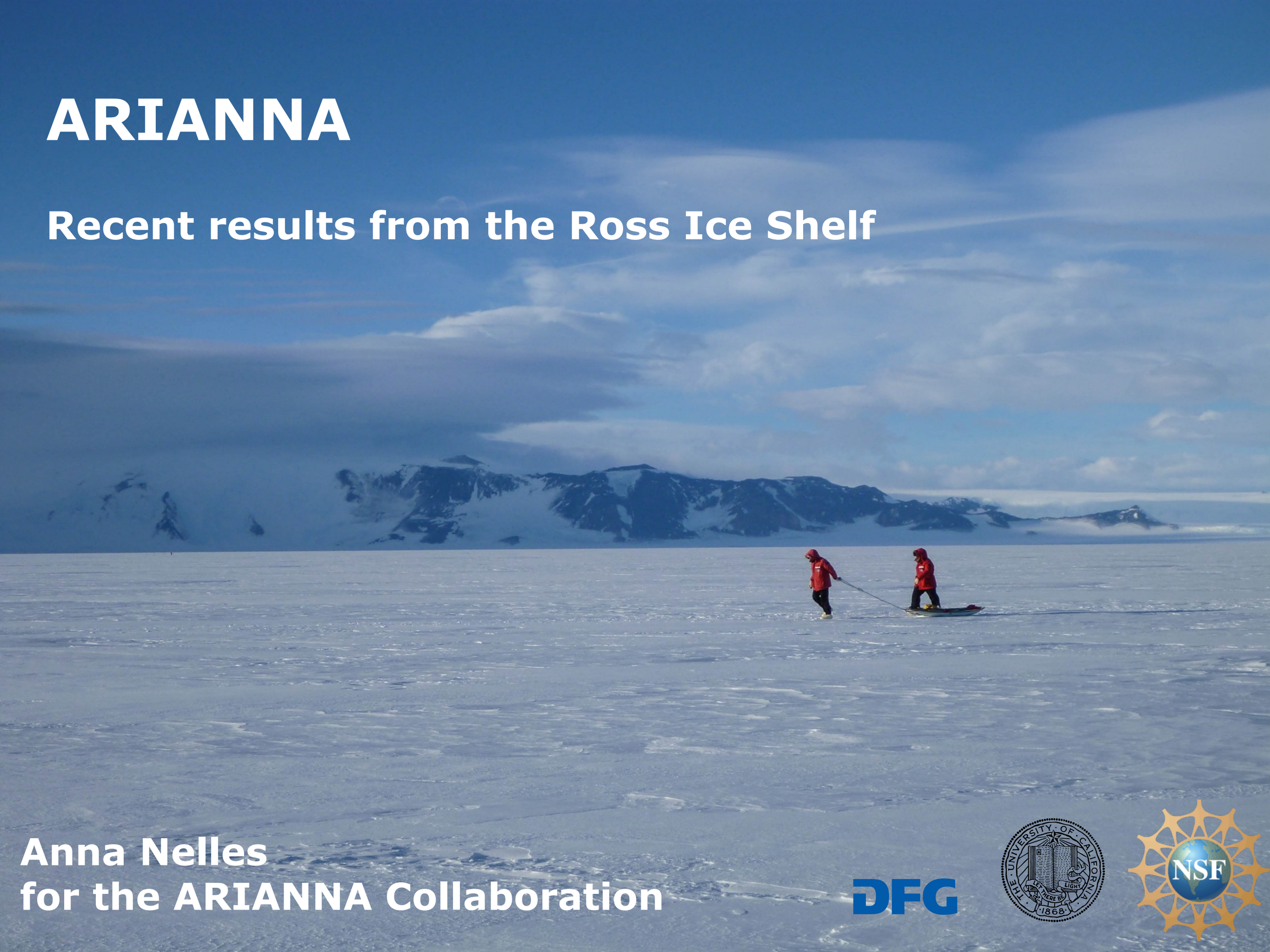
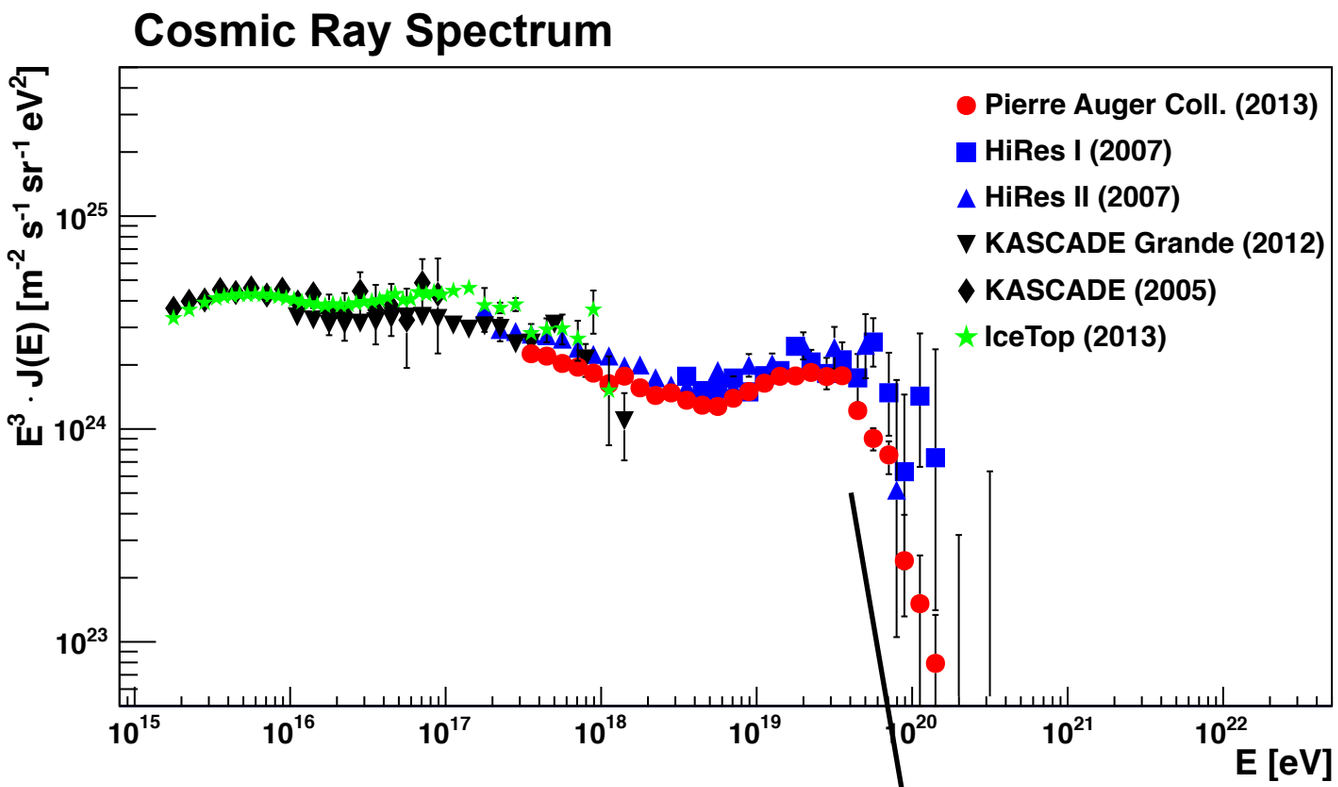
ARIANNA

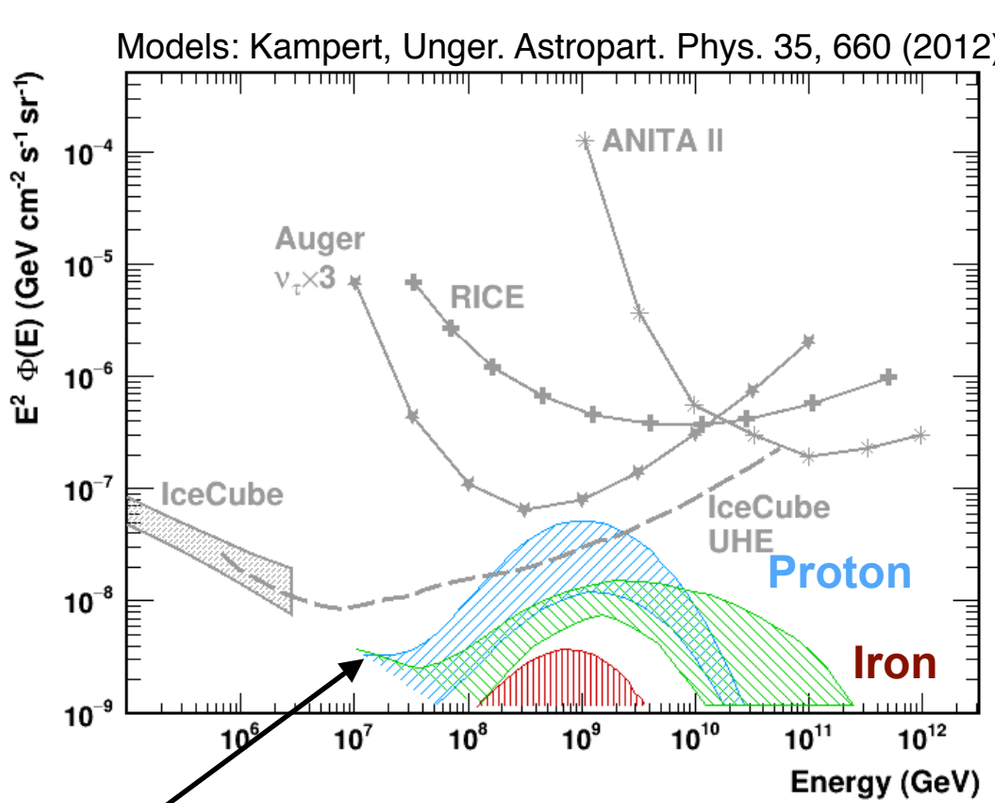
Recent results from the Ross Ice Shelf



Anna Nelles
for the ARIANNA Collaboration

Looking for the counterpart



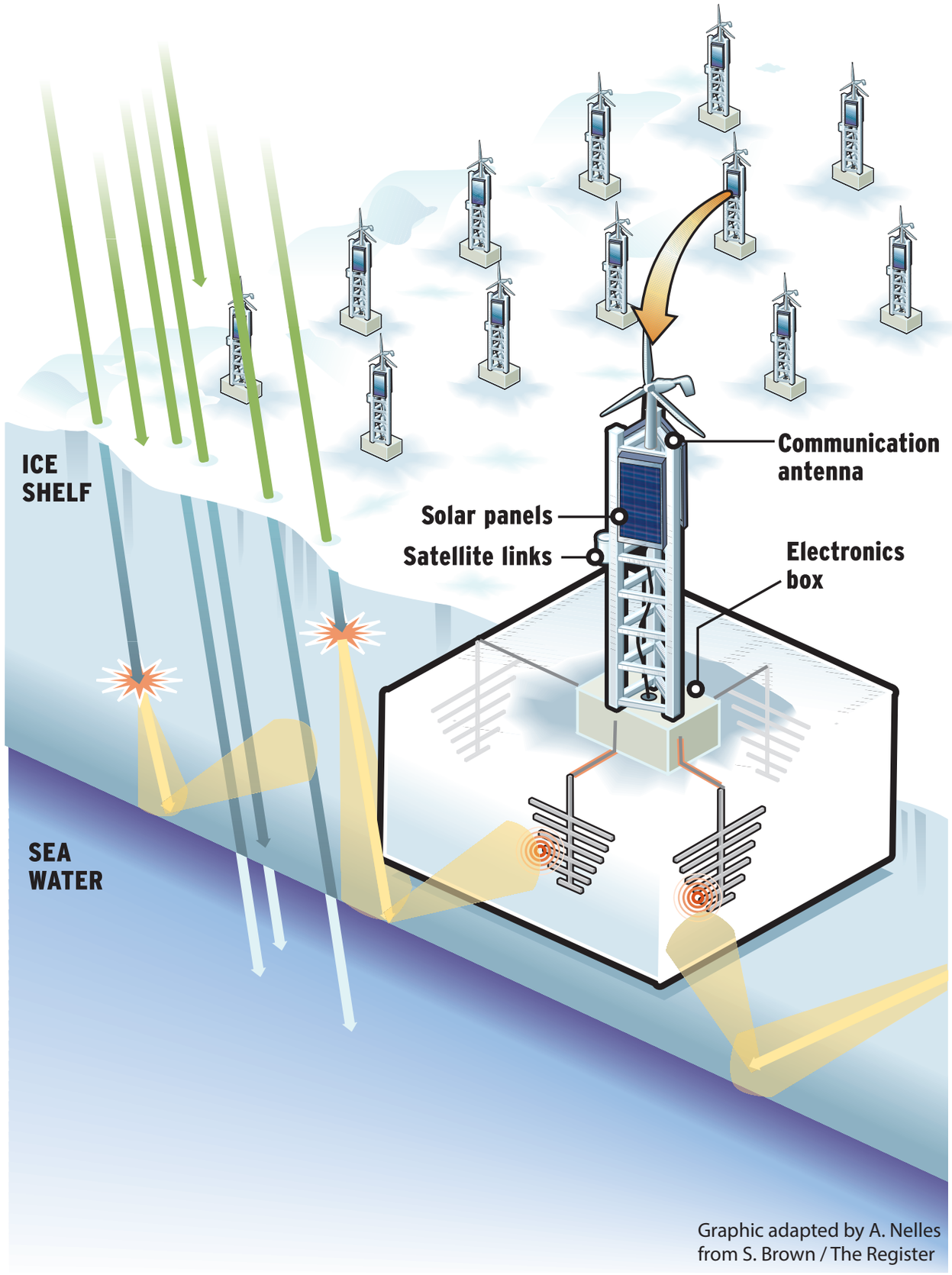


Varied: composition, evolution, transition

$$p + \gamma_{CMB} \rightarrow \Delta^{+} \rightarrow \pi^{+} \rightarrow \nu$$

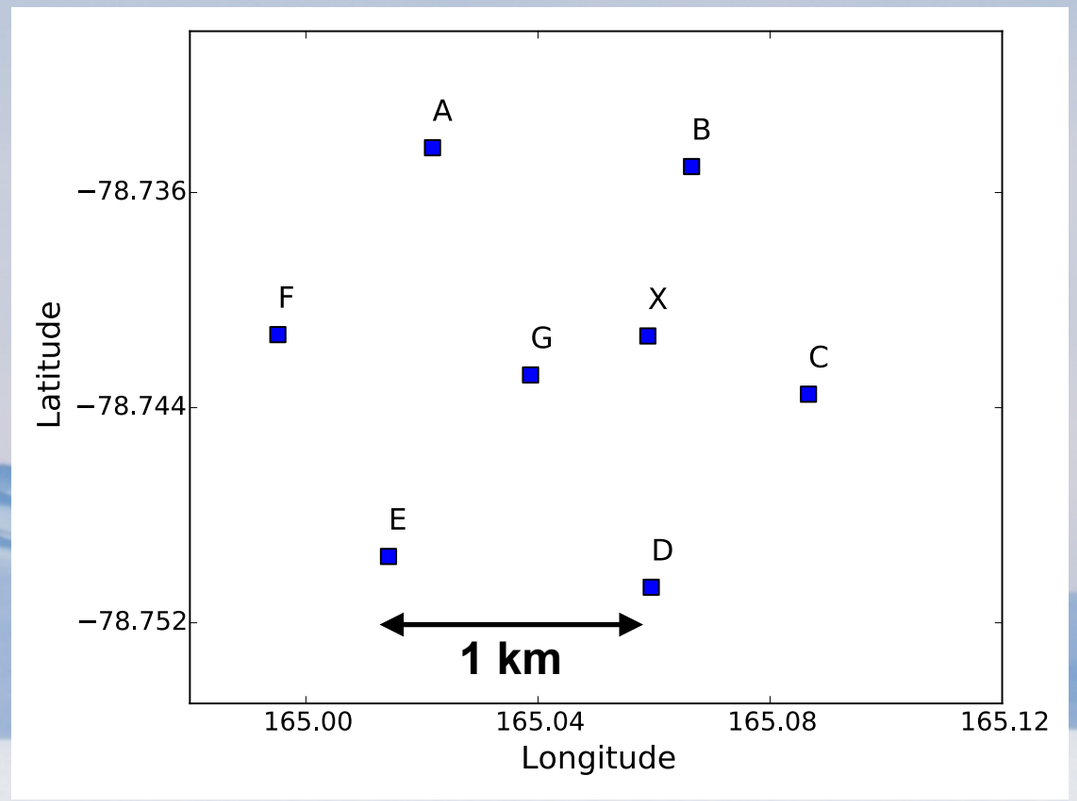
Concept of ARIANNA

- On ice-shelf: Ice-water boundary **almost perfect reflector** for radio emission
- **Independent antenna stations** can be installed at low costs on the surface
- Real-time data transfer via satellite
- Solar and wind power possible
- **High gain antennas (50 - 1000 MHz)** can be used to instrument a large volume
- Array of about 1200 antennas needed: ~ 30 Million USD



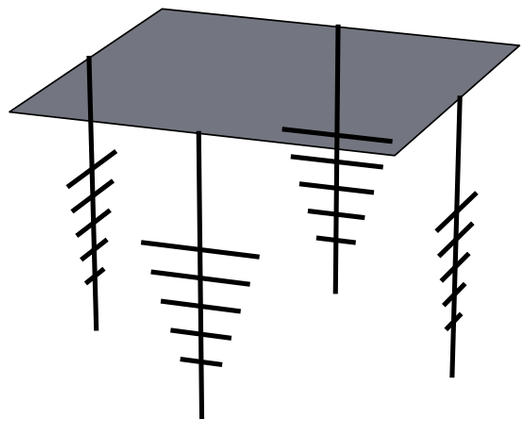
Current status of ARIANNA

First hexagonal array in operation since 2015

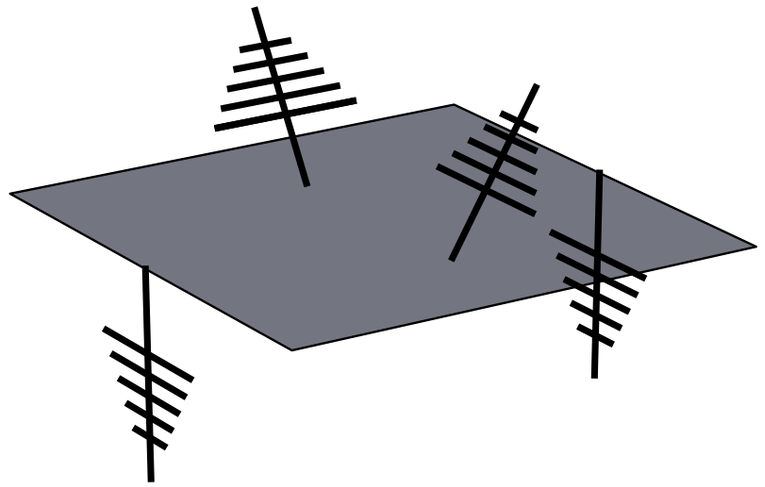


Current status of ARIANNA

7 regular stations

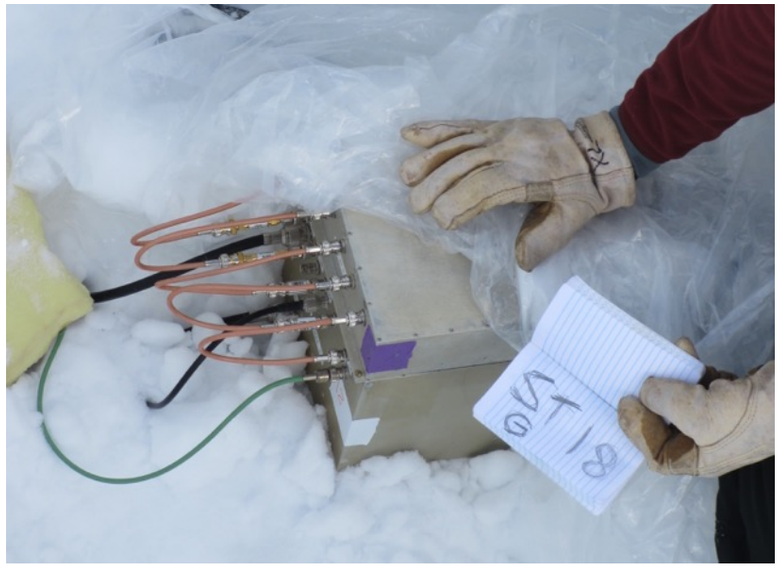


1 “Cosmic Ray” station

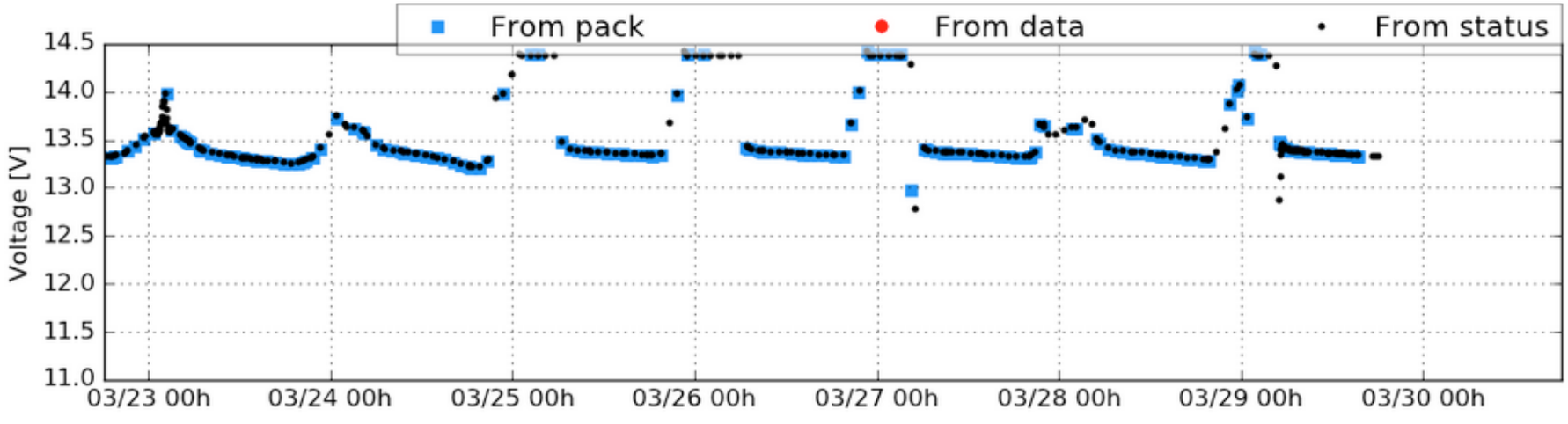


Current status of ARIANNA

- Stations with four data channels
- 2 GHz or 1 GHz data digitization, waveforms of 256 samples
- Trigger: coincidence in antennas of threshold crossings

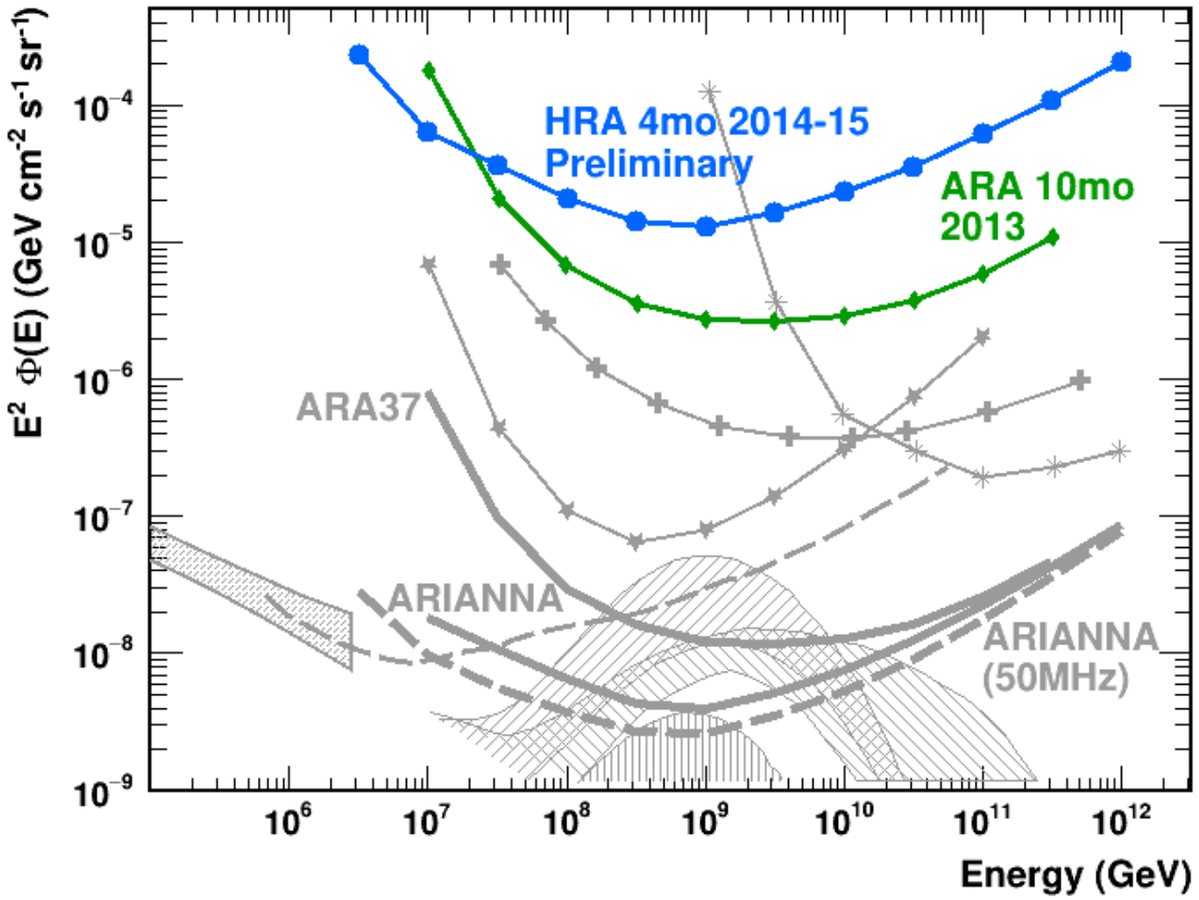


- Solar powered with 20 Amph Li-Ion batteries for buffering
- Power consumption station: 2.2 - 3 W (5W if comms on)
- Satellite communication (and long range wifi), real-time data transfer



Outlook on Limits

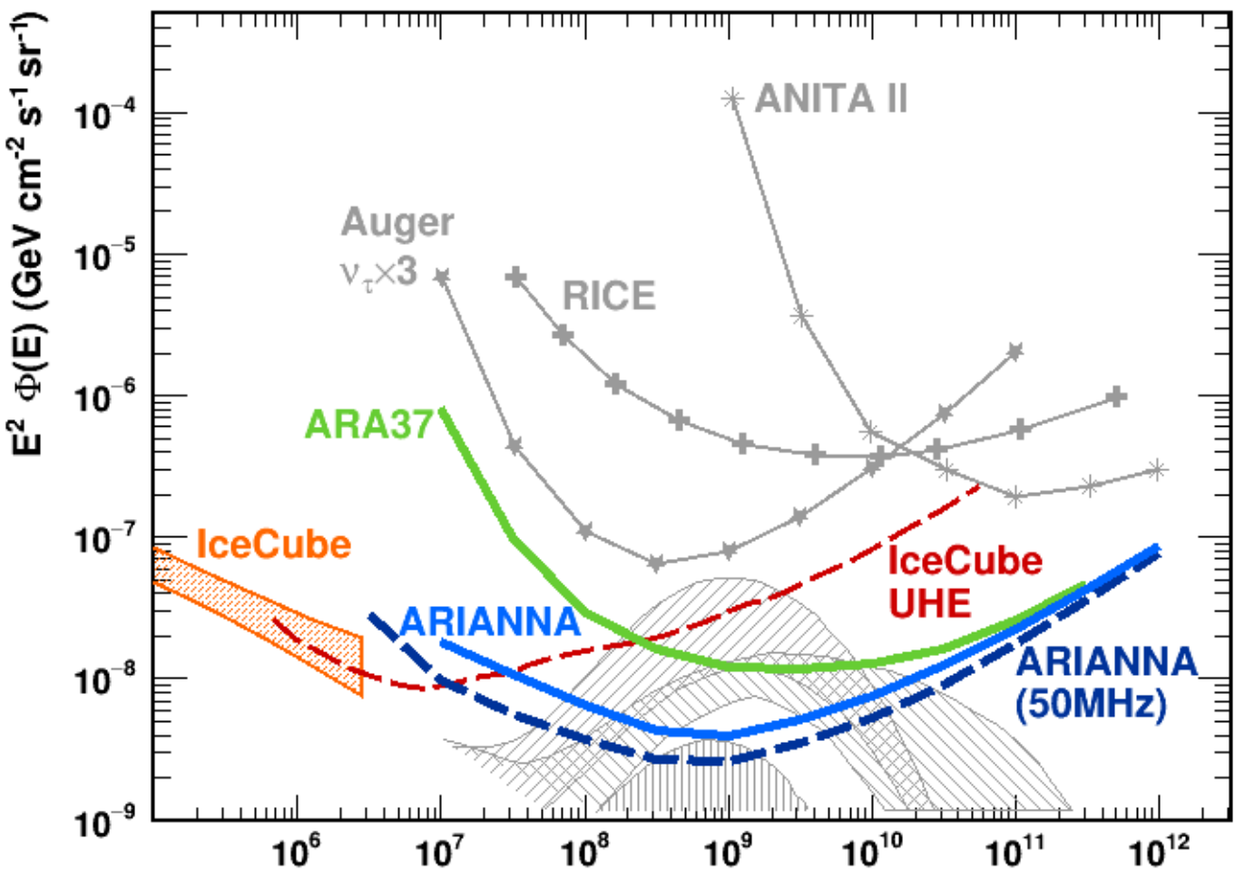
Limits from ICRC 2015



- Current status:
  - All first set-ups running, however too small to have any impact on neutrino limits

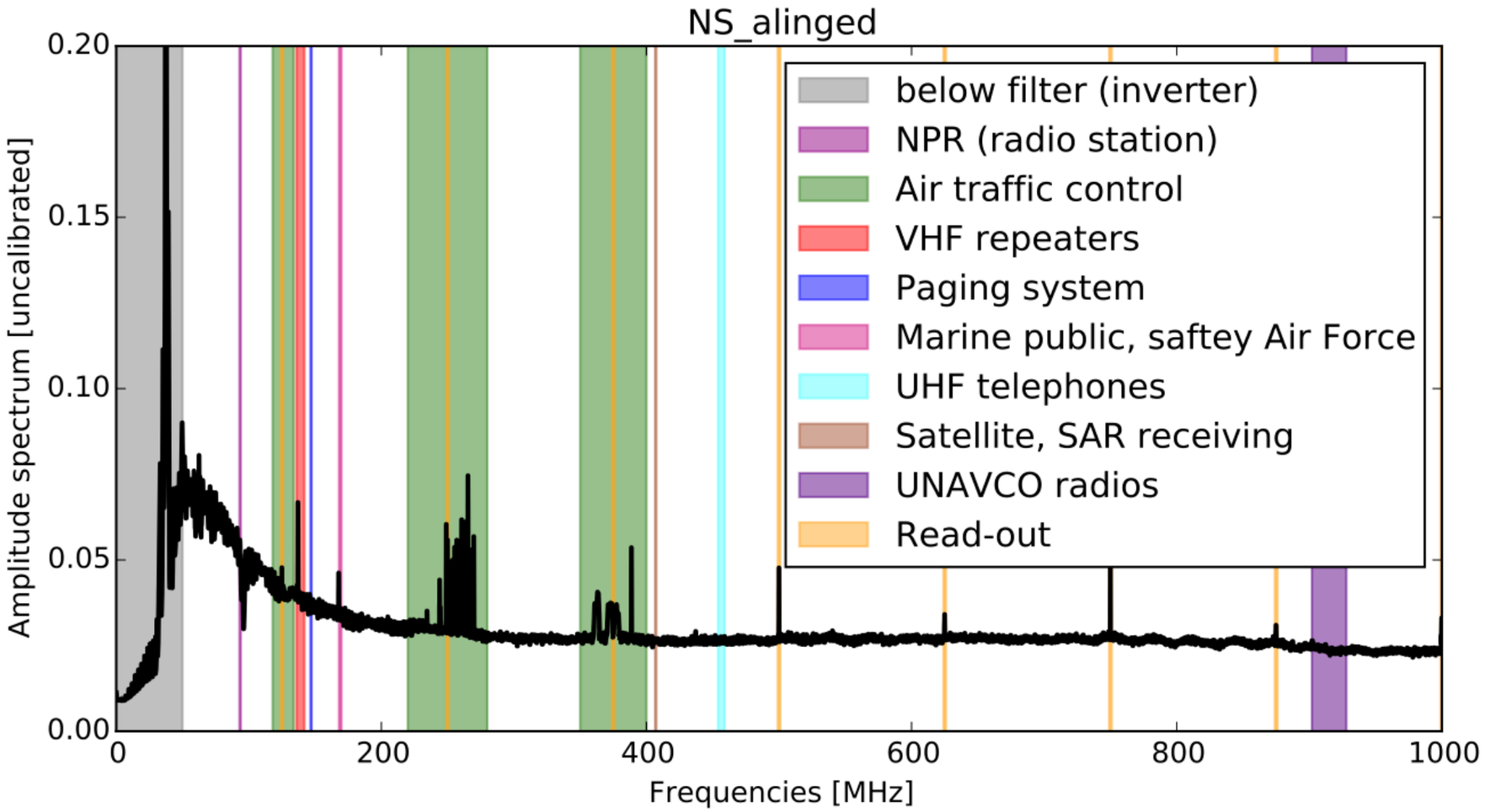
- Projected sensitivity:
  - Radio detection will set significant limits at interesting energies

Projected sensitivities after 5 years



IceCube measurement from Phys. Rev. D91, 022001 (2015)
ARA37 projection using arXiv:1507.08991v2
IceCube UHE limit from Ishihara, PoS 1064 (ICRC 2015)
see S. Barwick Overview Talk (ICRC 2015)

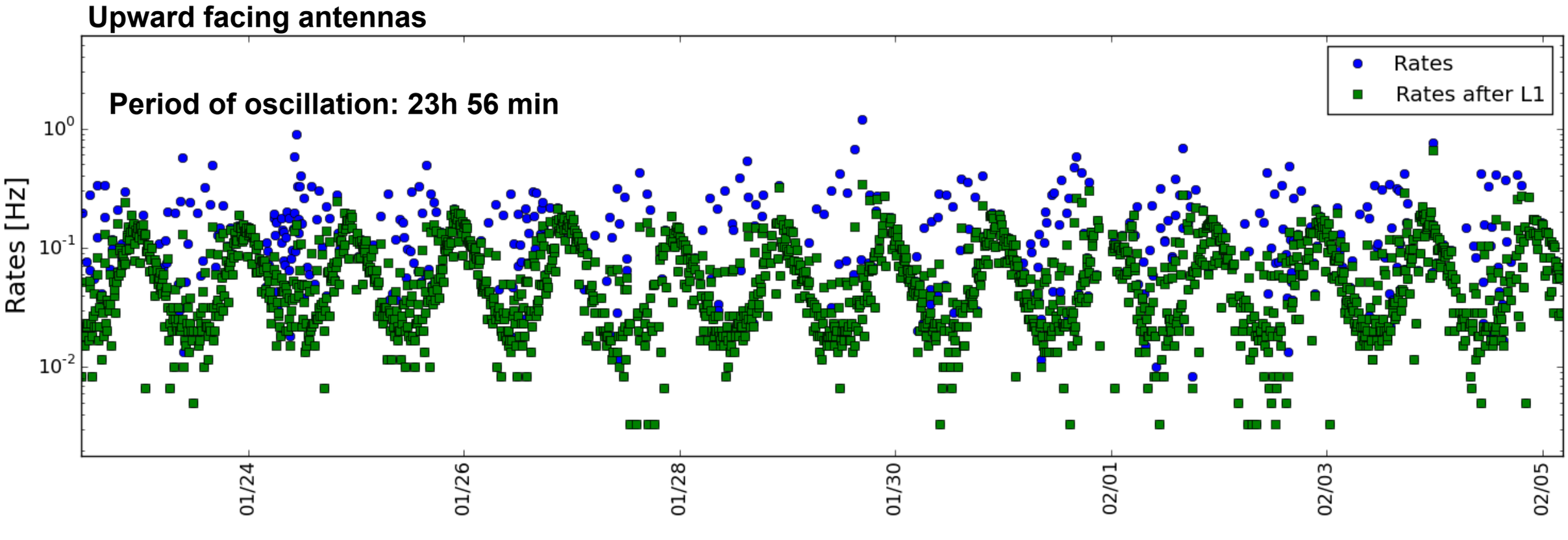
Continuous background



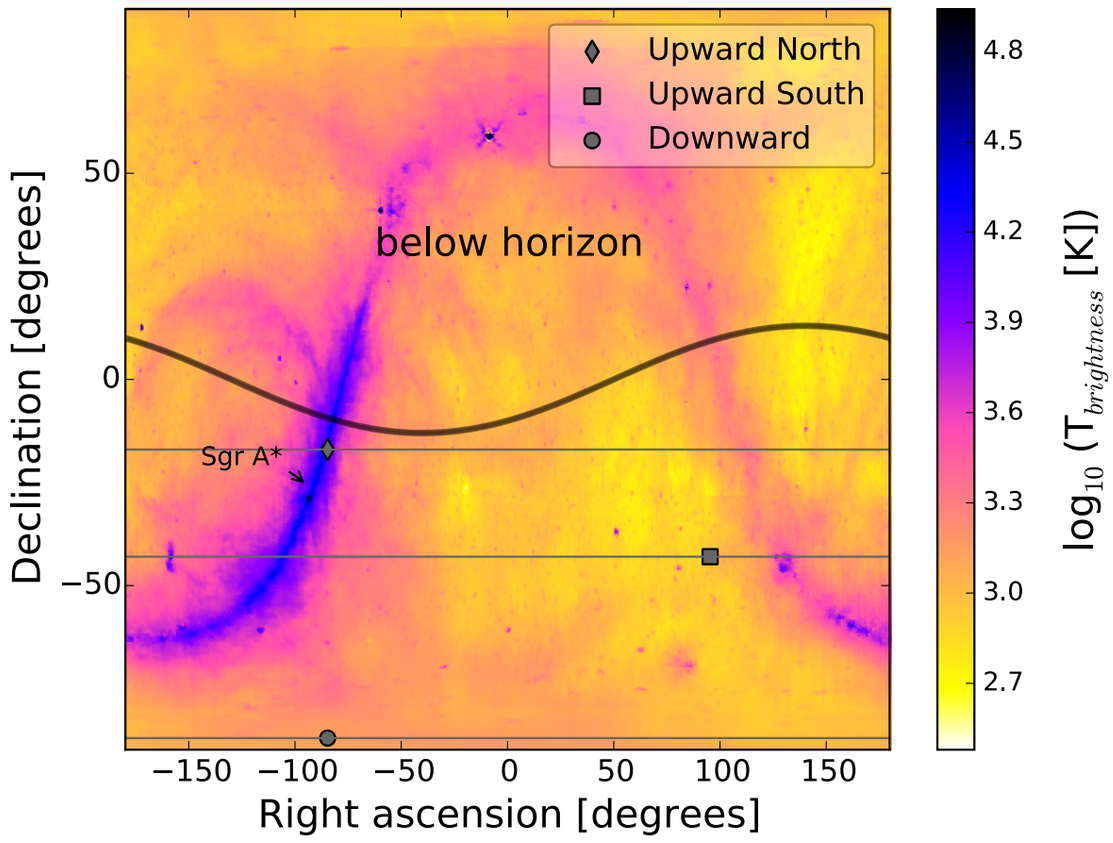
Spectrum integrated over 1ms of data

- Dedicated study with oscilloscope and upward pointing antenna 50-1000 MHz
  - **extremely quiet radio environment**
  - small, time-varying contribution of **narrowband emitters**
  - spectrum clearly dominated by Galactic noise

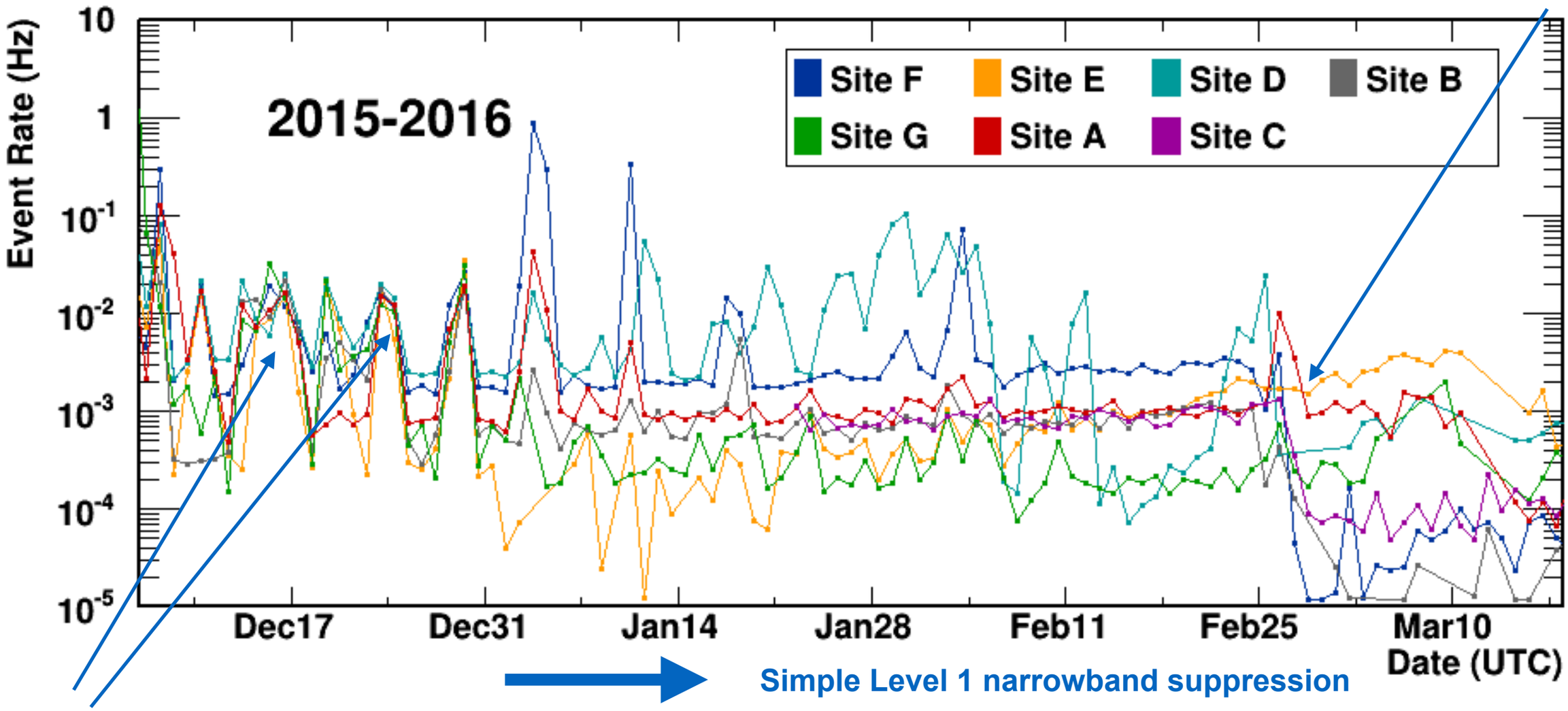
Galactic Background



- Irreducible background: Galactic radio emission
- ARIANNA is triggering on the Galactic noise floor (3.5 sigma) in upward facing antennas

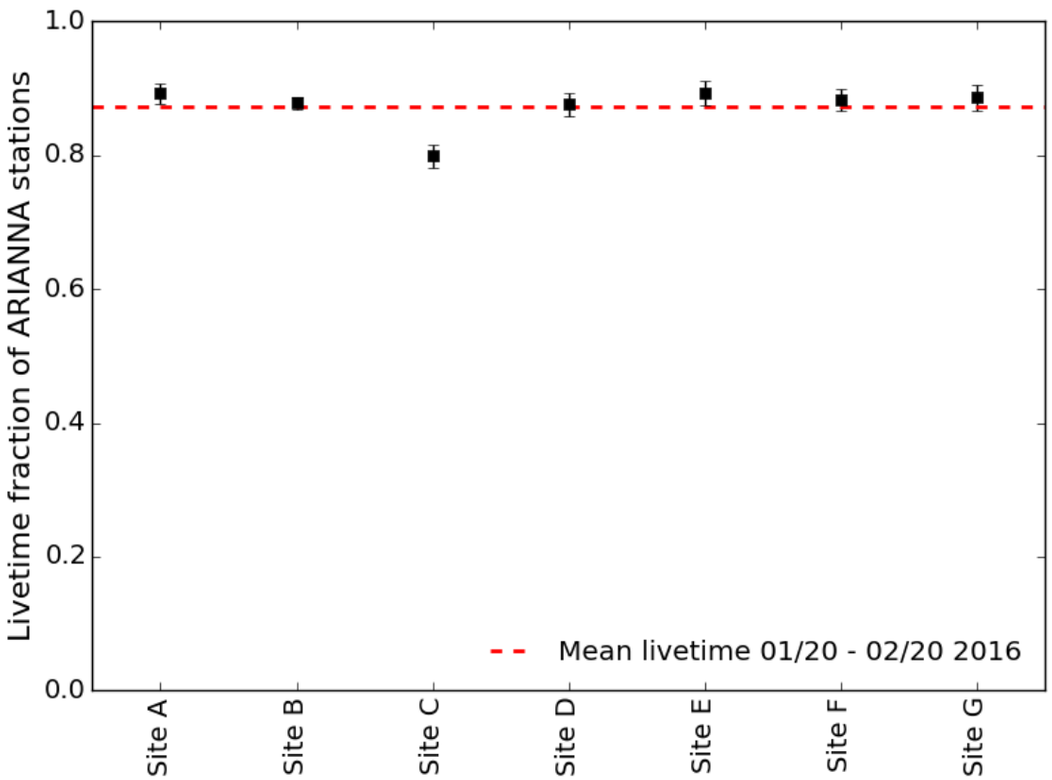


Triggered background



- ARIANNA stations run on fixed threshold triggers on ~ 4 sigma noise level
- **Only short periods (< 1% of time) of (wind-related) pulsed background**

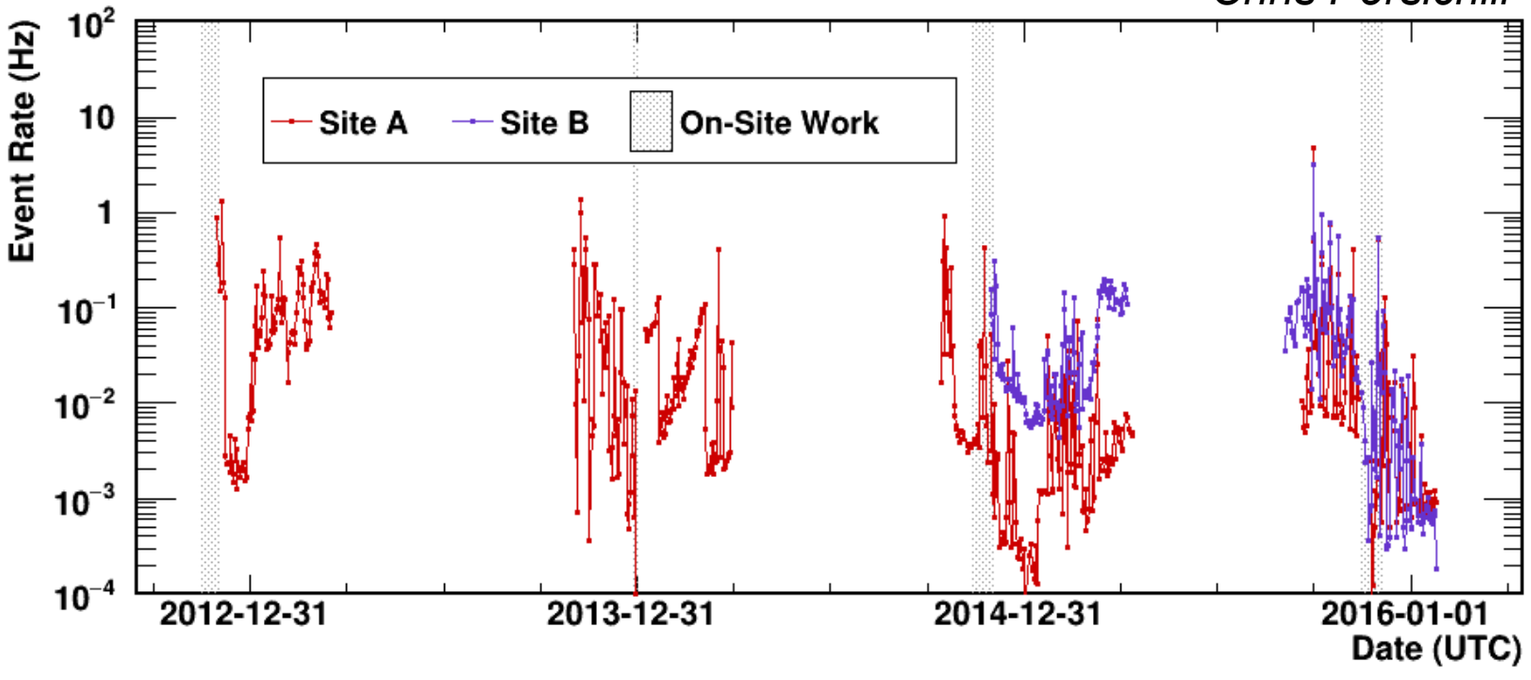
Livetime



- Goal: 100% livetime
  - no data-taking during communication
  - battery performance improved in last season
  - only a few hours with dead-time due to high trigger rates

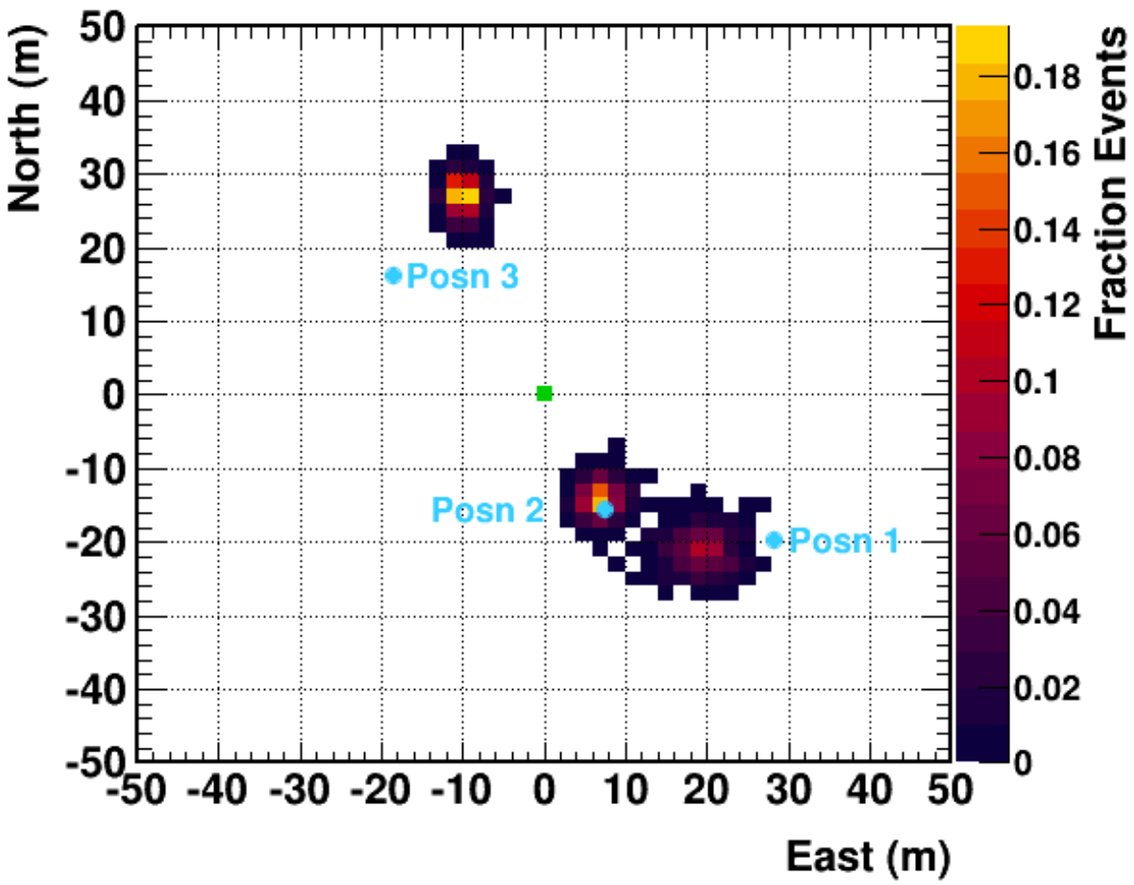
- Stations have become more radio-quiet over the years and show consistent performance

Chris Persichili

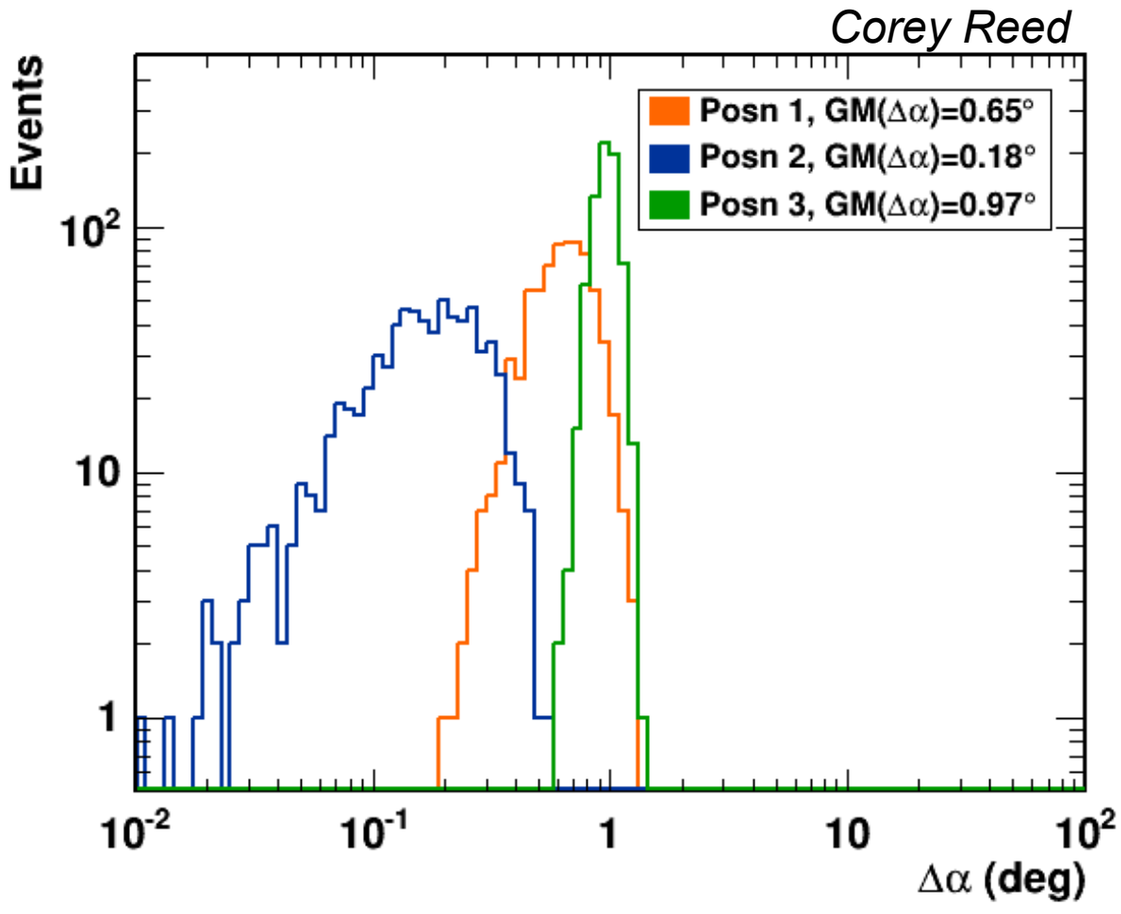


Ice studies through signal bouncing

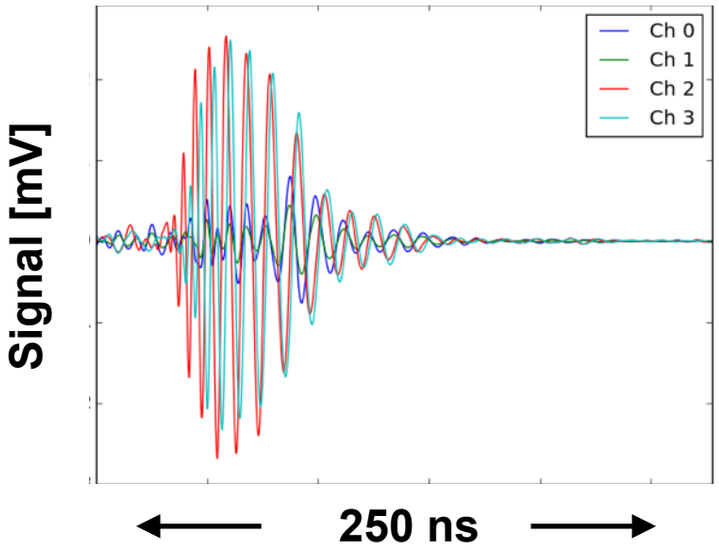
- Quality of the ice will need more studies since it is essential for reconstruction
- First studies very promising:
  - Several papers about ice studies already published
  - Bounced signal reconstructs to position within 1 degree
- Plans for next season: drill hole to lower transmitter



Corey Reed



Signal search strategy



Signal + Detector simulation
(**Cosmic rays** and **neutrinos**)

Search for events with good correlation with template

Find **cosmic ray** candidates

Search for coincidences in other stations

Use measured event as new template

Confirm and reconstruct **cosmic rays**

Search for **neutrino** signals

No candidates

Neutrino limits

Candidates

Event recon-struction

Signal simulation

Signal simulation
(CoREAS, ZHS, …)

↓

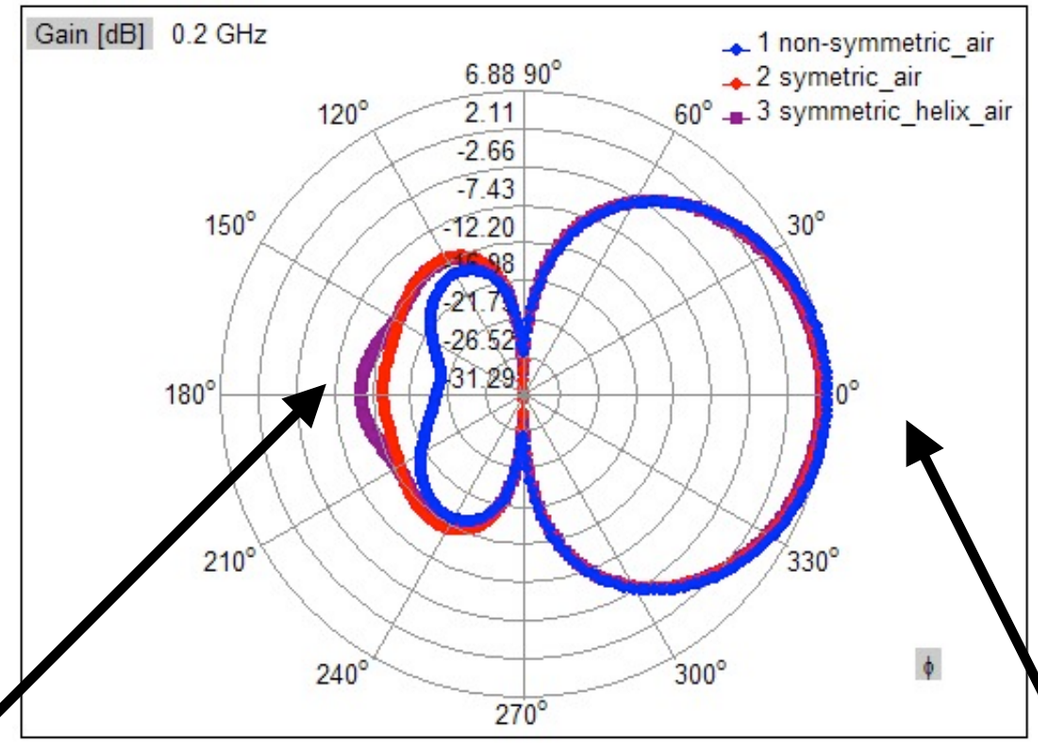
Antenna response

↓

Amplifier response

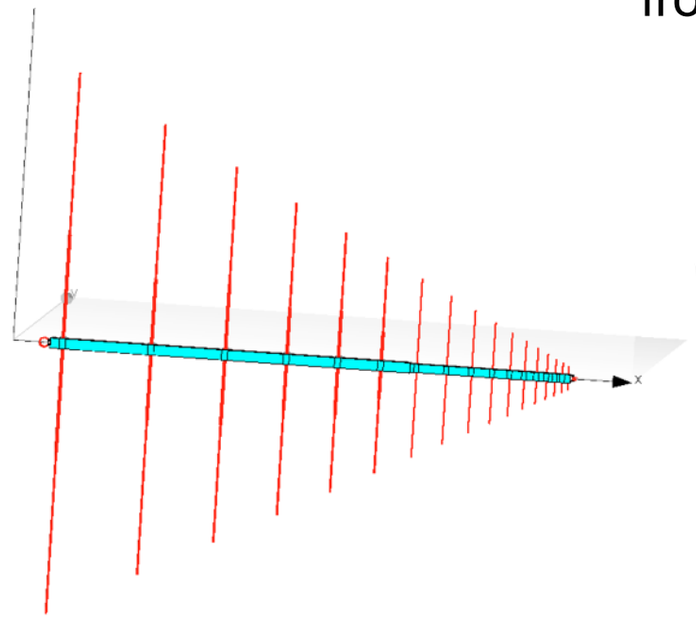
↓

Digitization and trigger

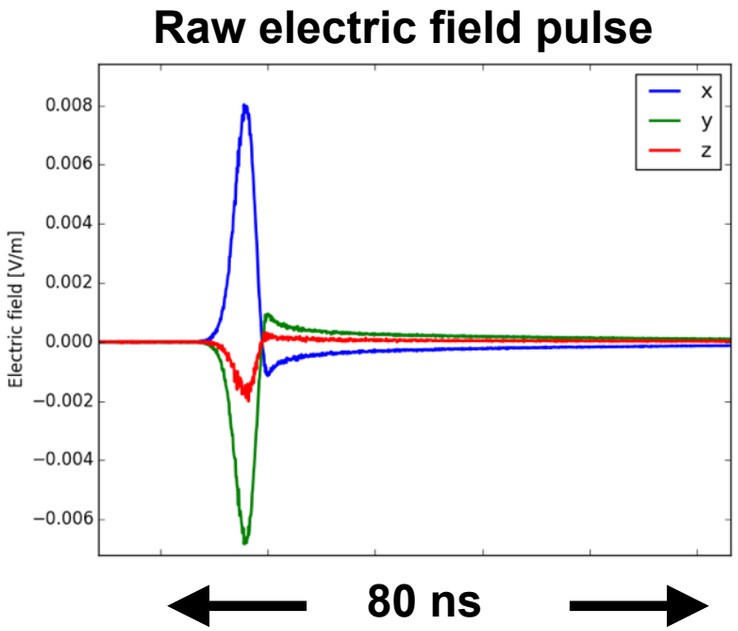


back-lobe

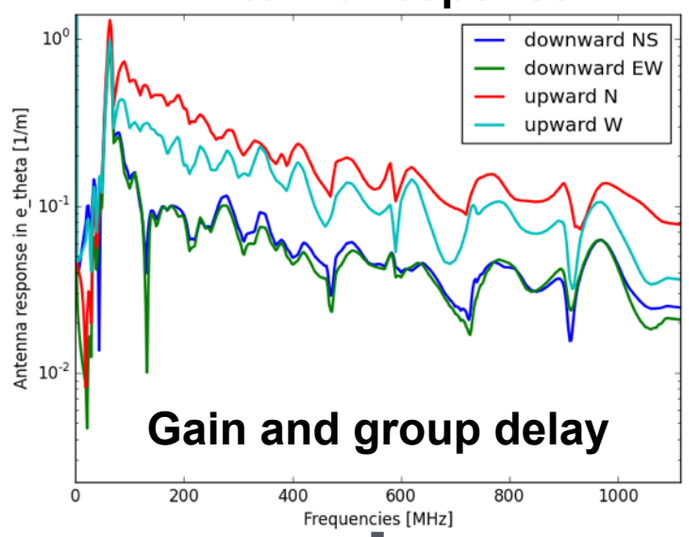
front-lobe

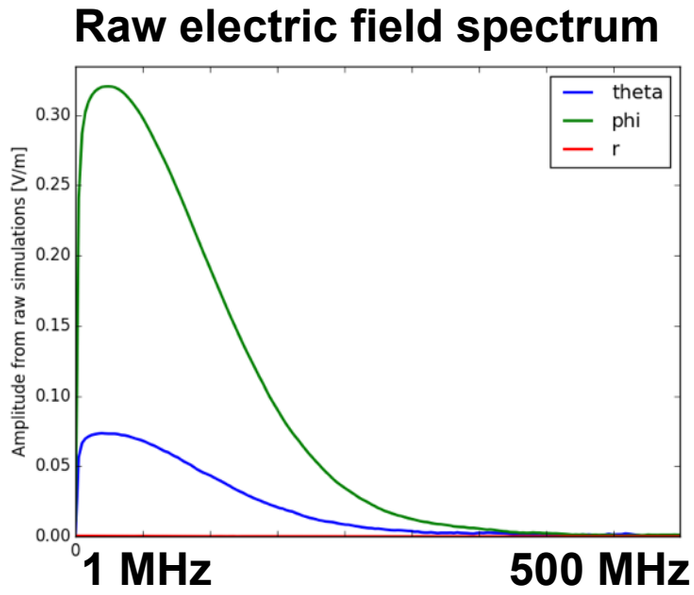


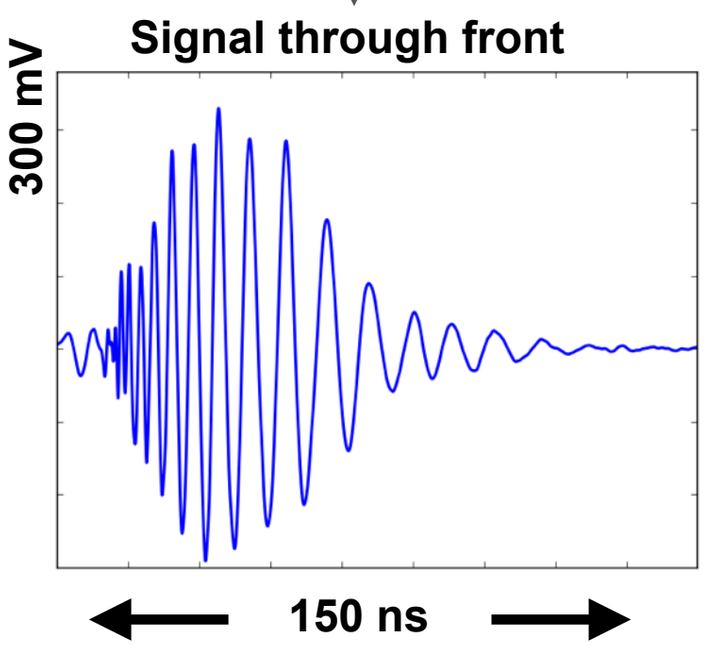
Cosmic Rays

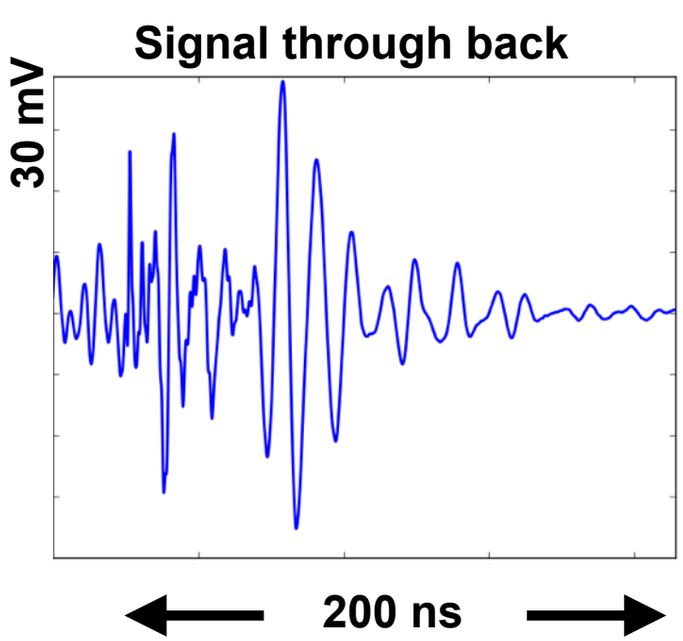


Convolve with









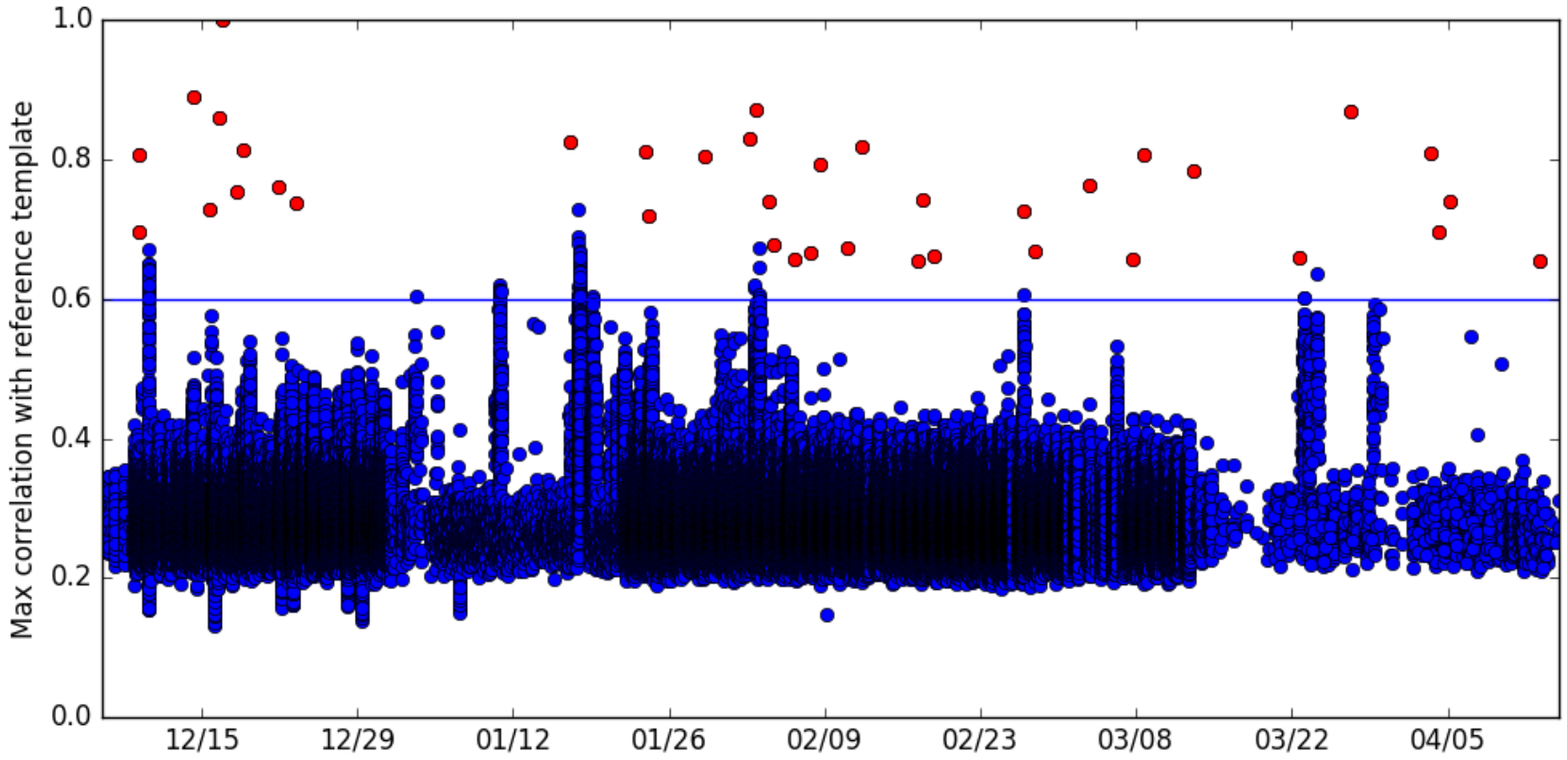
- Air shower signals through front-lobe of LPDA have a **unique characteristic**
- High frequency chirping followed by lower frequencies
- Due to short broadband pulses and group delay of antenna

Cosmic Rays in upward antenna

Site X

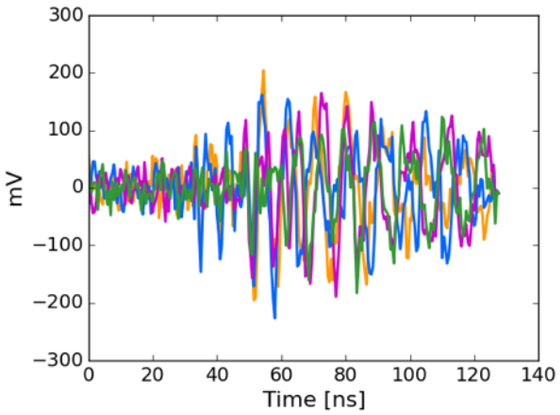
Using simulations as search template

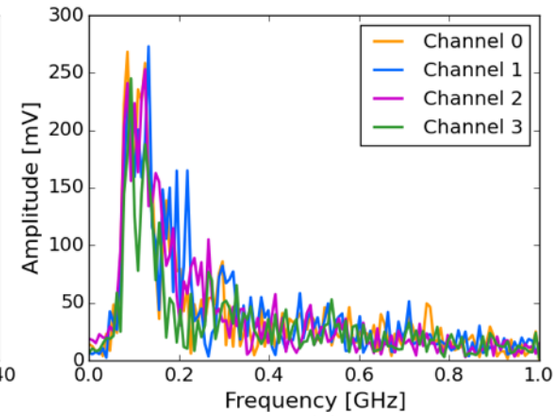
Using data as search template **in red: confirmed cosmic rays**



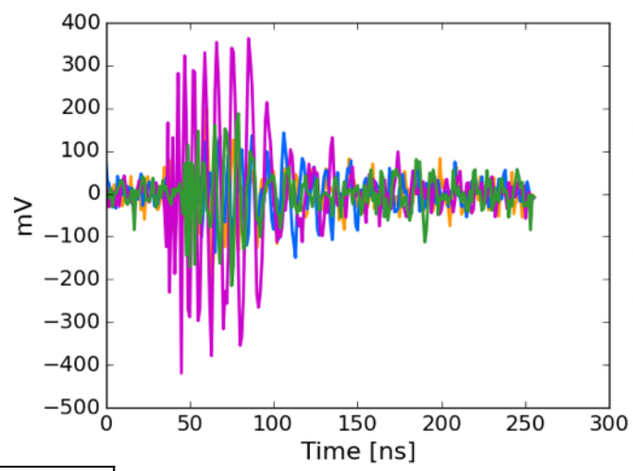
- Cosmic rays in through front-lobe of LPDA have predicted **unique characteristic**
- Correlation with simulations show separate population of individual events, in RFI free periods
- Signals are strongly polarized and in qualitative agreement with expectations
- Simulations are not as good as data (yet)

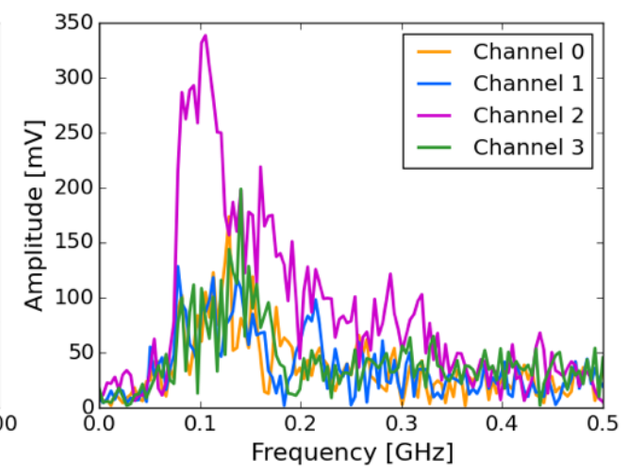
Measured air shower





1 km





Cosmic ray station
Upward pointing channels 2,3
Better low-frequency resolution
Signal detection in forward direction

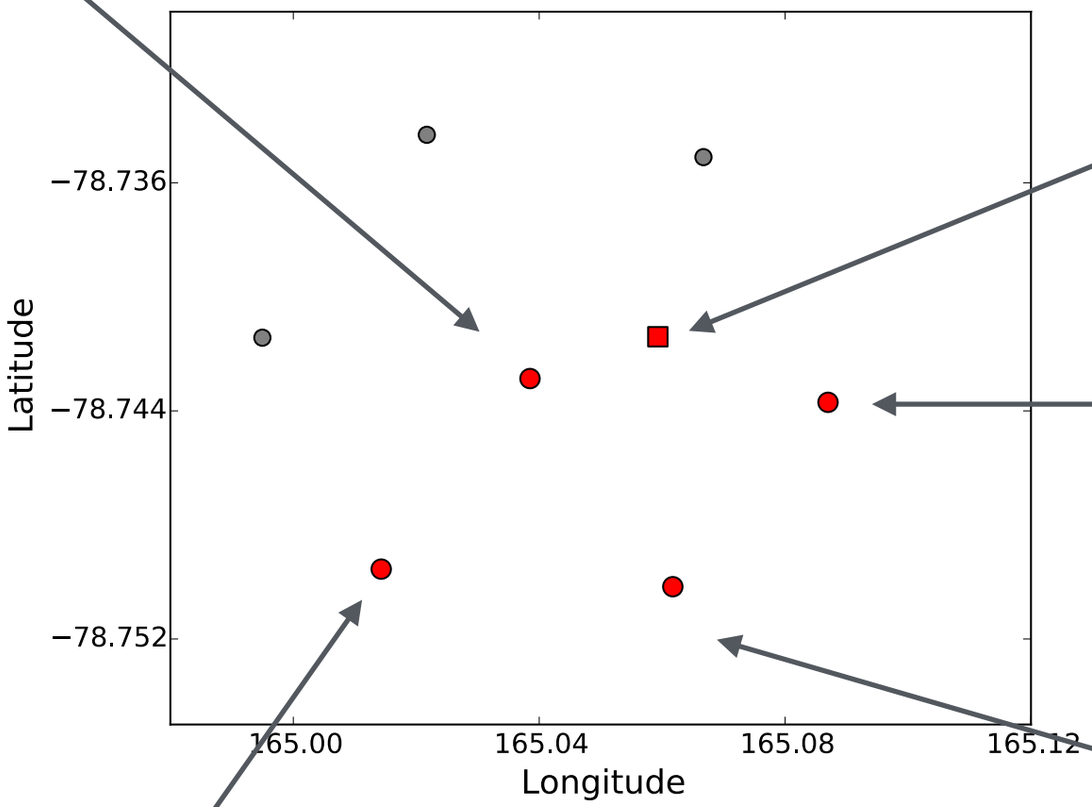
December 21st 2015
1450734371 UTC

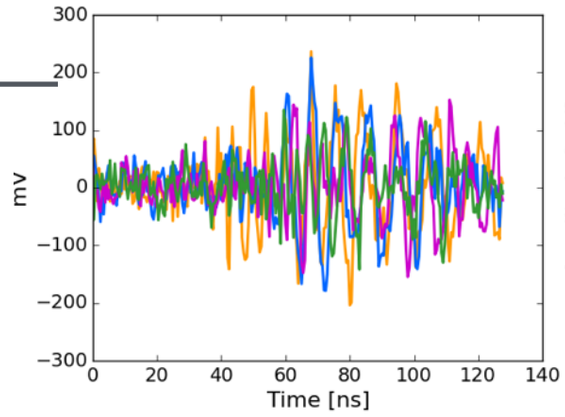
Four independent direction reconstructions

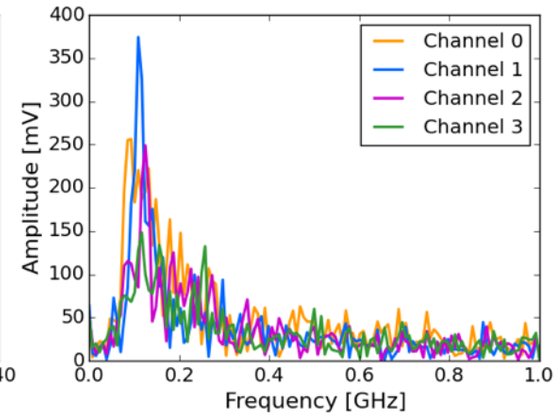
Azimuth = 47˚ +/- 2˚

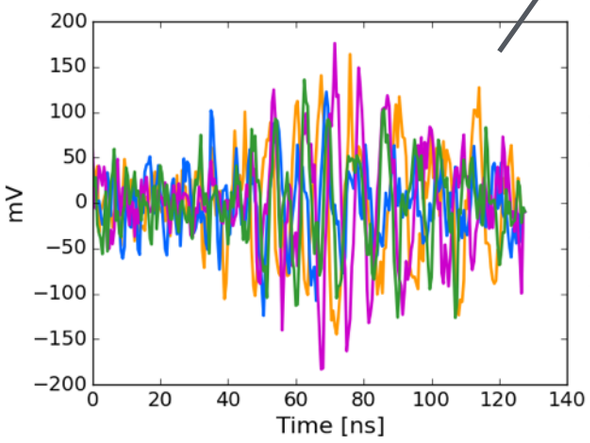
After Fresnel:
Zenith = 49˚ +/- 2˚

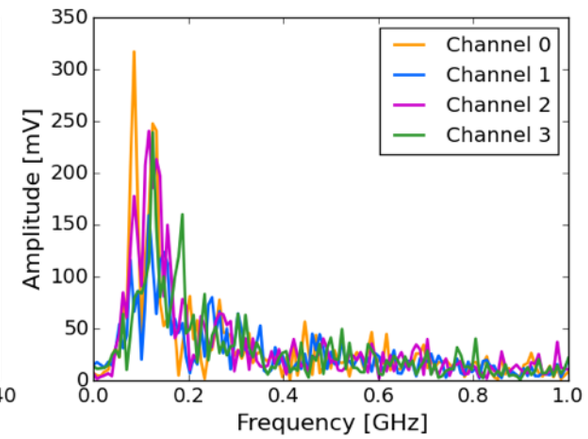
Before Fresnel:
Zenith = 75˚ +/- 3˚

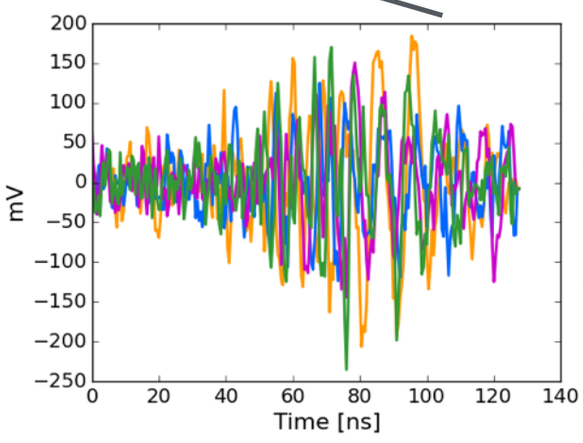


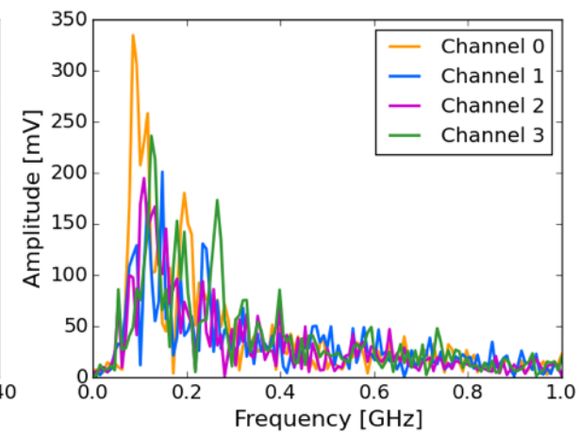




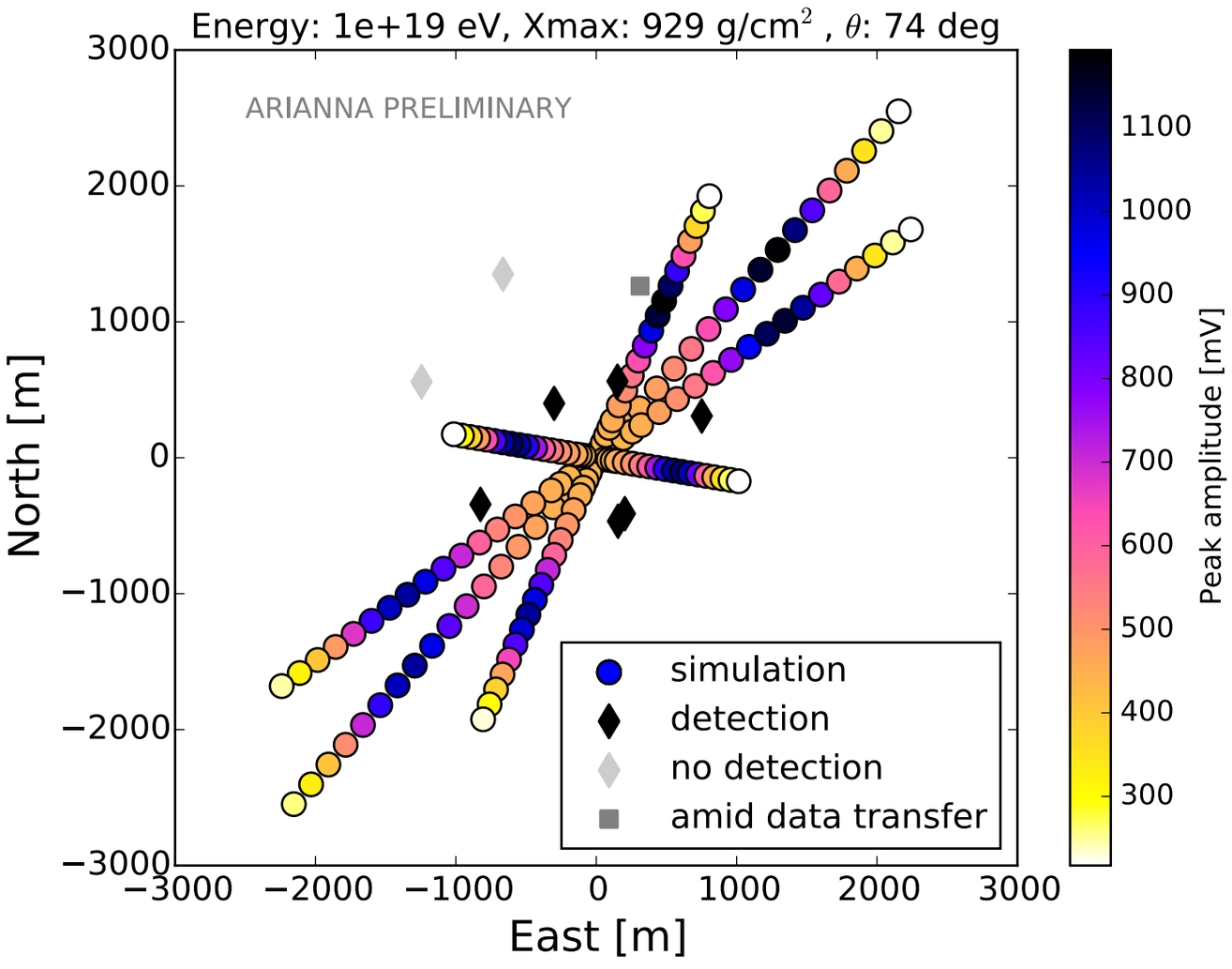






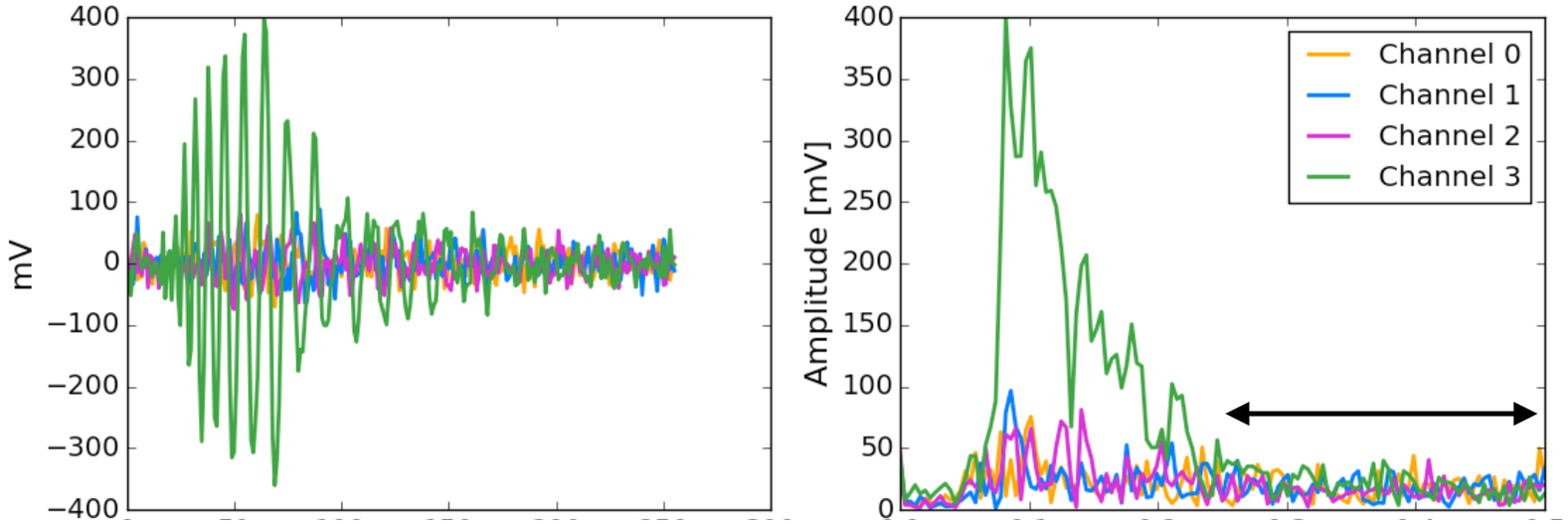


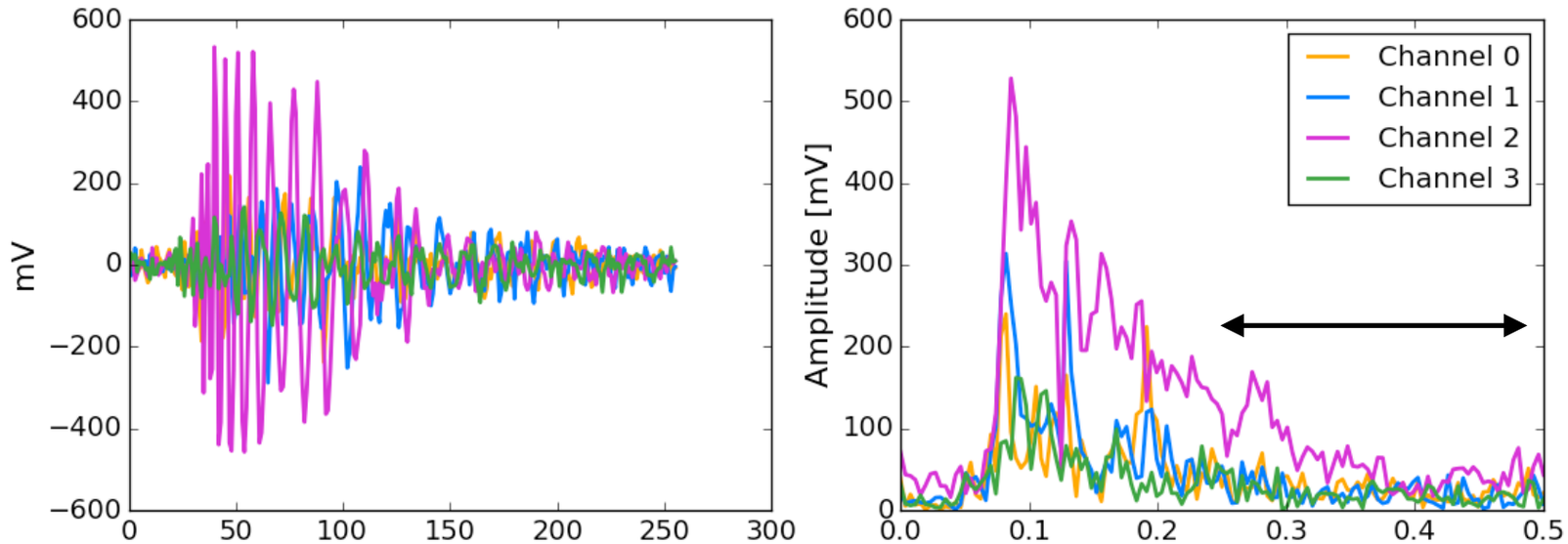
Air shower simulation

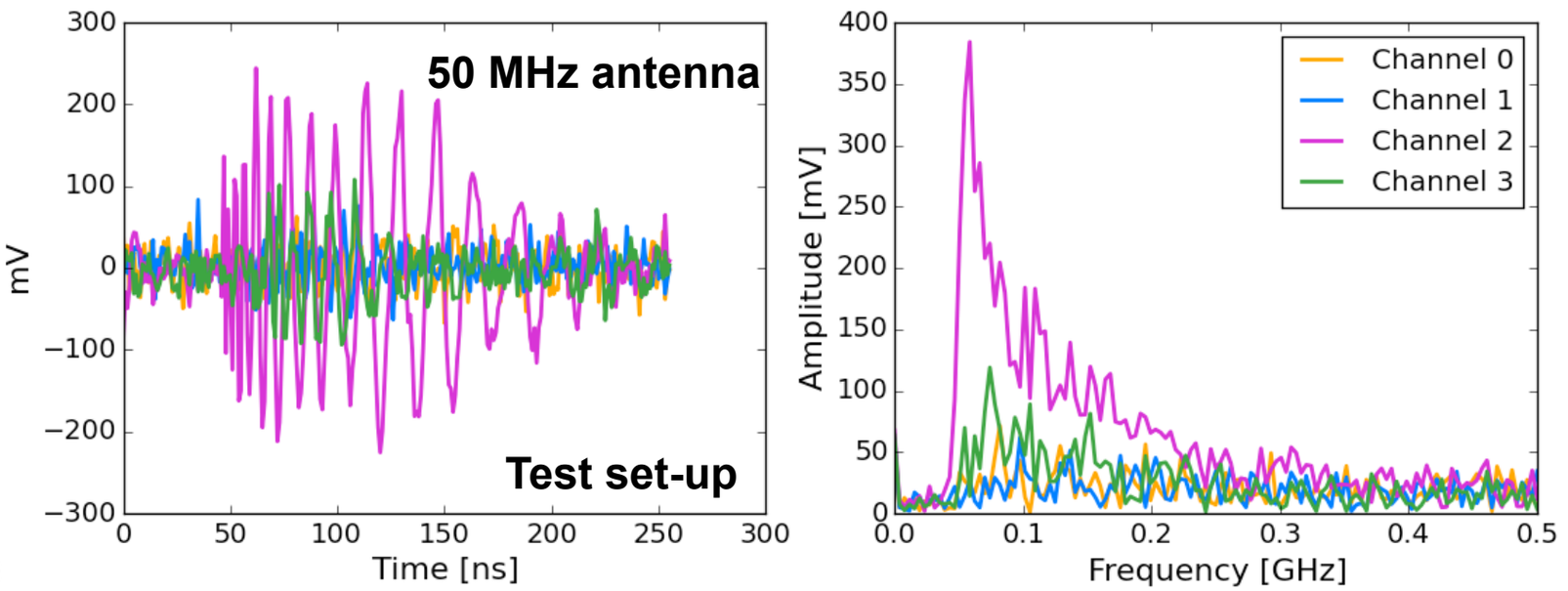


- Detected multiple coincidences: **horizontal showers**
- Full detector simulation and dedicated simulations for big events
- Experiment with method as tested in LOFAR and AERA
- Use polarization information
- Fully independent reconstruction of air shower parameters

Measured air showers



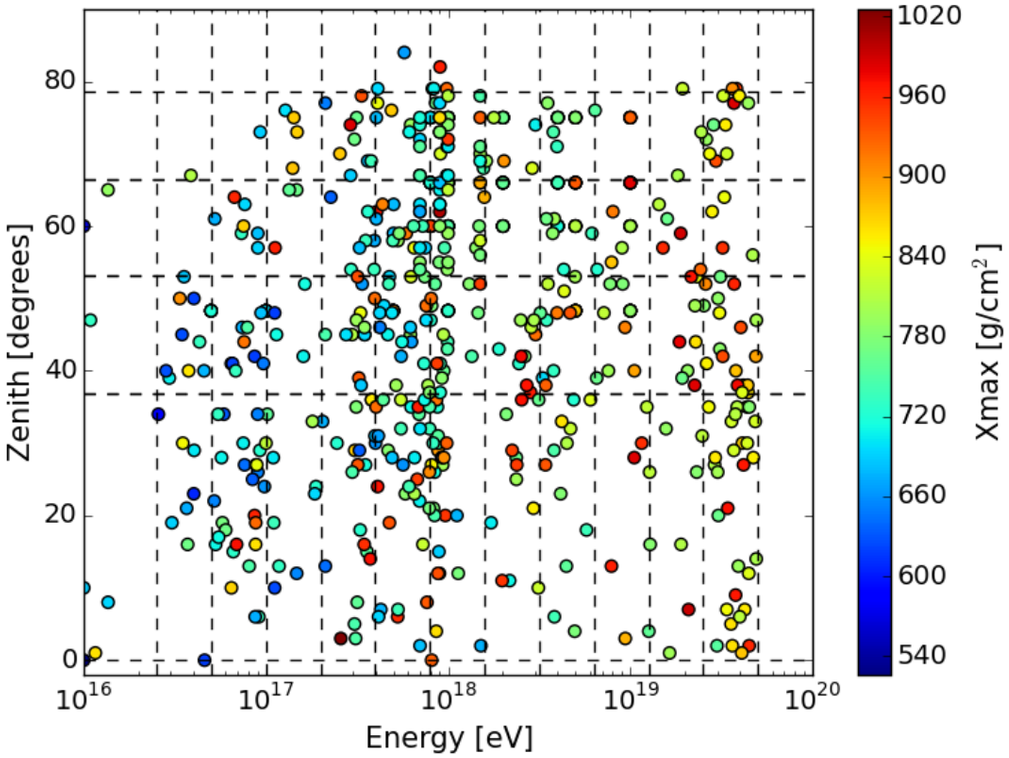




- ARIANNA directly measures air showers from 50 - 500 MHz with **no filtering against RFI**
- Signals will be interesting to study **spectral behaviour** of air shower signals
- Antenna and amp response still to unfold

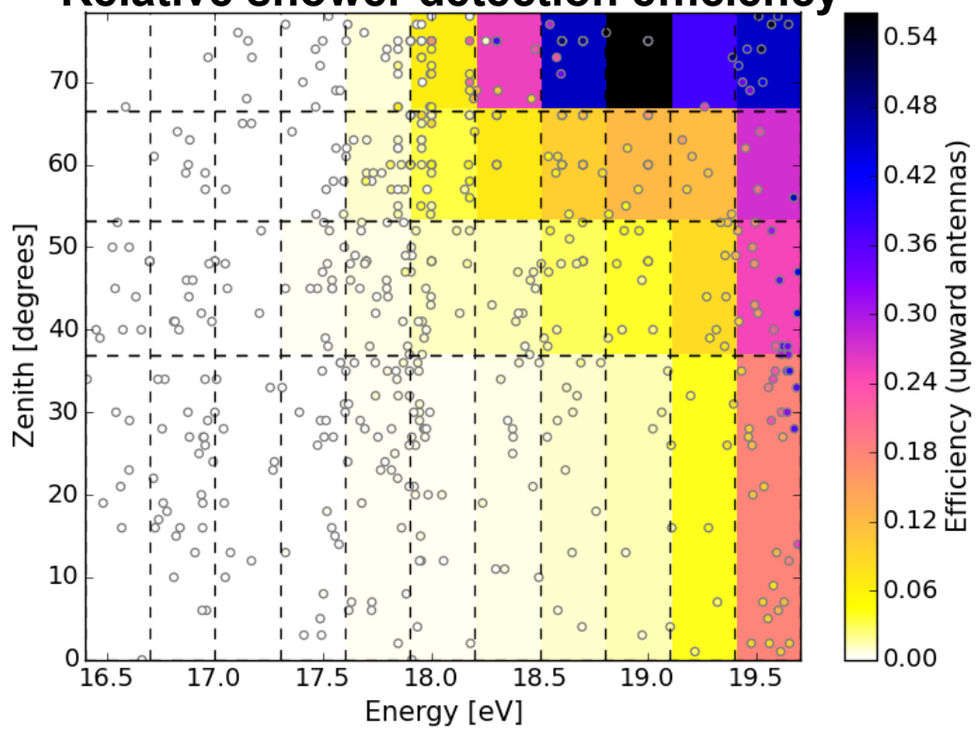
Cosmic Ray rate calculation

CoREAS air shower simulations

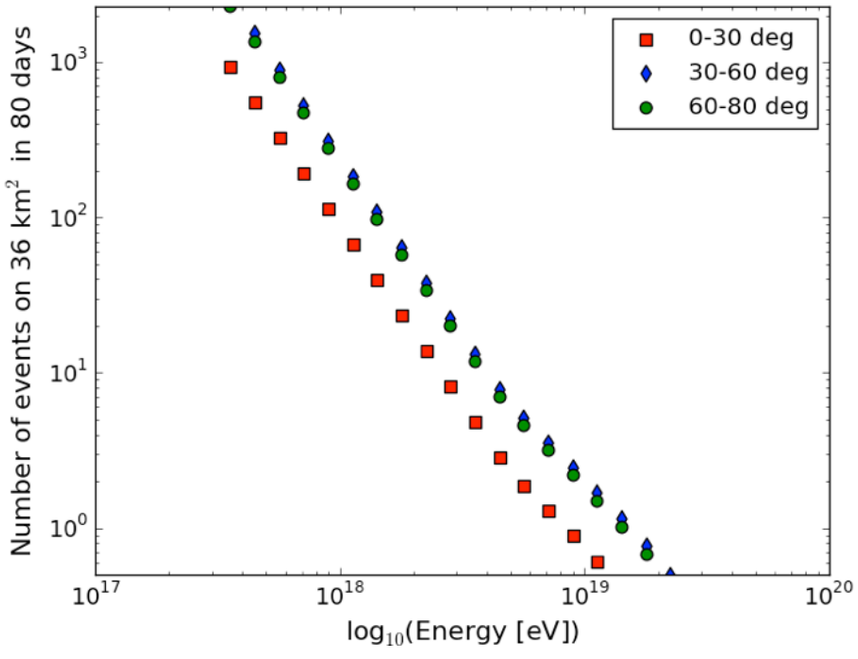


+ detector =

Relative shower detection efficiency



“Known” cosmic ray flux



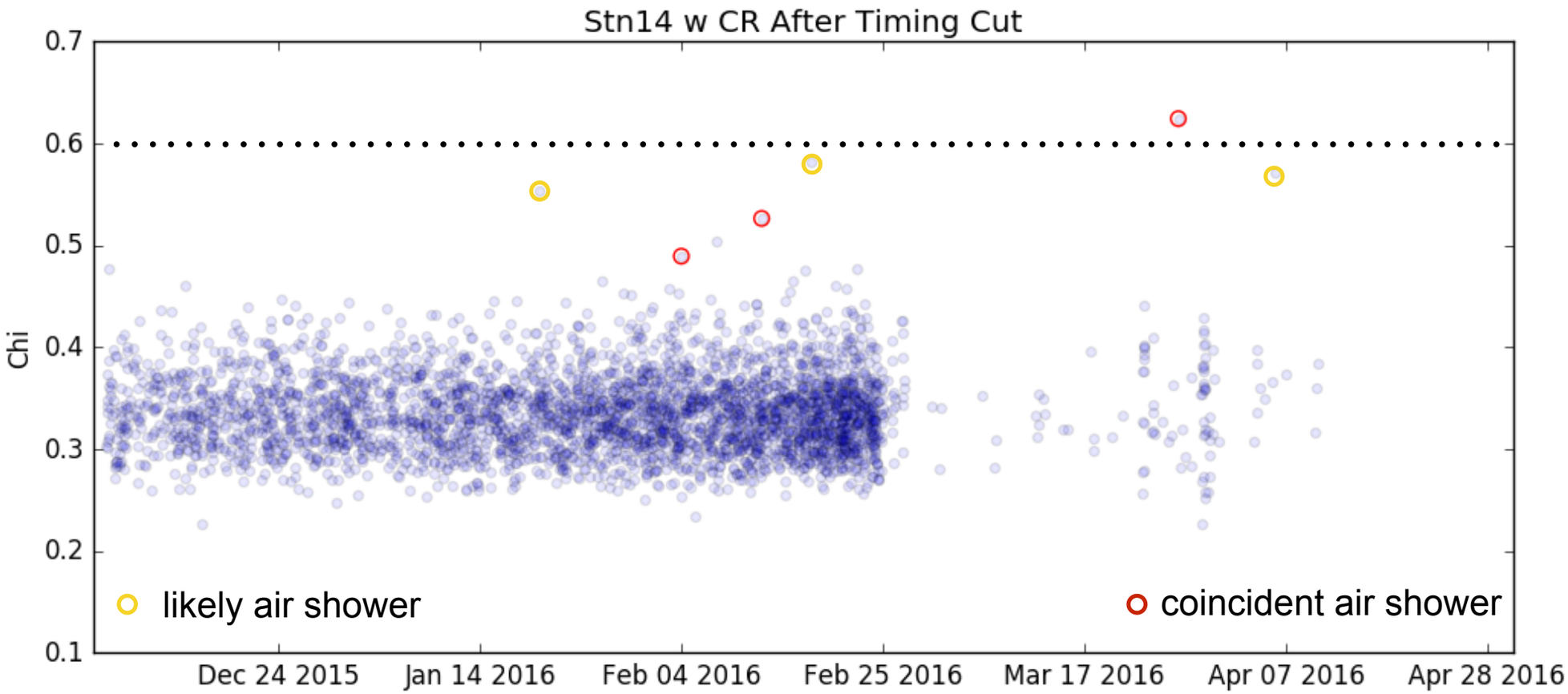
x Livetime of ARIANNA
x Efficiency of ARIANNA

Cosmic ray rates in ARIANNA

If rates matches data: Good understanding of detector

Neutrino search

- Neutrino search based on three very simple assumptions
  - Events **cannot be clustered** in time: livetime loss < 2%
  - Events **cannot be narrowband signal**
  - Events need to have **correlation better than 0.6** with neutrino template

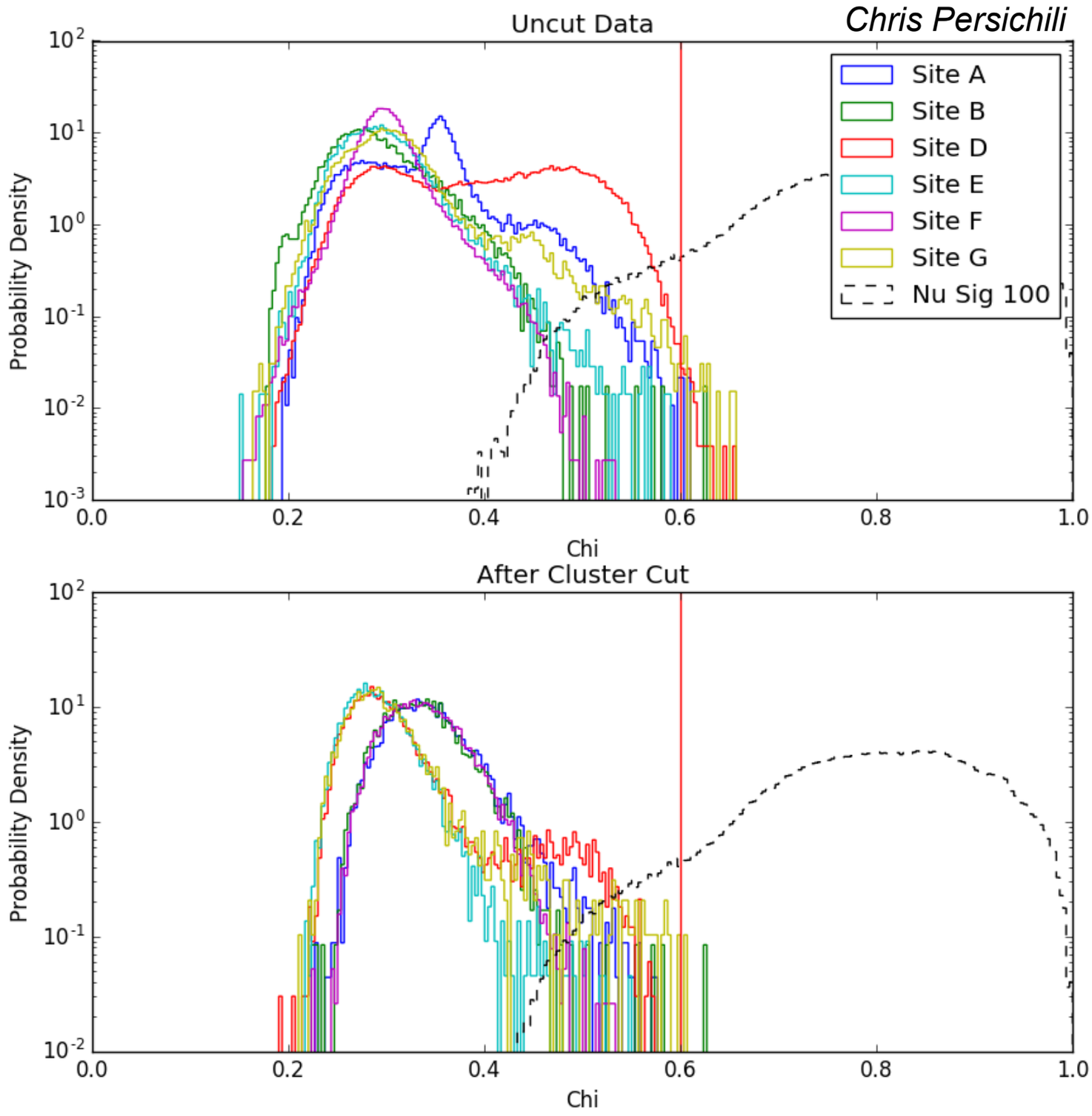


Neutrino efficiency

- Events **cannot be clustered** in time (periods of high trigger rates) livetime loss < 2%, no efficiency loss

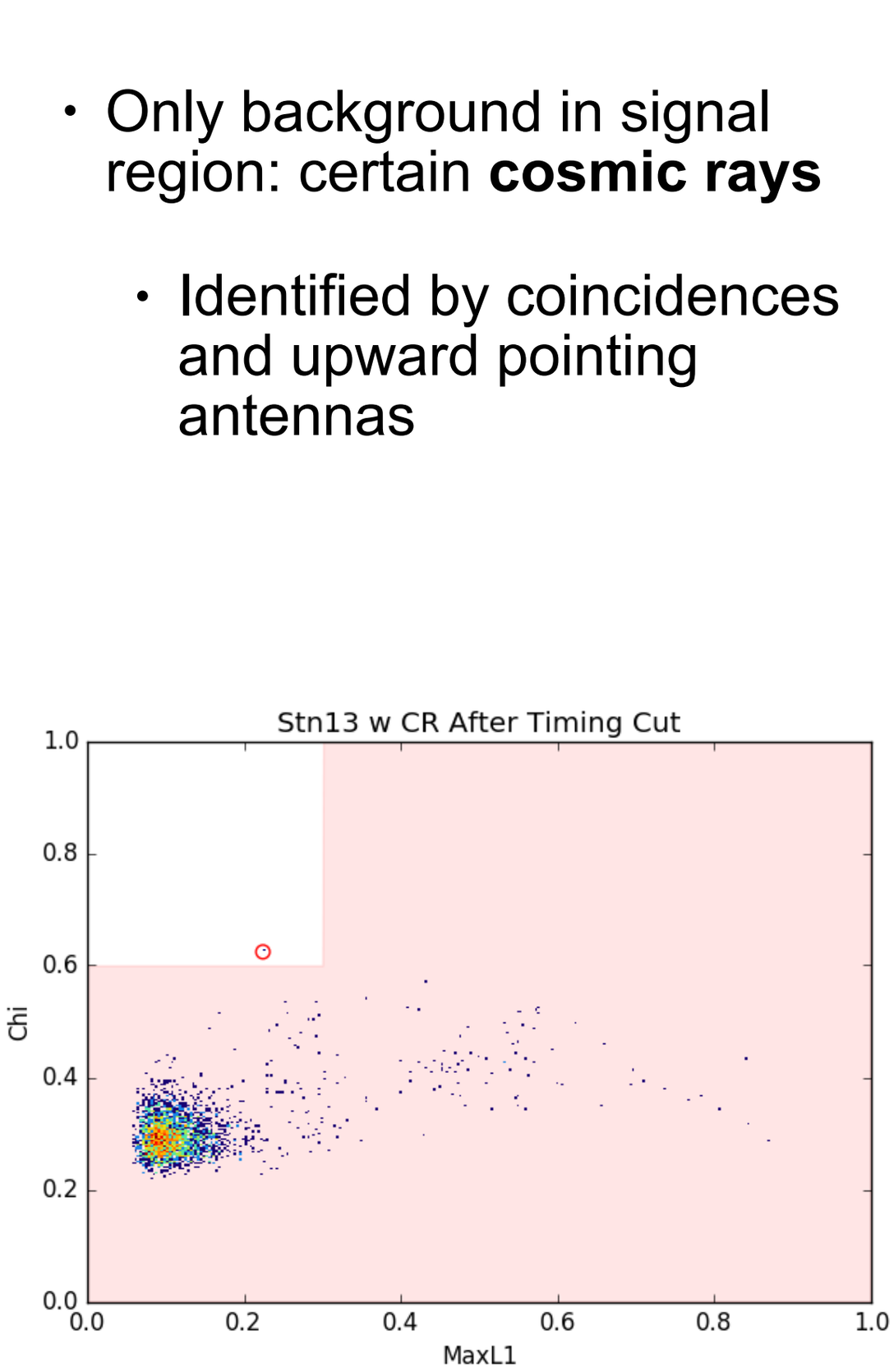
- Events **cannot be narrowband signal,** L1 parameter excludes fraction of 6×10^{-5} neutrinos

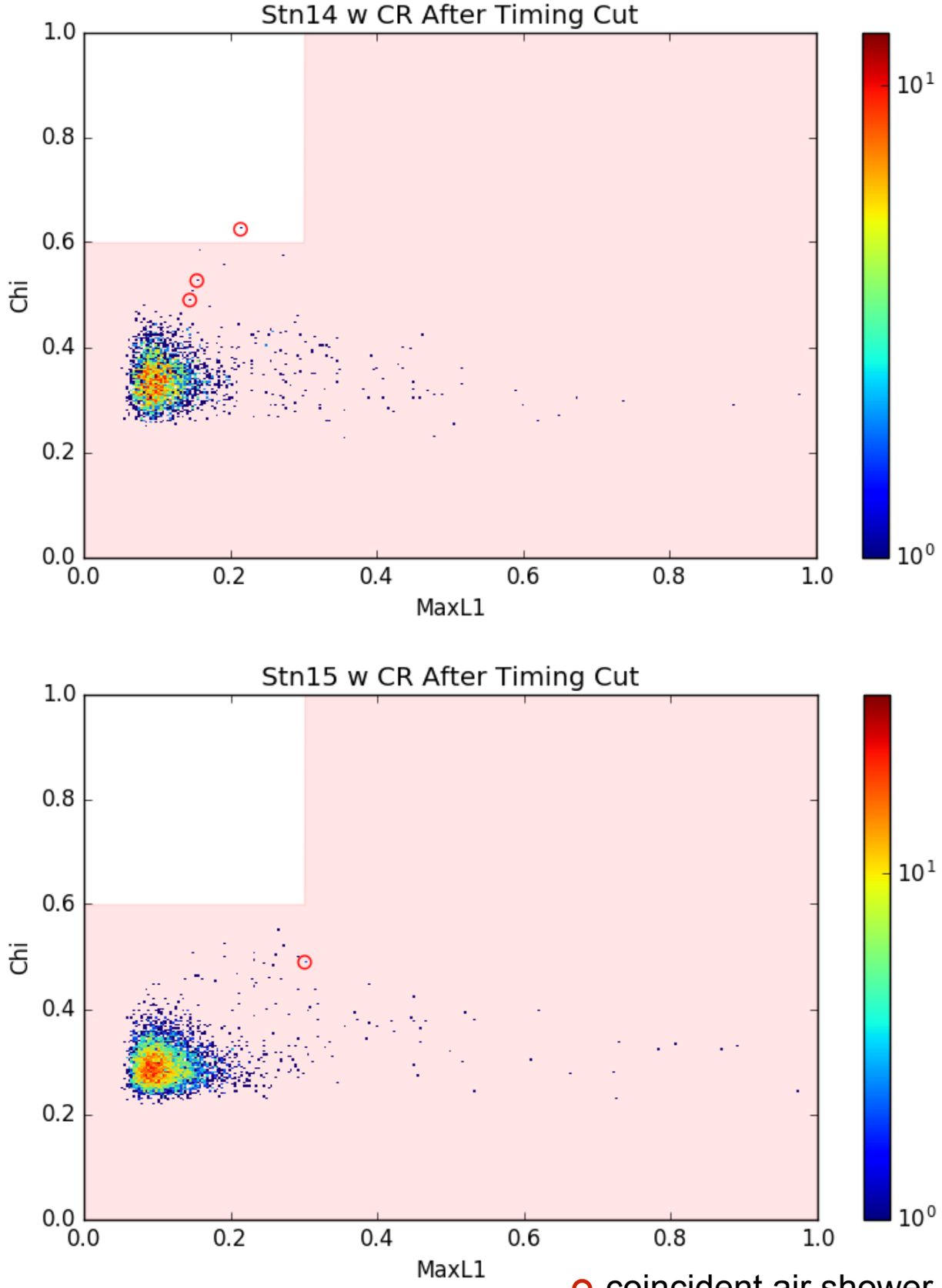
- Events need to have **correlation better than 0.6** with neutrino template, largest efficiency factor



Neutrino search

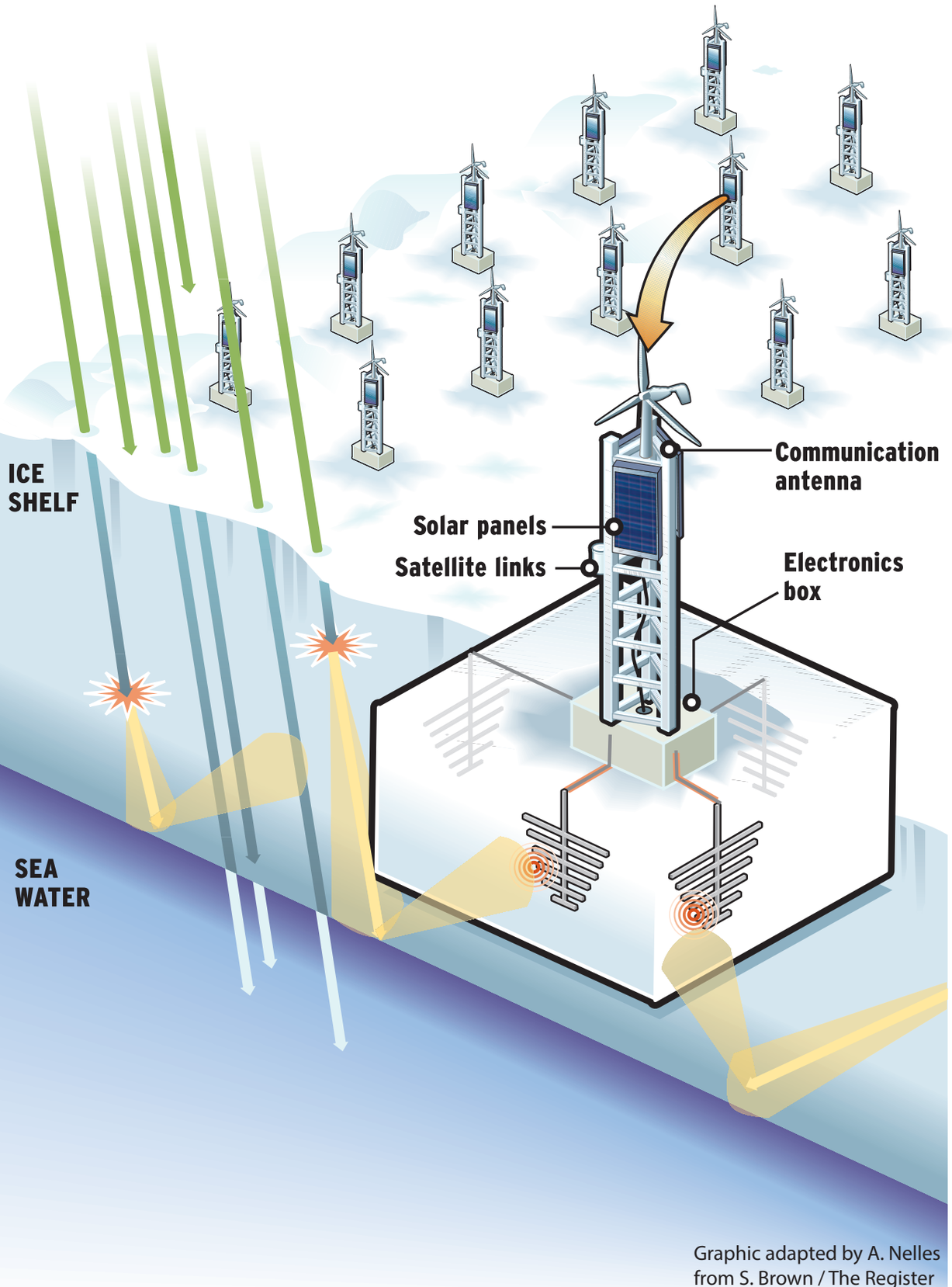
- Only background in signal region: certain **cosmic rays**
  - Identified by coincidences and upward pointing antennas





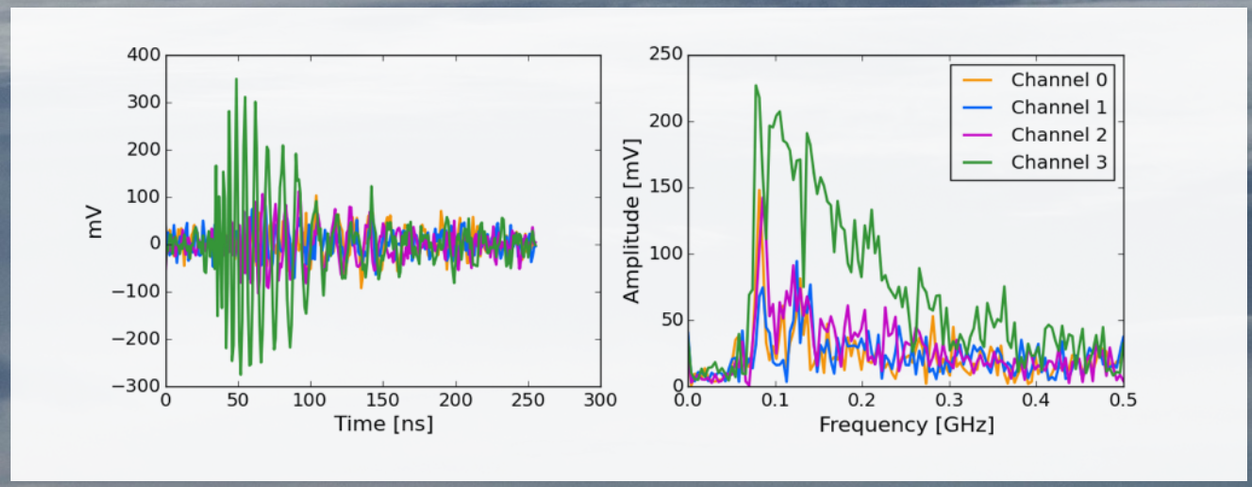
coincident air shower

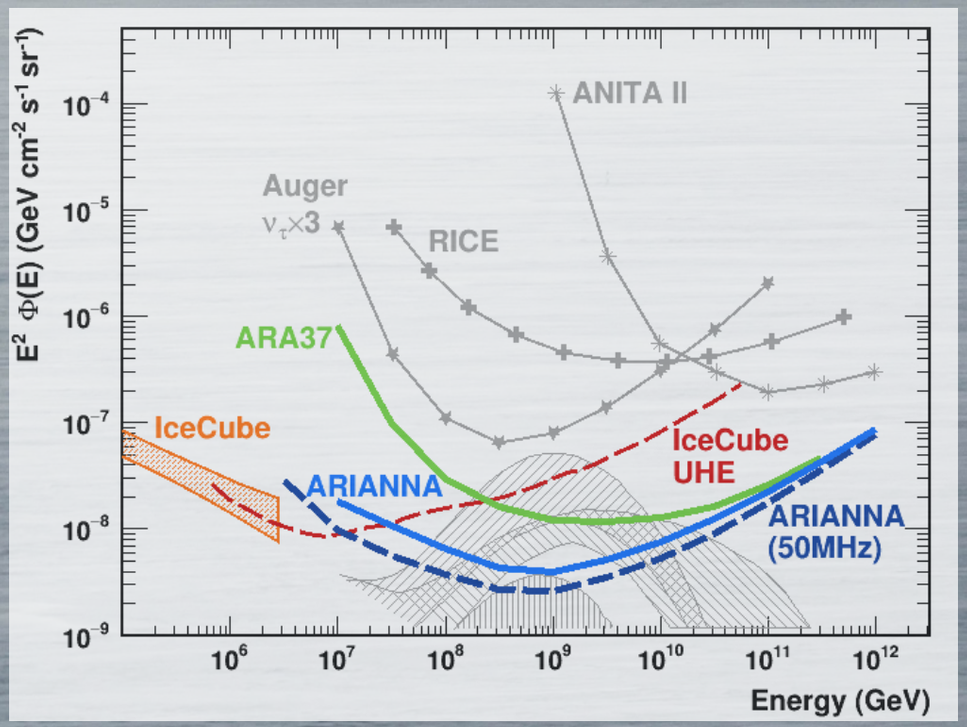
Future Plans



- R&D with current ARIANNA:
  - Increase livetime by adding wind generators
  - Study ice properties in detail
  - Upgrade Cosmic ray station
- Future ARIANNA:
  - Decide on final station design:
    Number of channels,
    sampling,
    data-transfer options,
    antenna orientation, …
  - Aim: 1296 stations
    (~ 30 Million USD)

We are looking forward to the next three years of operation of ARIANNA and to a large radio array for neutrino detection in 2020.





With thanks to my colleagues from the ARIANNA Collaboration