Optimizing for an Interferometric Trigger

A. Vieregg

From work with K. Bechtol, A. Romero-Wolf

Also from a two deployments to Greenland with: C. Miki, J. Kovac, D. Saltzberg, C. Deaconu, R. Nichol, S. Wissel

How Do You Push Down to 1 PeV with Radio?

1) Be as close as you can be to events (so signals appear strong at the detector)

→ Directly embed antennas in ice

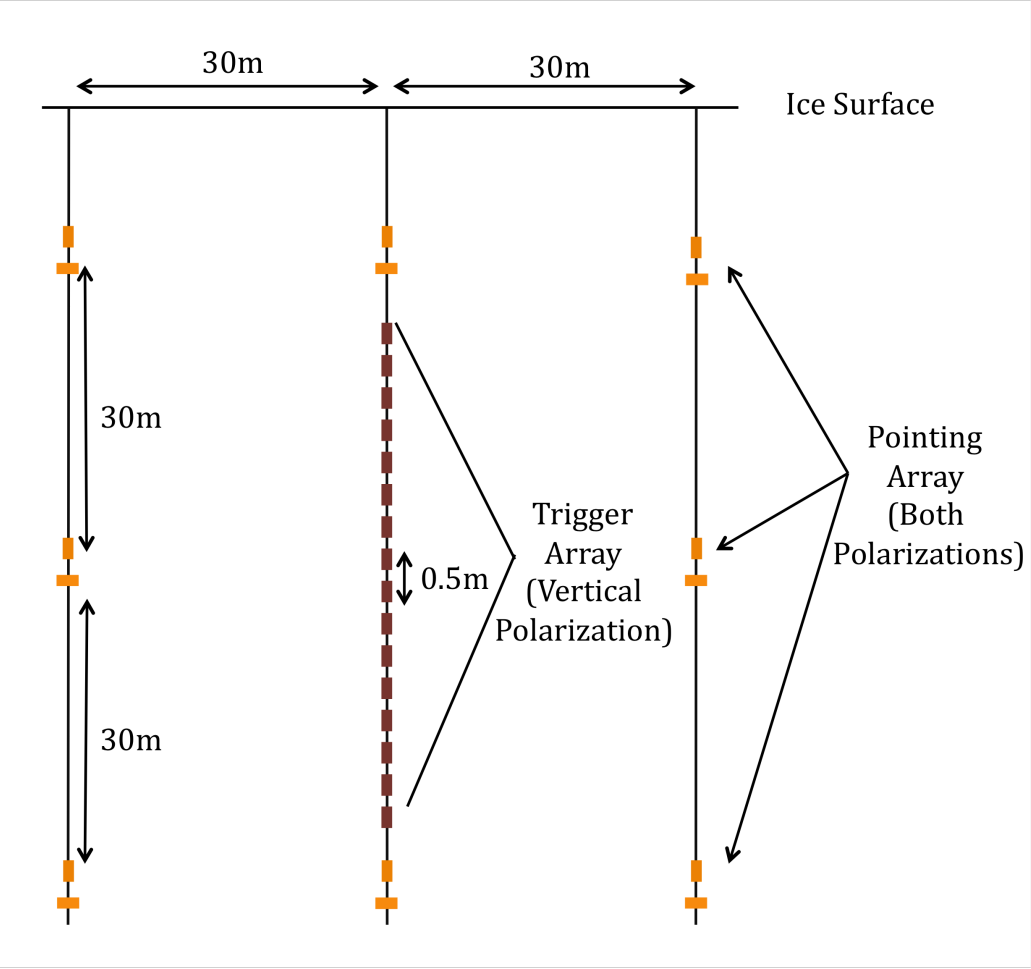
2) Need radio-clear ice to see far away (~1 km attenuation length)

3) Need to achieve the highest signal to noise in the detector as possible to see small signals

→ Need extremely high effective gain antenna

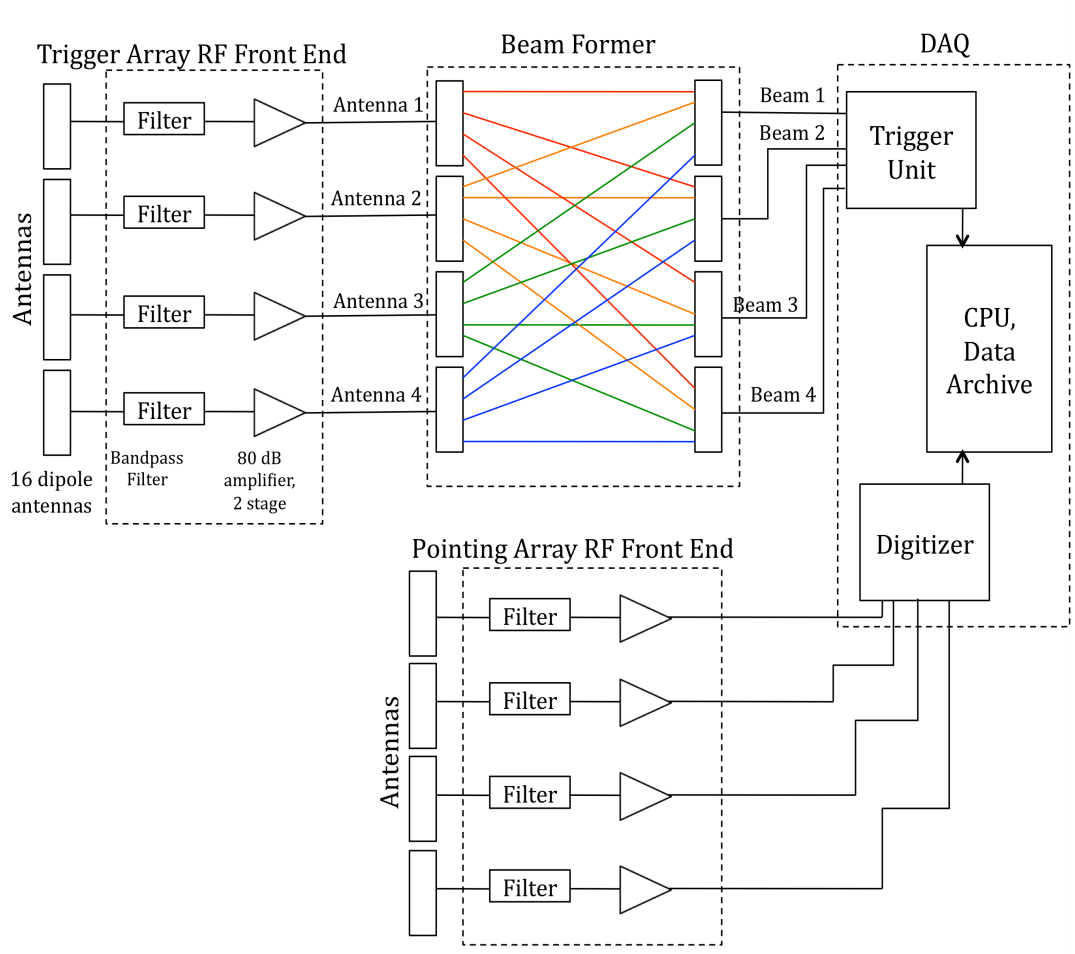
- Problem: high gain broadband antennas don't fit down holes, and extremely high gain antennas are hard to make

- Answer: a phased array of low-gain antennas



A Phased Array for PeV and UHE Neutrinos

- Beamforming: for a given incident direction, calculate the system delay required between antennas to see the signal in-phase in all the antennas
- The signal is correlated between antennas and noise is uncorrelated: increase the SNR as sqrt(N)
- Create many beams at once to cover the solid angle of interest
- Analog or digital



Example: 16 Antenna Station

Back of the envelope calculation:

→ For 16 dipoles (2.15 dBi each), the effective gain per beam is 14.2 dBi.

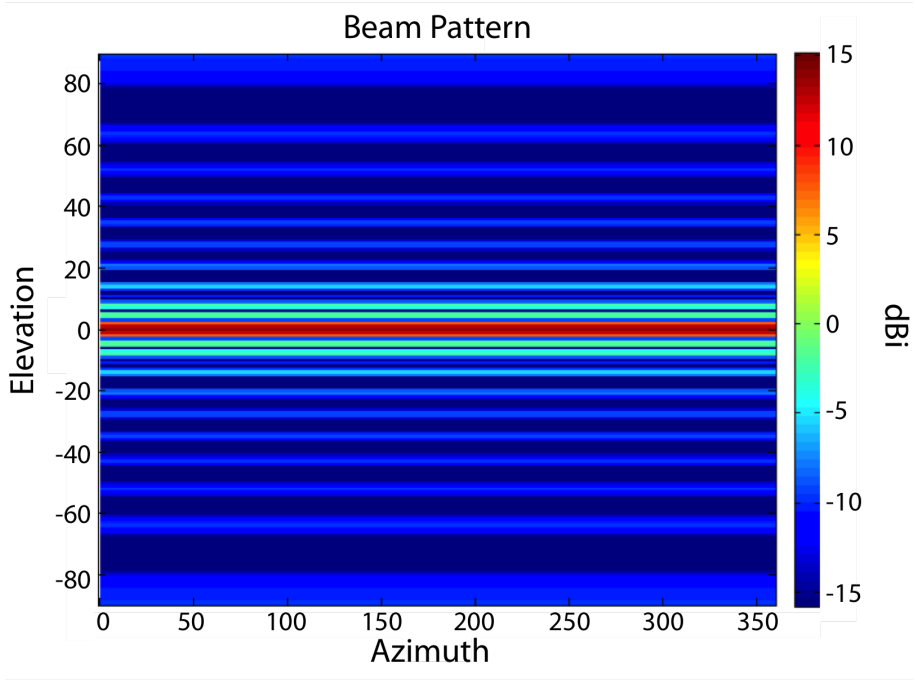
→ A factor of ~ 4 in electric field threshold

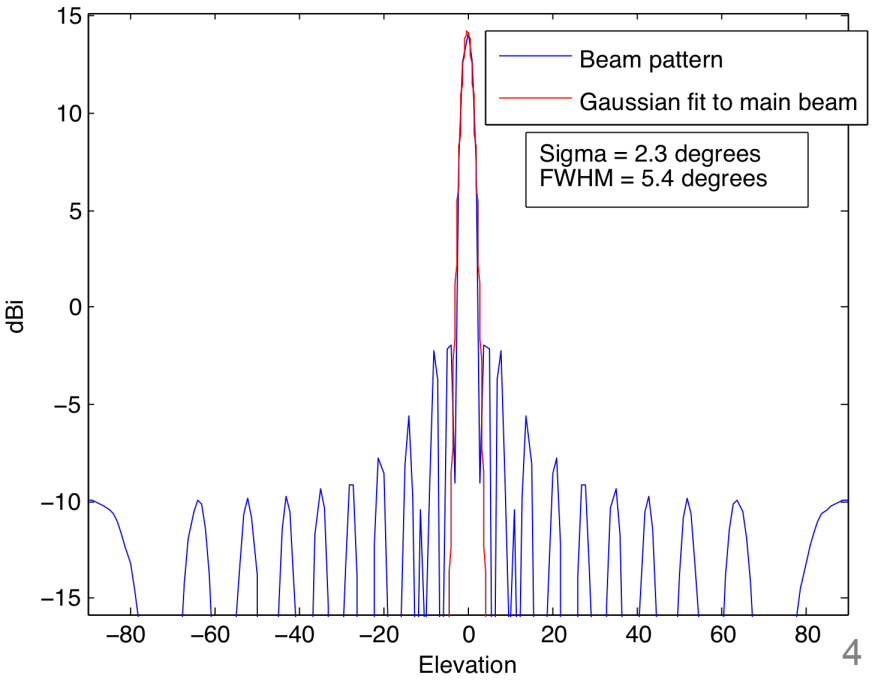
→ A falling neutrino spectrum means that is a large factor in neutrino event rate.

→ With more antennas, you push the threshold down farther.

- 16 antennas in one hole and closely packed @ 200 MHz
- Only need ~10 beams to cover the solid angle of interest (horizon down to -50°)

→ deployed 8-antenna phased array prototype in June 2015 to Greenland





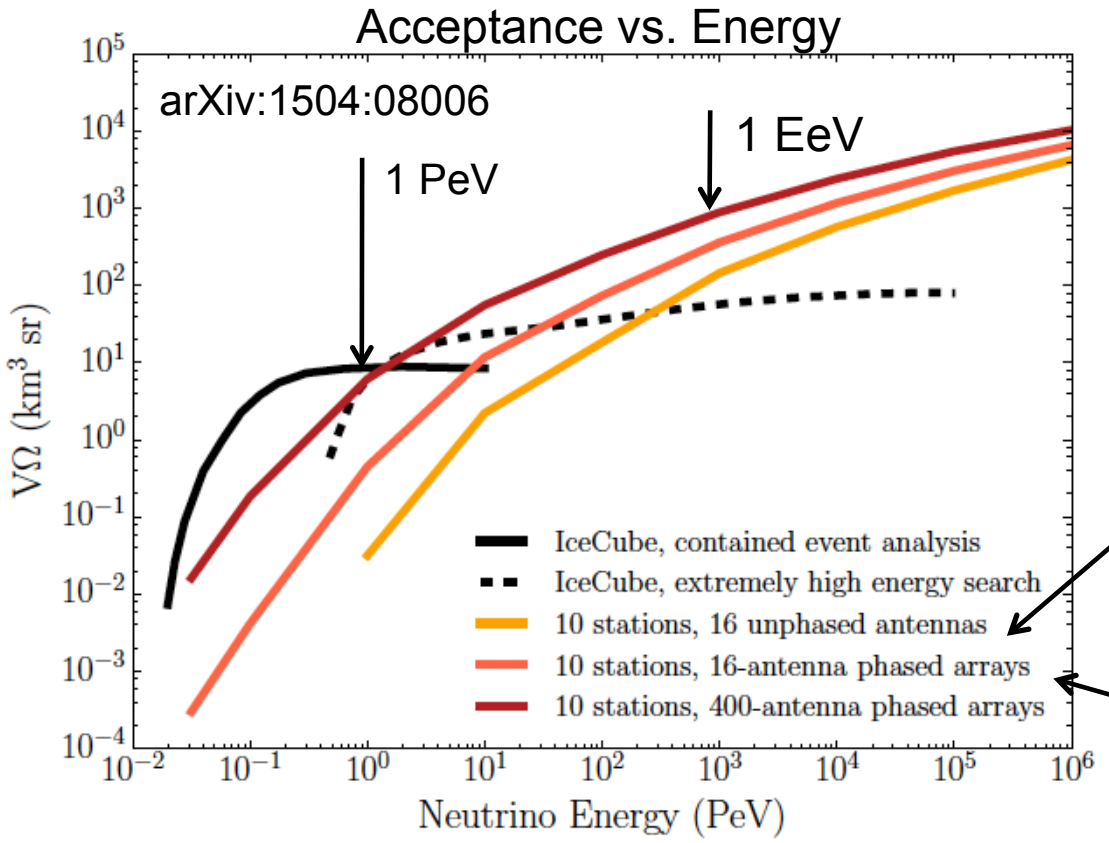
Benefits of a Closely Packed Trigger Array

- Closely packed means bigger beams (i.e. the number of bins in your interferometric map is smaller)
- That means the “trials factor” is smaller for noise to fluctuate up to pass the trigger
- Physically small means the vertex distance from which an event appears plane-wavey is much closer (so interferometry, which assumes plane-waveyness, works better)
- Note: Of course pointing resolution sucks (on purpose). Co-located “pointing array”?

Another Benefit of a Beamformed Trigger

- Rejection of man-made noise. Just don't look where it comes from! (a la ANITA's phi masking)

Acceptance Comparison for 10 Stations @ Summit

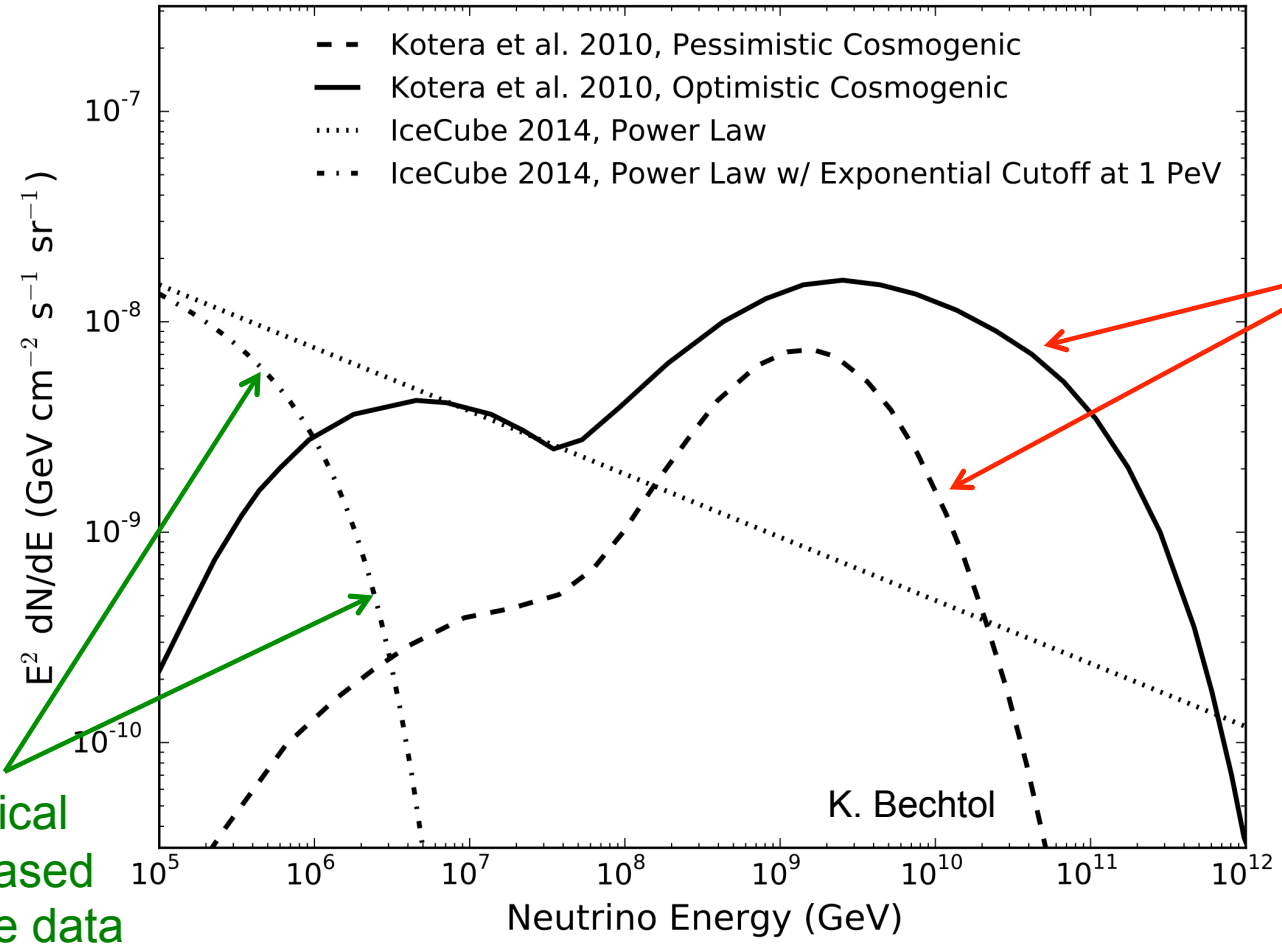


Current approach of ARA, ARIANNA (triggering on each antenna separately)

The phased array outlined earlier (triggering on the coherent sum of antennas)

- Stations act independently and are far apart
- Increase is x10 at low energies and x3 at high energies simply from phasing (yellow → orange)
- Phasing 400 antennas provides good energy overlap with IceCube above 1PeV

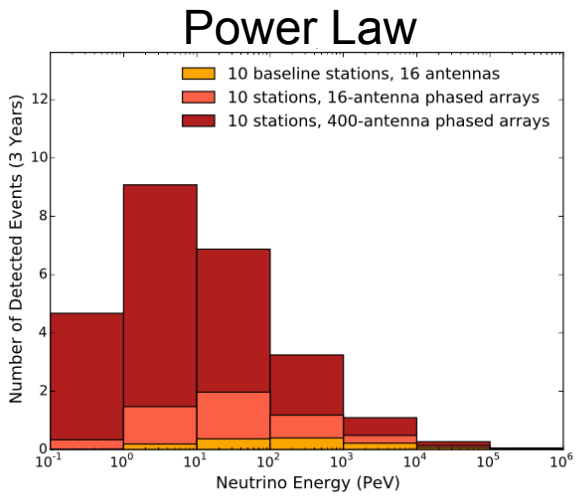
Try Testing Different Models in the Simulation

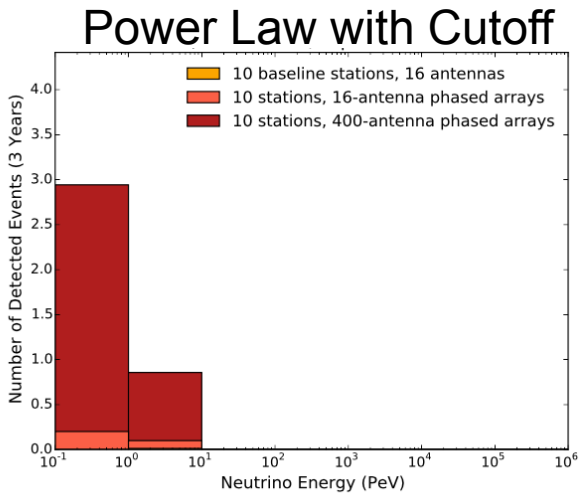


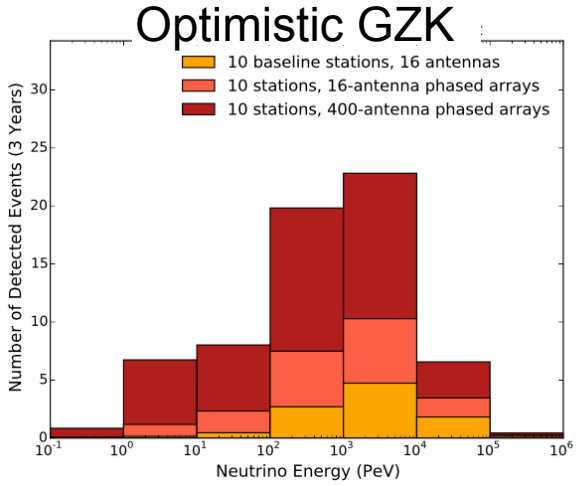
GZK Models (optimistic and pessimistic)

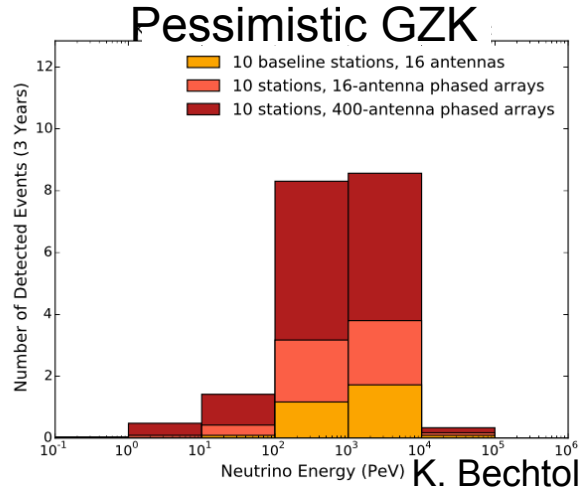
Astrophysical Models, based on Icecube data

Projected Event Rates: 3 years, 10 stations @ Summit









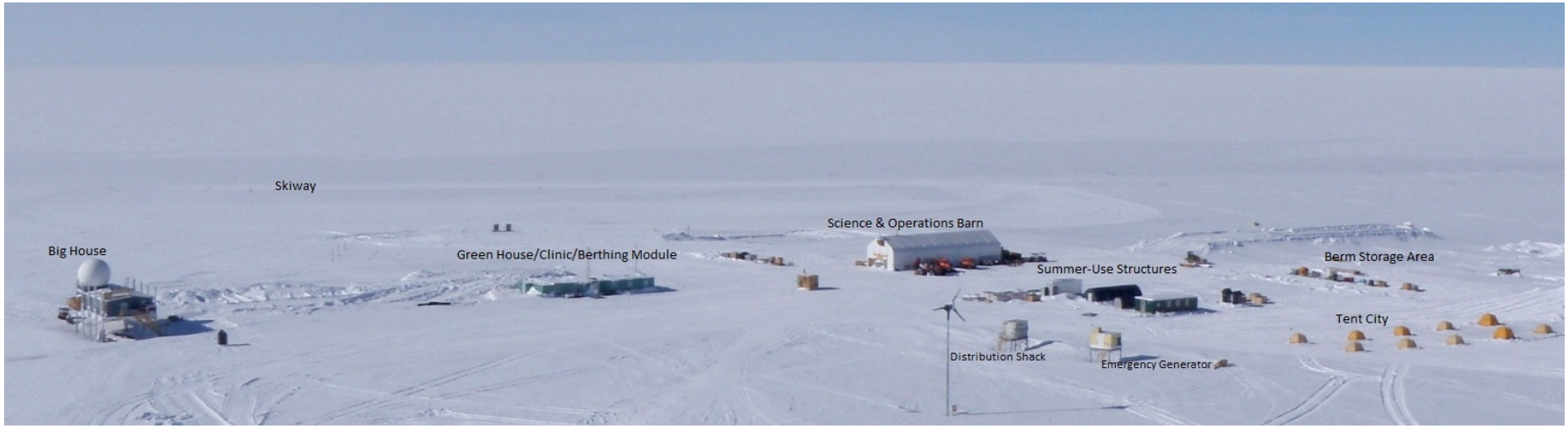
K. Bechtol

Just by phasing 16 antennas per station, can distinguish between spectrum with a cutoff or not

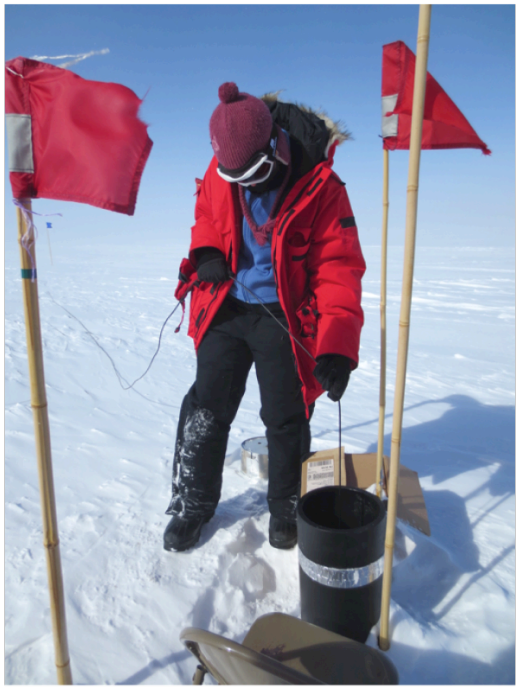
Station Configuration	Power Law	Power Law with Cutoff	Optimistic GZK	Pessimistic GZK
16-antenna, old method	1.3	0.0	10.0	3.1
16-antenna, phased	5.6	0.3	25.1	7.7
400-antenna, phased	25.3	3.8	65.3	19.1

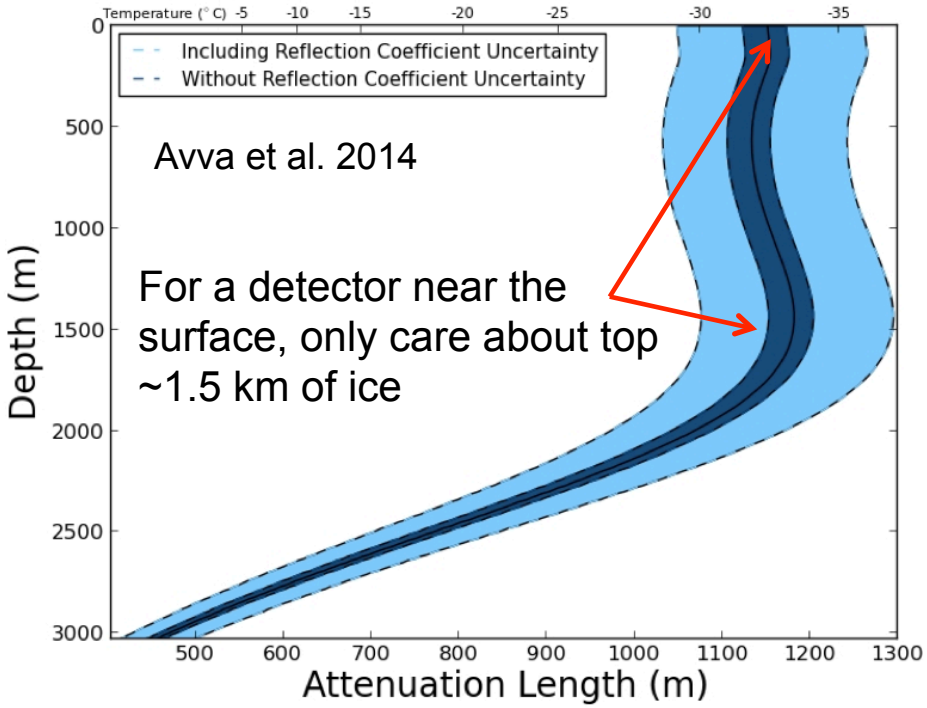
Site Exploration Summit Station Greenland

- Most ice volume of any reasonable site
  - 3 km thick ice at Summit Station, water layer at bottom (reflections add to effective volume)
- Sunlight 10 months/year → solar power
- Relatively quick to get to (direct flight from New York)
- Sees Northern Sky
- Year-round, NSF-Operated
- Access: C-130 flights, annual overland traverse, long summer season
- Plans for a new station called “Isi,” construction begins 2015



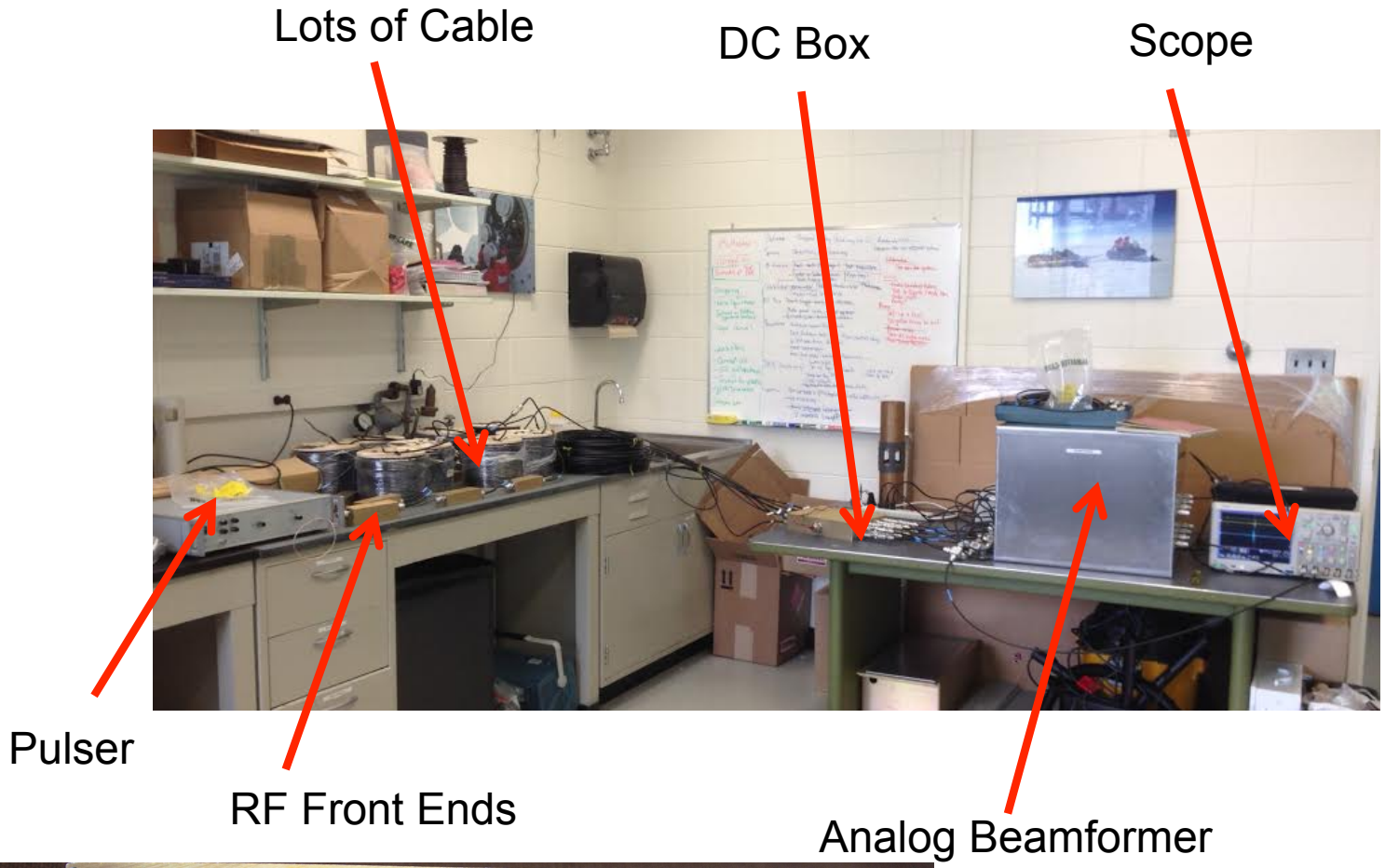
Summit Station Site Characterization June 2013

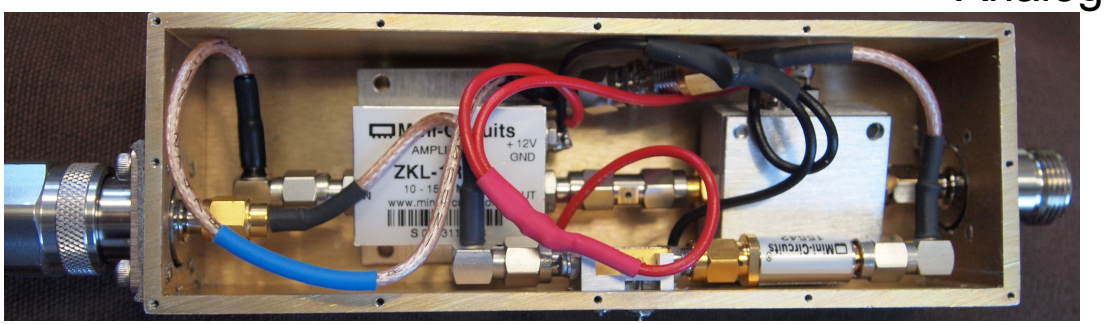




- Measured the attenuation length of the ice at 100-1000 MHz
- Measured firn properties (100m depth vs. 200m at South Pole)
- ~1 km attenuation length at 300 MHz, slightly less than South Pole

Deployment of an 8-Channel Phased Array in June 2015

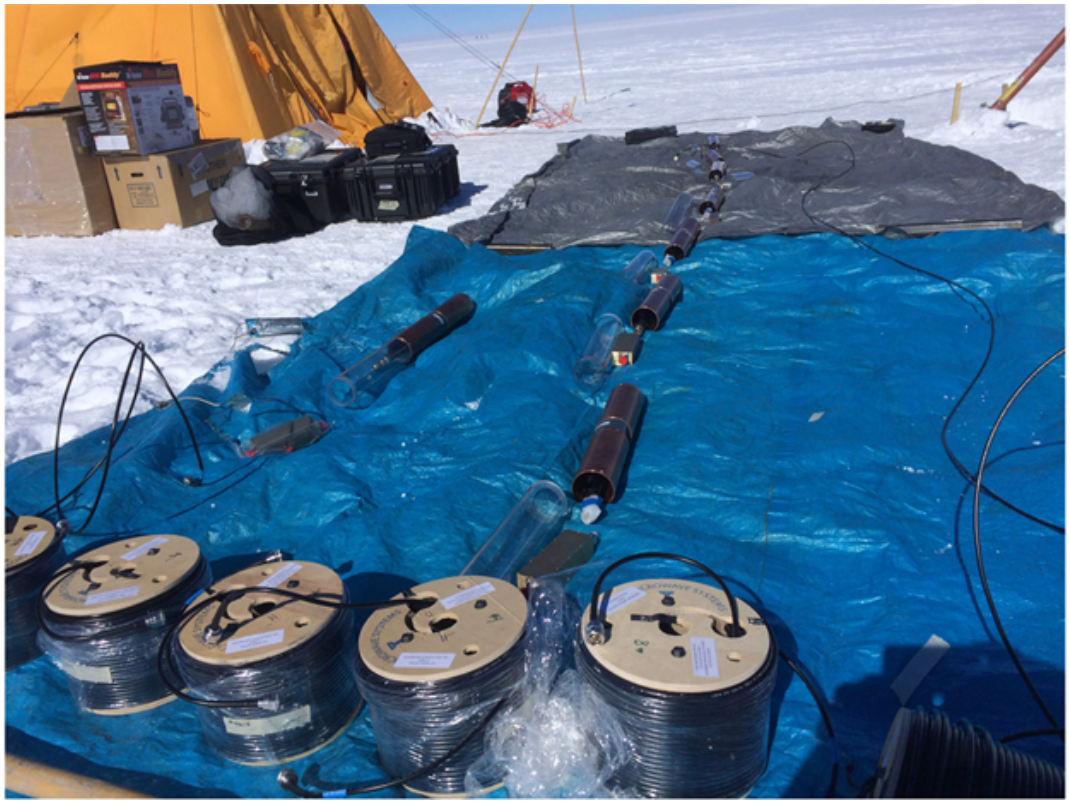




The Test Site at the DISC Borehole

- Took Noise Data (triggering on beams and antennas to compare)
- Took pulser data with pulser on the surface (efficiency scans for beam vs. antenna trigger)

Some More Pictures



Thinking Broadly

- A compact interferometric trigger array for ARA?
- Is many stations with a small number of antennas the way to go, given the new scientific landscape (PeV neutrinos)?
- The trigger scheme, the antenna geometry choice, and the analysis choices are coupled