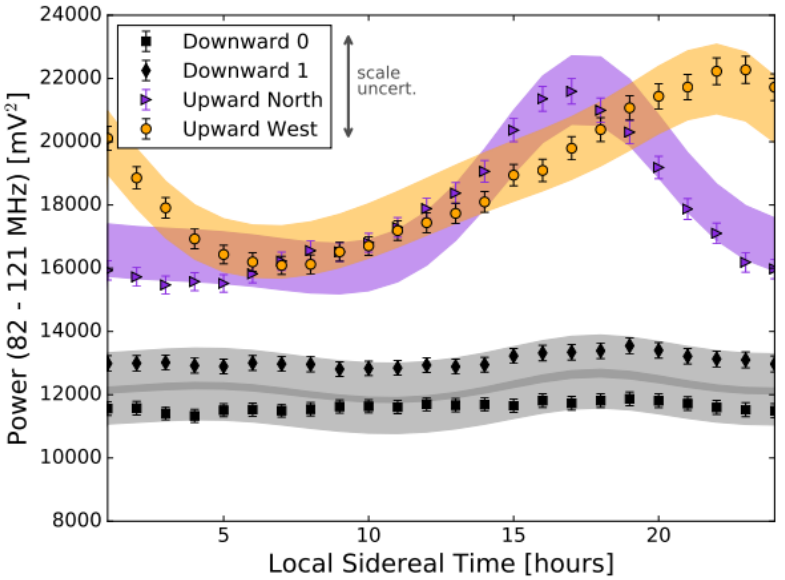
Event Rates: Continued



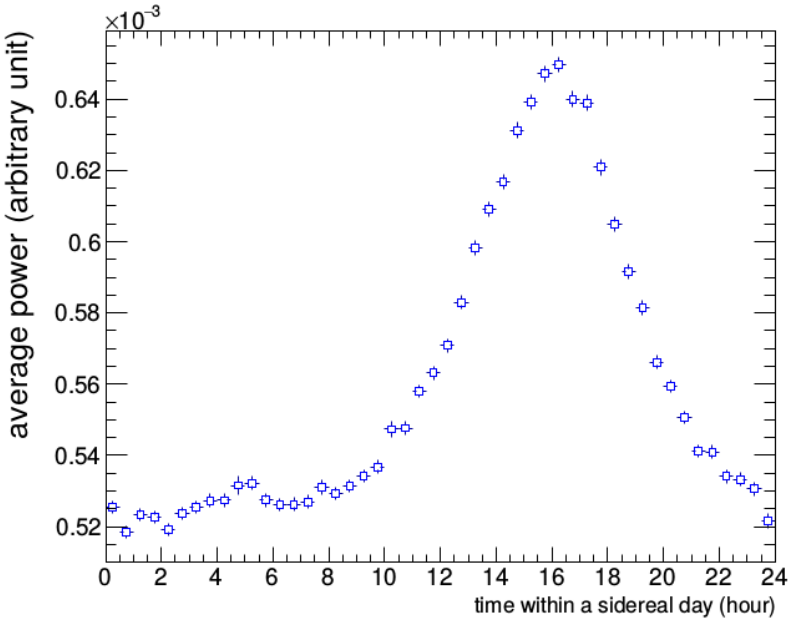
Current State of ARIANNA: The HRA



A. Nelles
arXiv:1612.04473



CR Site X



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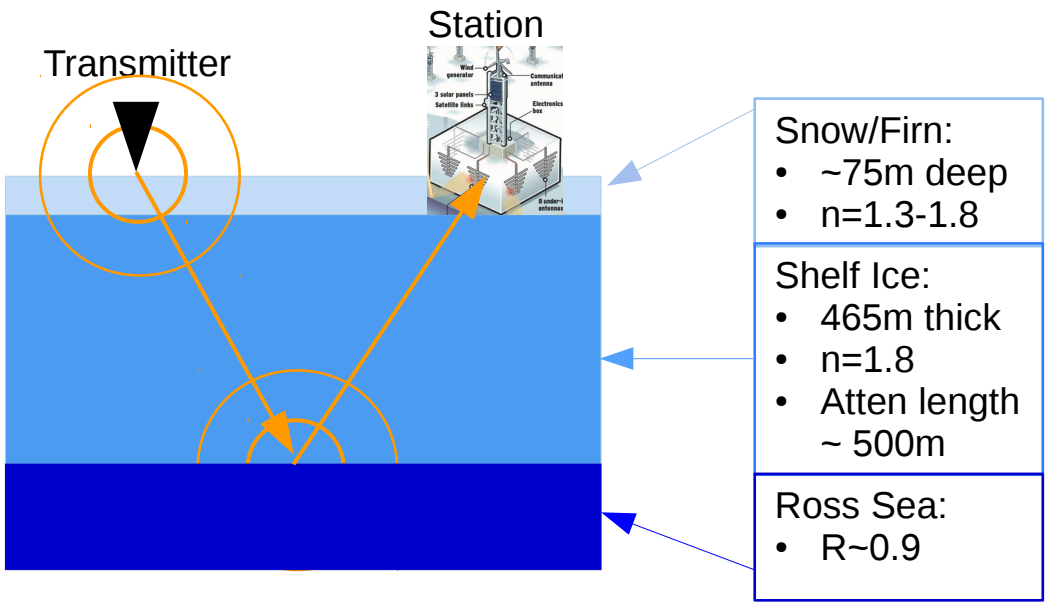
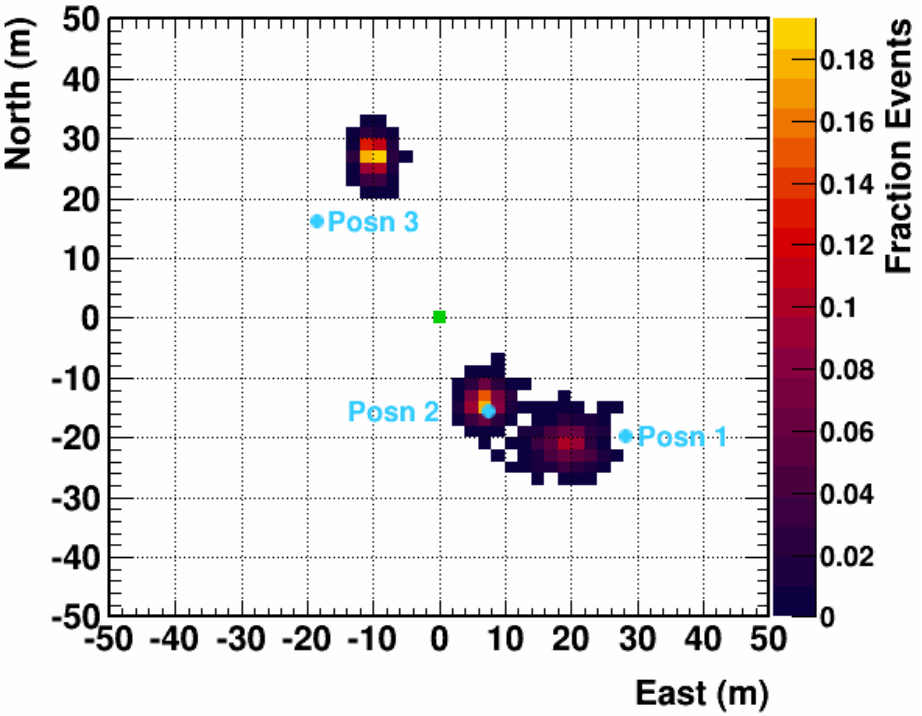
HCR Station

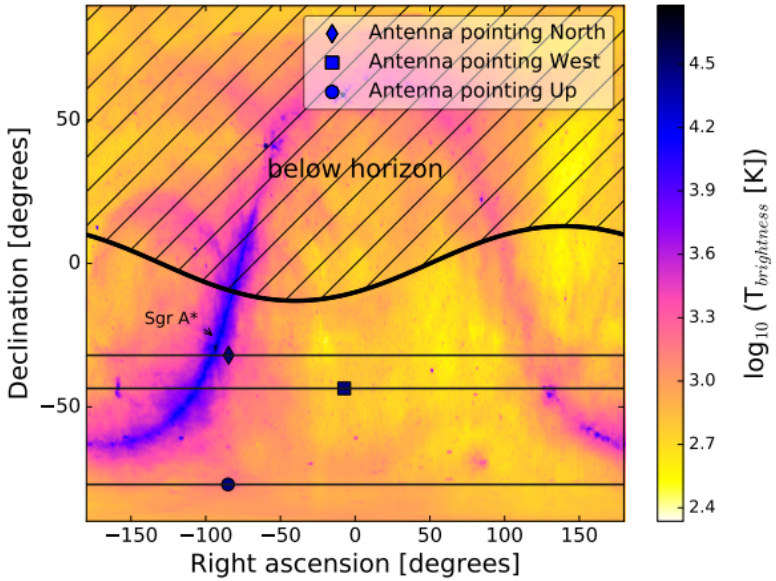
The Ice at Moore's Bay





Bounce studies at ARIANNA site show direction resolution of ~1deg

Current State of ARIANNA: The HRA



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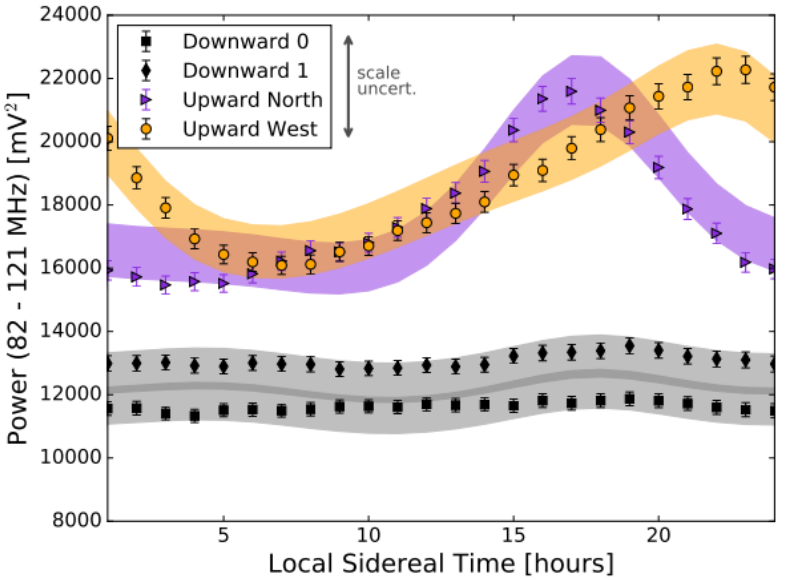
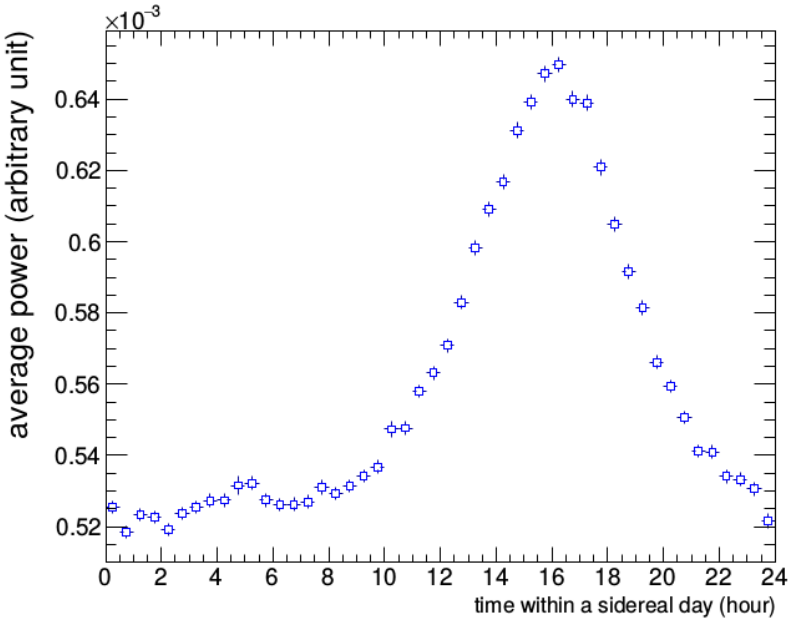


CR Site X



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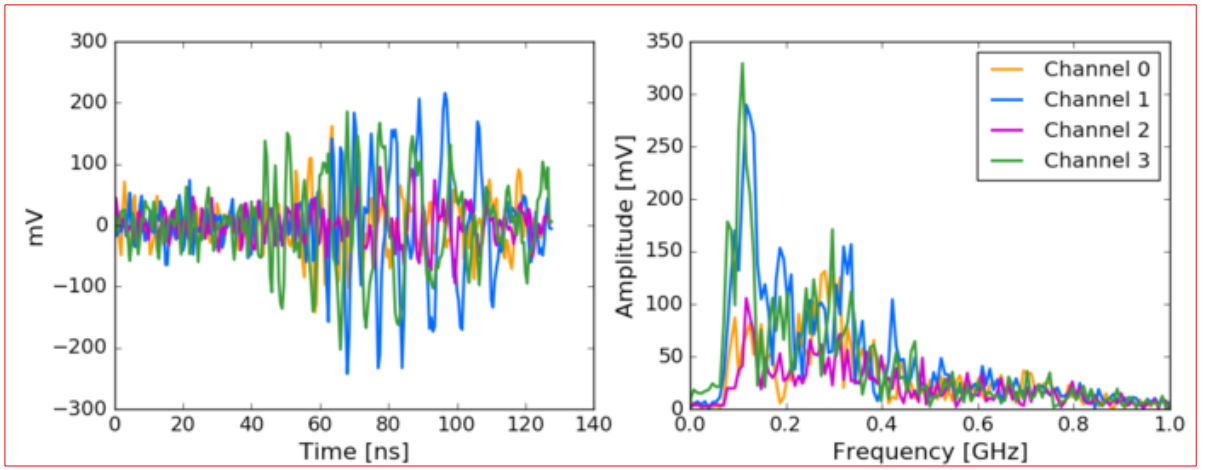
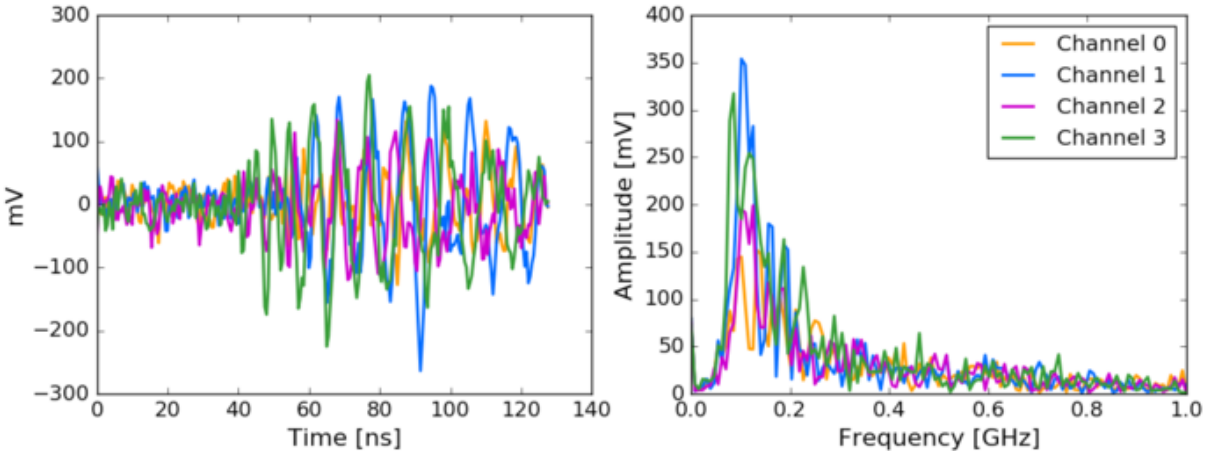
HCR Station

Multi Station Coincidence

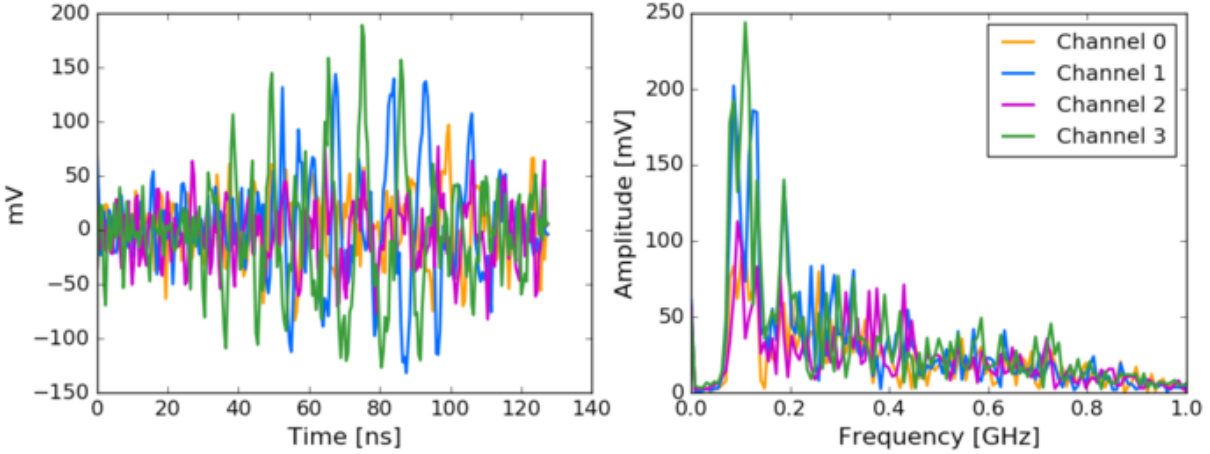
Site B

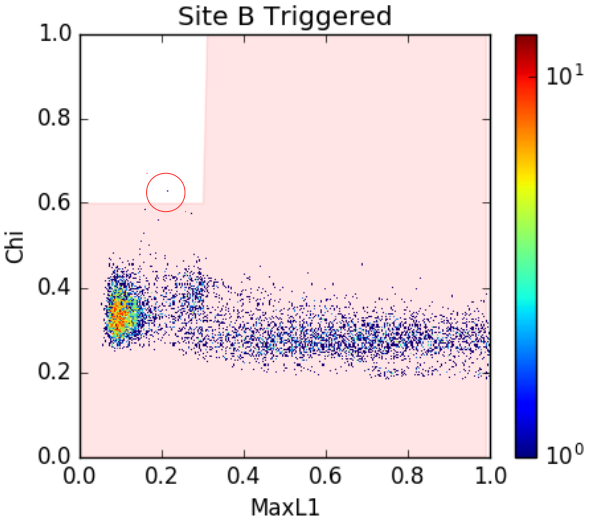


Site C



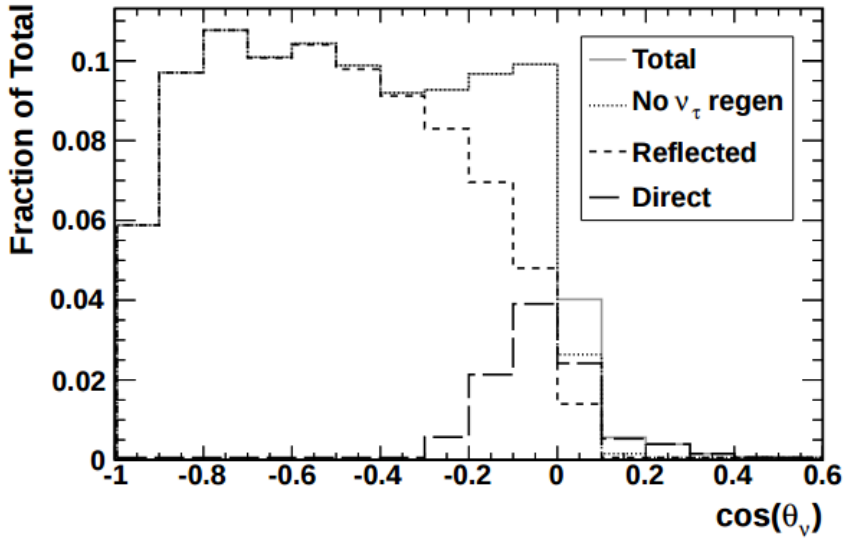
Site F

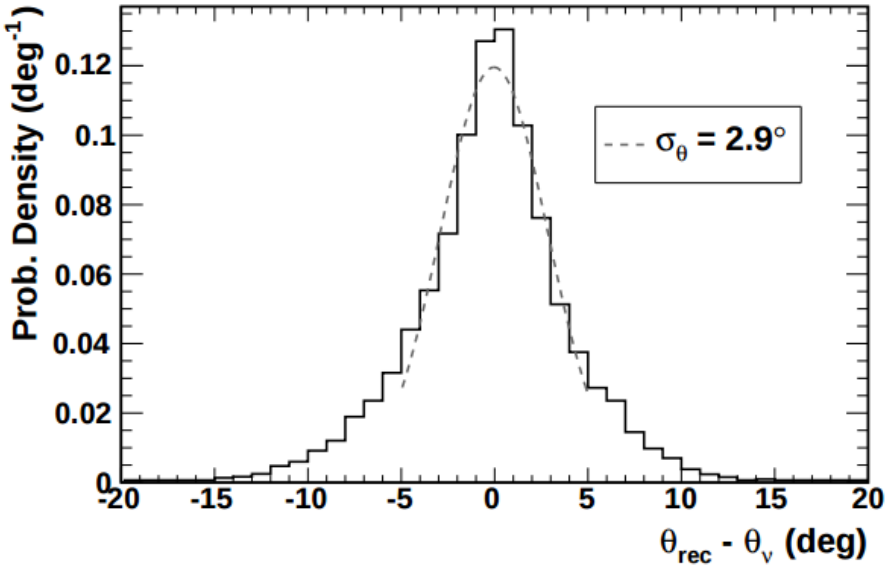


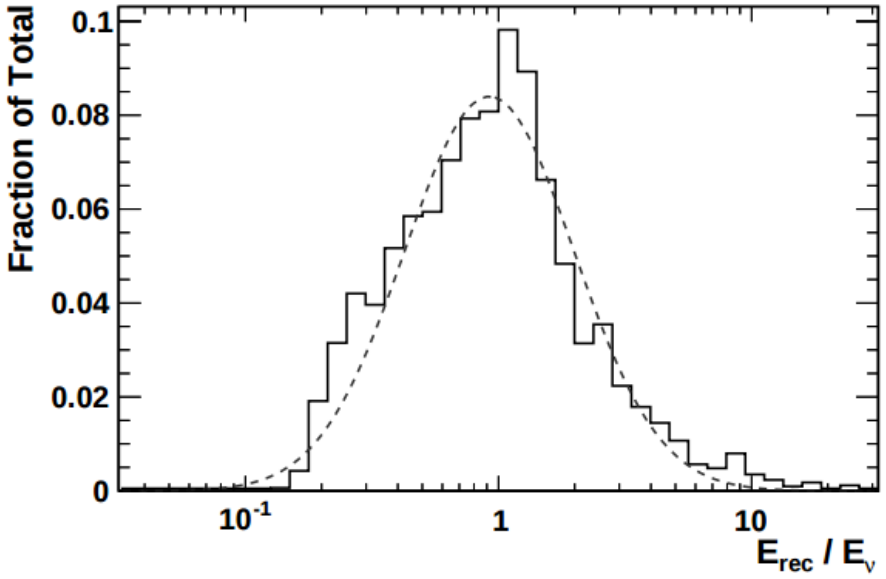


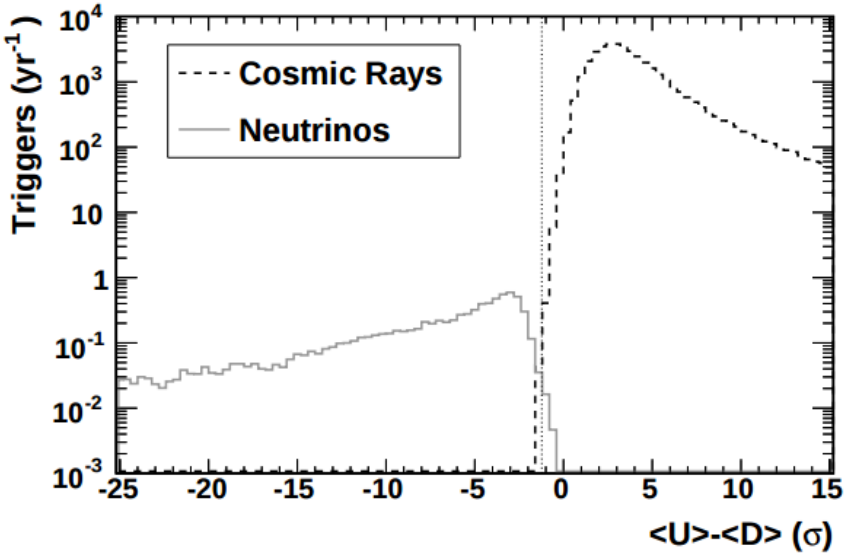
- Triggers in 2 other stations within 1s
- Previously identified as a cosmic ray candidate from high correlation to CR template
- Shows the need for upward facing antennas

ARIANNA Capabilities









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