ARIANNA: tent camping and neutrino hunting in Antarctica

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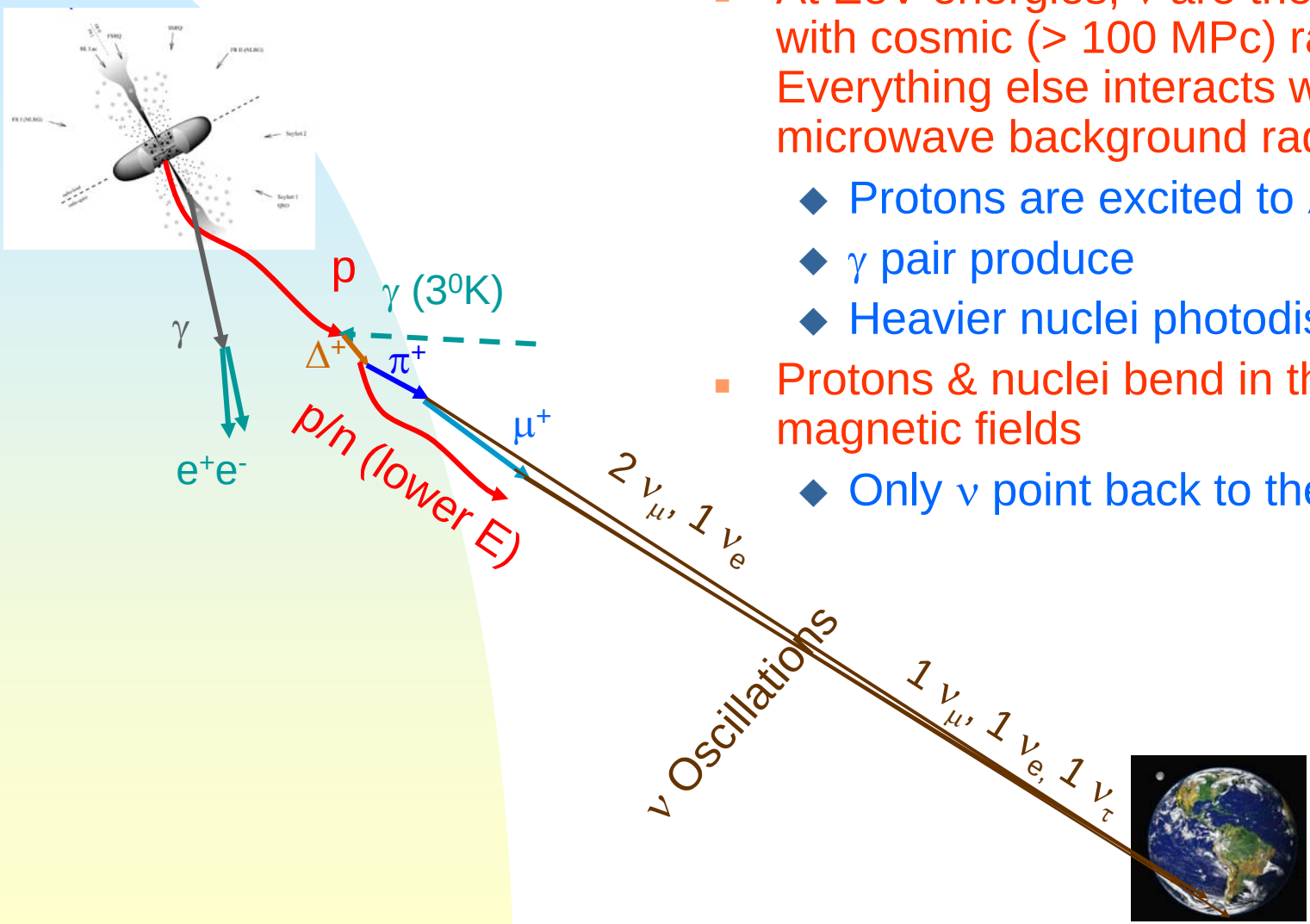
- GZK neutrinos
- Radiodetection of neutrinos
- ARIANNA
- Our field season

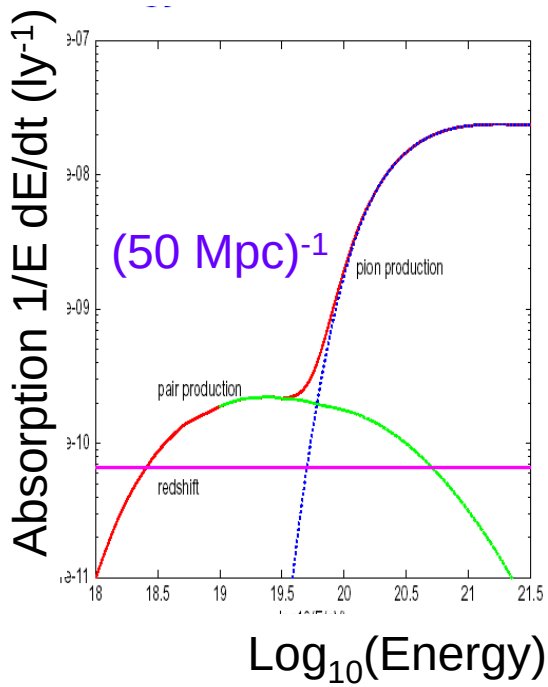
Probing the EHE Cosmos



- At EeV energies, ν are the only particles with cosmic (> 100 MPc) range. Everything else interacts with the 3^0K microwave background radiation
  - Protons are excited to Δ^+
  - γ pair produce
  - Heavier nuclei photodissociate
- Protons & nuclei bend in the interstellar magnetic fields
  - Only ν point back to their sources

EHE neutrinos

- Experiments have observed cosmic-rays with energies up to $3*10^{20}$ eV
  - Range, < ~ 75 Megaparsecs
    - Sources must be nearby
  - Association with Active Galactic Nuclei?
    - Correlated with local mass density
- ν produced by decay of Δ^+
- ν ~ infinite range, so probe the EHE universe over cosmological distances
  - Evolution of high-energy universe
  - The microwave flux & cross-section are well known --> only depends on CR flux
- Point source ν also possible



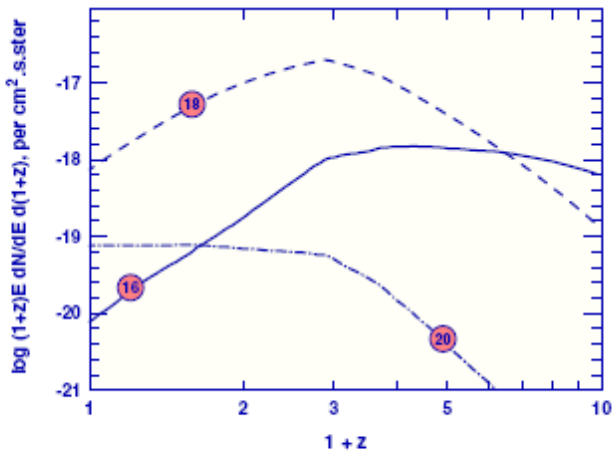


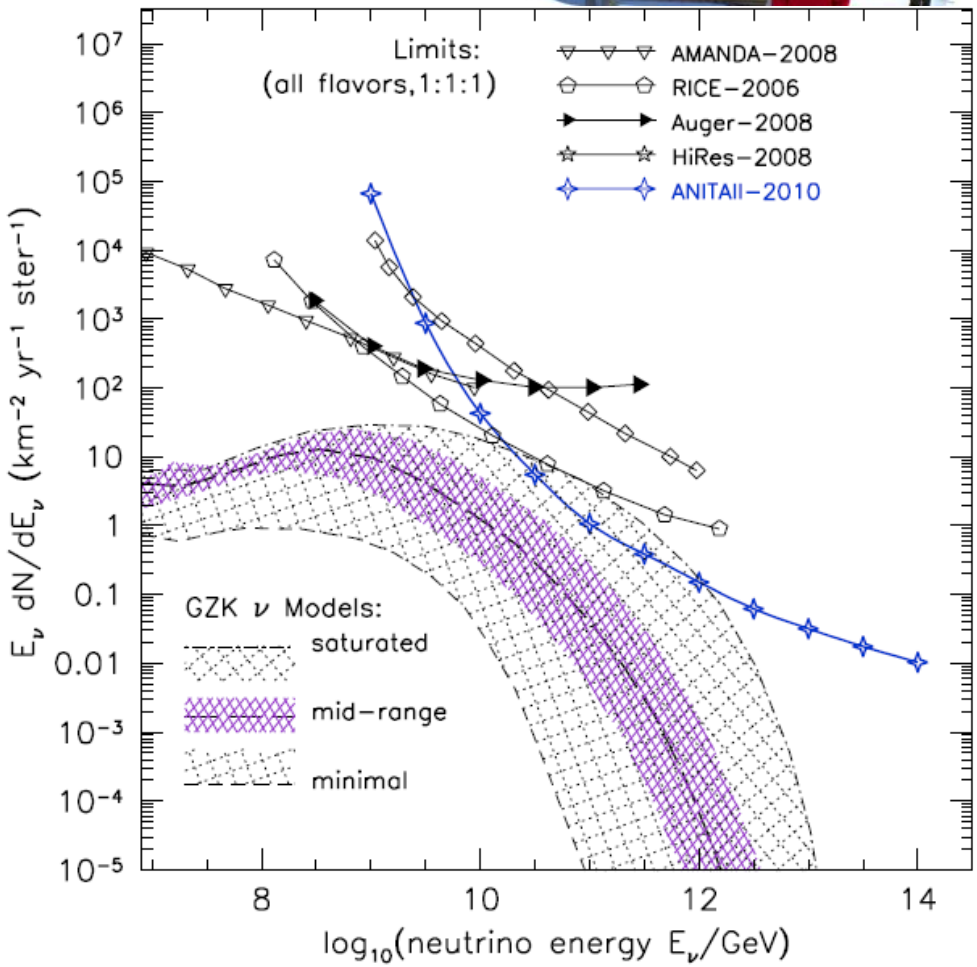
Figure 4. Contribution of different redshifts to the cosmogenic neutrino flux at 10^{16}, 10^{18}, and 10^{20} eV.

Current Limits

From arXiv:1003.2961
(ANITA Collaboration)

Limits from:
ANITA – Balloon
Auger – Air shower
Rice – radio@Pole
AMANDA – Optical@ Pole

Not shown
Saund – Acoustic/ seawater
NuMoon, etc. – radio/moon
FORTE – satellite radio in Greenland

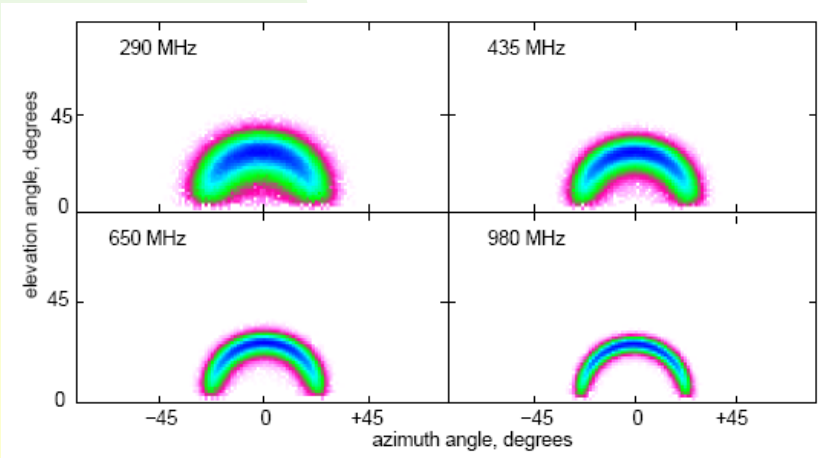


Detector Basics

- Desired threshold ~$10^{16\text{-}17}$ eV
- ~ 100 km^3 needed for ~100 GZK events in 3-5 years
  - Current (smaller) experiments have set upper limits
- The earth absorbs UHE neutrinos
  - Signal events are mostly horizontal or downgoing
- A 100 km^3 array needs signal attenuation lengths > 1 km
- Technology Choice: Radio Cherenkov radiation from showers
  - Coherent signal from ~ 20% excess e^- in showers
    - Radio signal ~ E_ν^2
- $10^{16\text{-}17}$ eV threshold requires sensors in detection volume
  - Distant experiments (targets 10^2-10^5 km from sensors) have thresholds > 10^{20} eV
- Acoustic radiation has ~~ 200 m attentuation length
  - Due to local heating; length too short

Radio Signal Characteristics

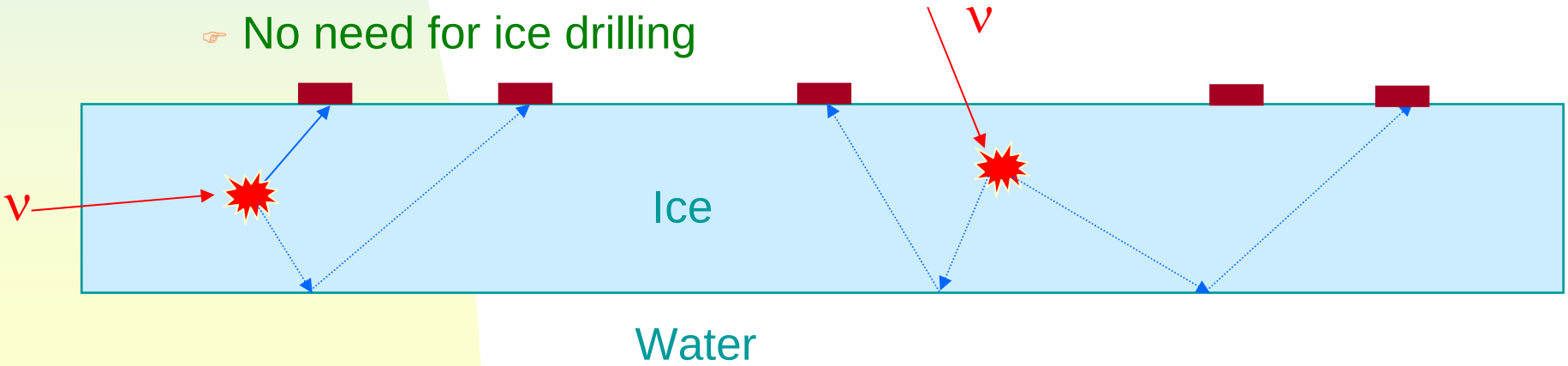
- Intensity rises with frequency up to coherence limit
  - Λ_{min}~ transverse width of shower
    - ~~ Moliere Radius
- Emitted around Cherenkov cone
  - Broad distribution at low frequencies
  - Narrow distribution at high frequencies



Cherenkov cone vs. frequency

Radio in the Ross Ice Sheet

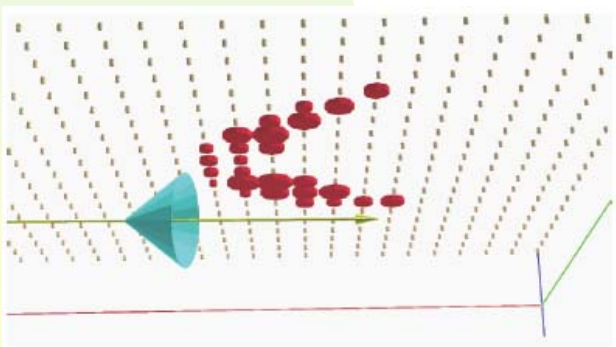
- Downgoing ν produce downgoing Cherenkov cones.
  - Usually need buried detectors to observe
- The Ross ice shelf is ~ 650 m of ice atop water
  - Site is ~ 100 km from McMurdo station
- The ice-water interface reflects radio waves
  - Surface detectors can be sensitive to downward going Cherenkov photons
    - Large increase in solid angle
    - No need for ice drilling

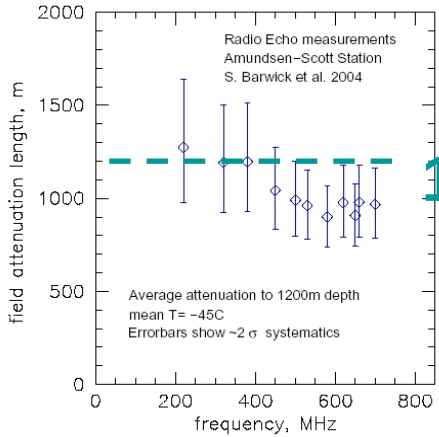


Dotted lines show reflected signal

Radio Signals in ARIANNA

- Surface stations with 8 (?) antennae
  - Octagonal arrangement with 4 m spacing
    - Octagon allows polarization measurement
    - Spacing allows angular determination
  - Frequencies between ~ 50 MHz and 1 GHz
- Tradeoff between density (good measurement of single event) and maximizing active volume

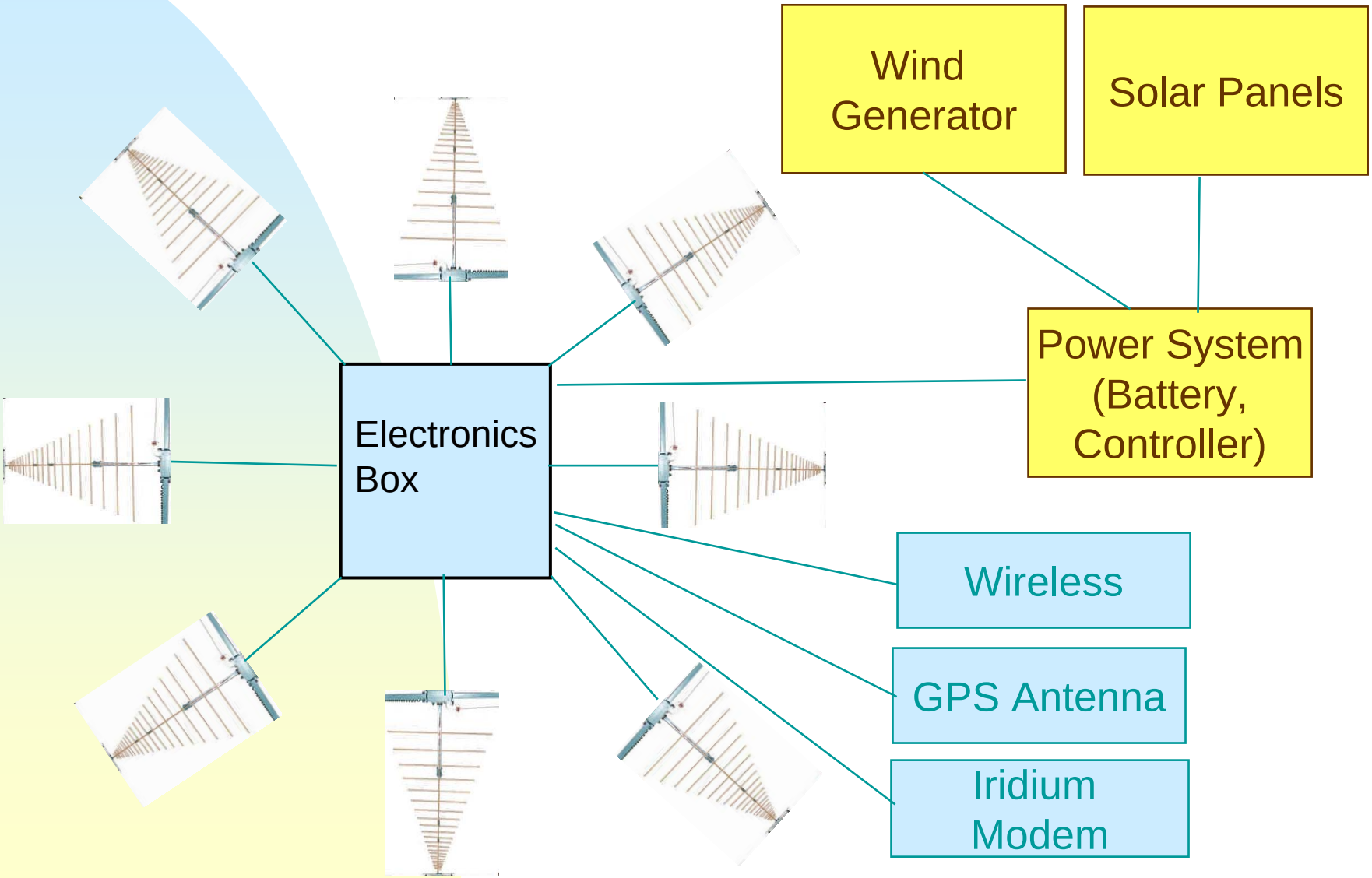




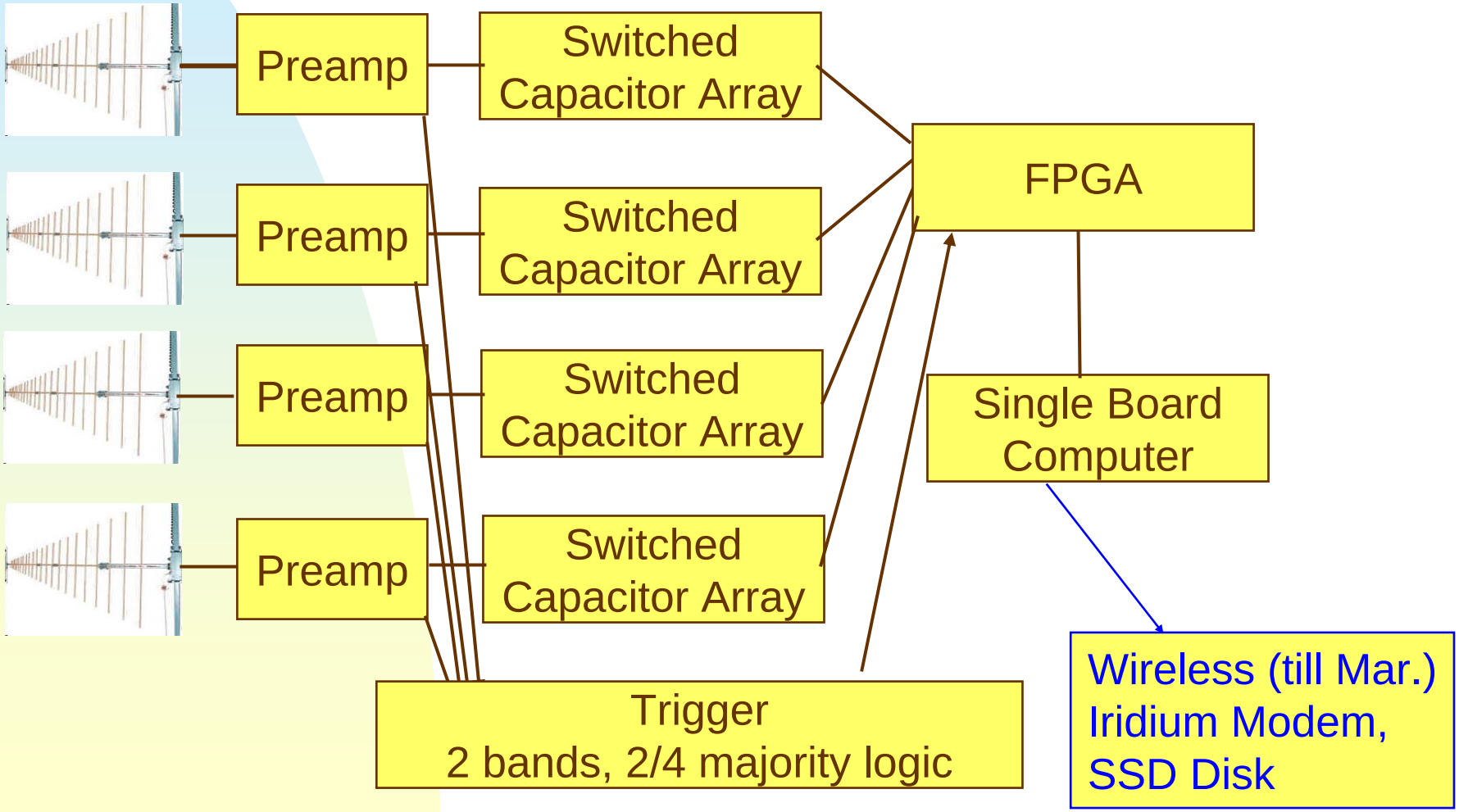
1 km

South Pole Ice

ARIANNA Detector



ARIANNA Electronics (prototype)



ARIANNA Field Season tests

- December, 2010
  - Thorsten Stezelberger (LBNL)
  - Martha Story (Raython PSC, logistics)
  - SK
- Goals:
  - Deploy Test Station in Moore's Bay
    - Leave 1 year (data collection)
      - Hope it survives winds, etc.
  - Site Characteristics
    - Radio backgrounds, noise, absorption length…
  - Logistics
    - Wind power, snow characteristics, internet access…

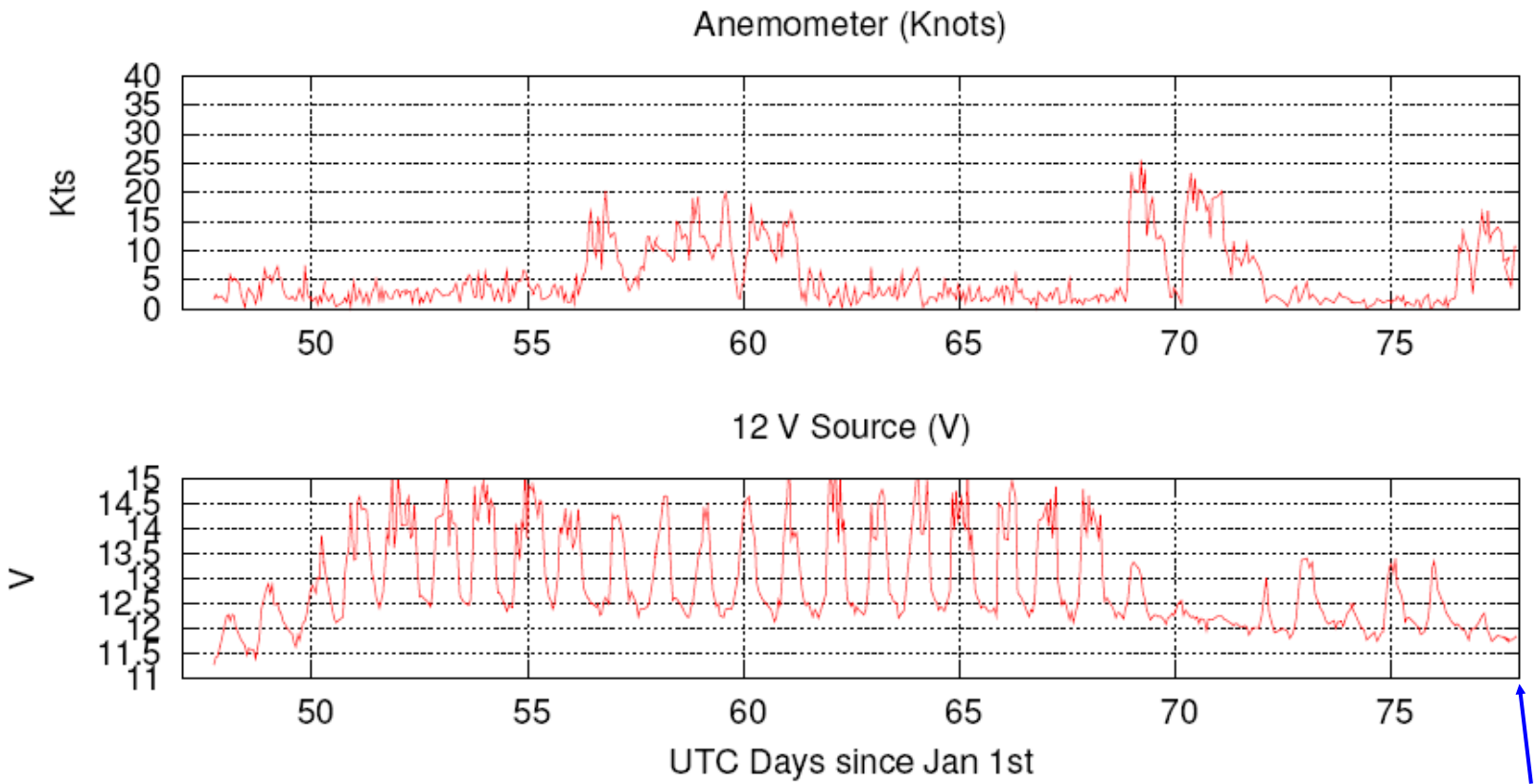
Slide Show

- For more on the trip, see my blog,
  - http://antarcticaneutrinos.blogspot.com/

Station Status

- Last message received April 3rd
  - When there was ~ 11 hours of sun/day
  - During stormy conditions – very overcast
- Previously – phoning home every 3 hours, with houskeeping data

Monitoring

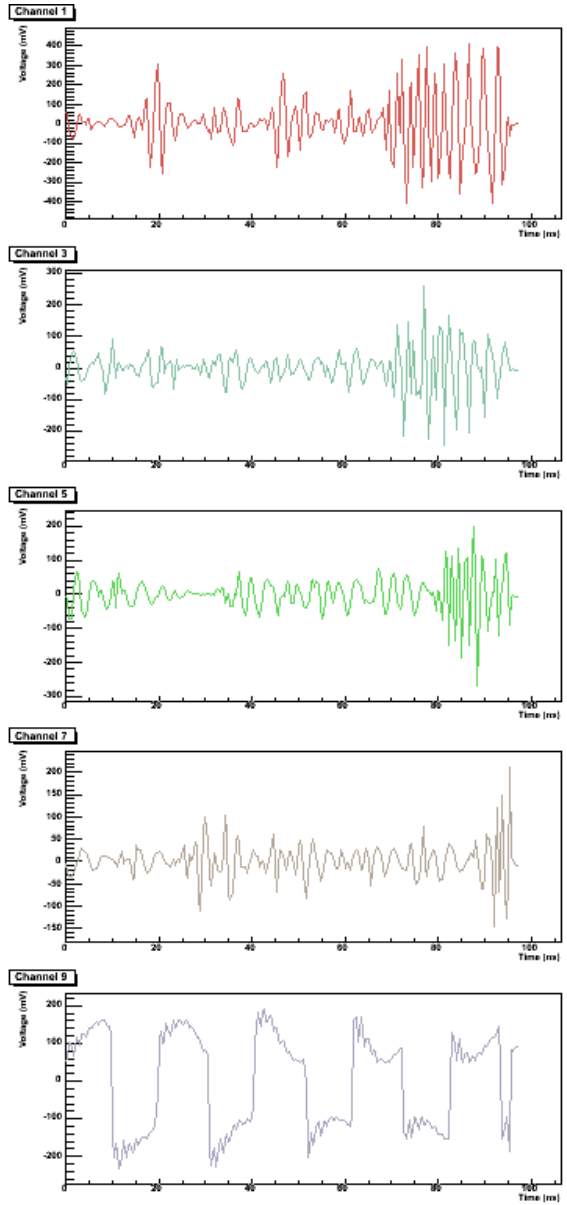


March 18th

Day-night variation visible in solar power output
Less wind than desired

Data Collection

- Trigger on >2 out of 4 stations above threshold
  - Read out all 4 antenna channels
- During summer, many triggers due to wireless internet
  - Switching power supplies?
- After the internet connection was removed, it appears that we are seeing mostly thermal noise triggers
- Analysis in progress



ARIANNA – the future

- Proposal at NSF for 5-7 station array
  - Good signs
  - Funding for larger prototype array also sought
- Redesigned, optimized electronics
  - Probably 8 channels/station
  - Much lower power
  - Better monitoring, triggering…
  - Central power???
  - Prototype for Austral summer 2011/12
- Deploy small array Austral summer 2012/13
- Eventually, want 10,000 stations

Conclusions

- A 100 km^3 neutrino detector should observe ~ 100 GZK neutrinos in 3-5 years of operation
  - Study UHE accelerators at cosmic distances
  - Point sources, neutrino-nucleon cross-section….
- The Ross ice shelf is an attractive location, offering sensitivity to the entire sky without the need for drilling
- We deployed a test station in Moore's Bay in December 2009. It is working well.
- We are proceeding with plans for a small array, which will be deployed in 2-3 years.