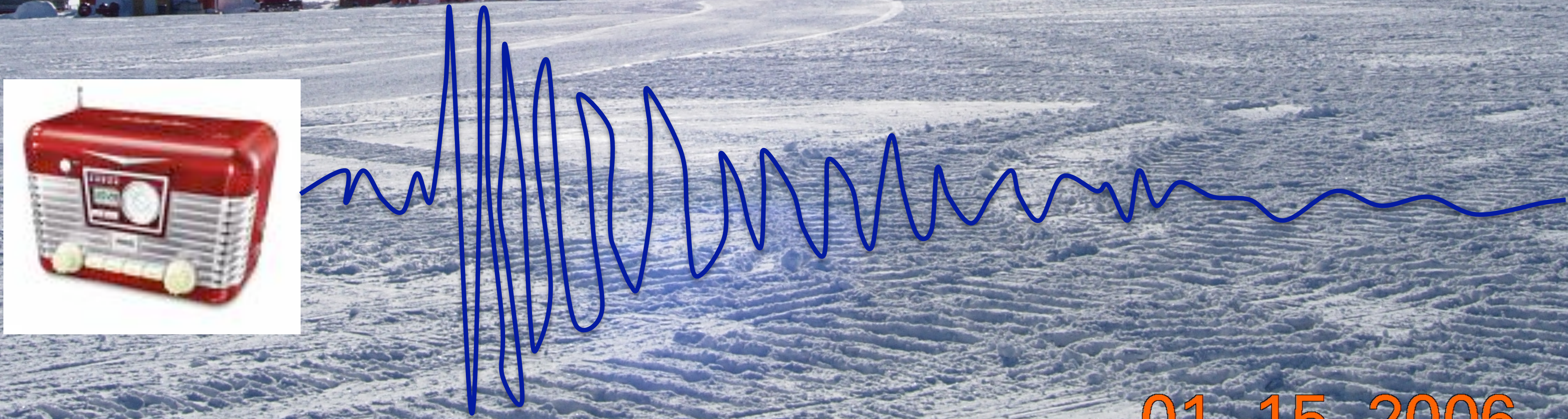
ARA: The Askaryan Radio Array

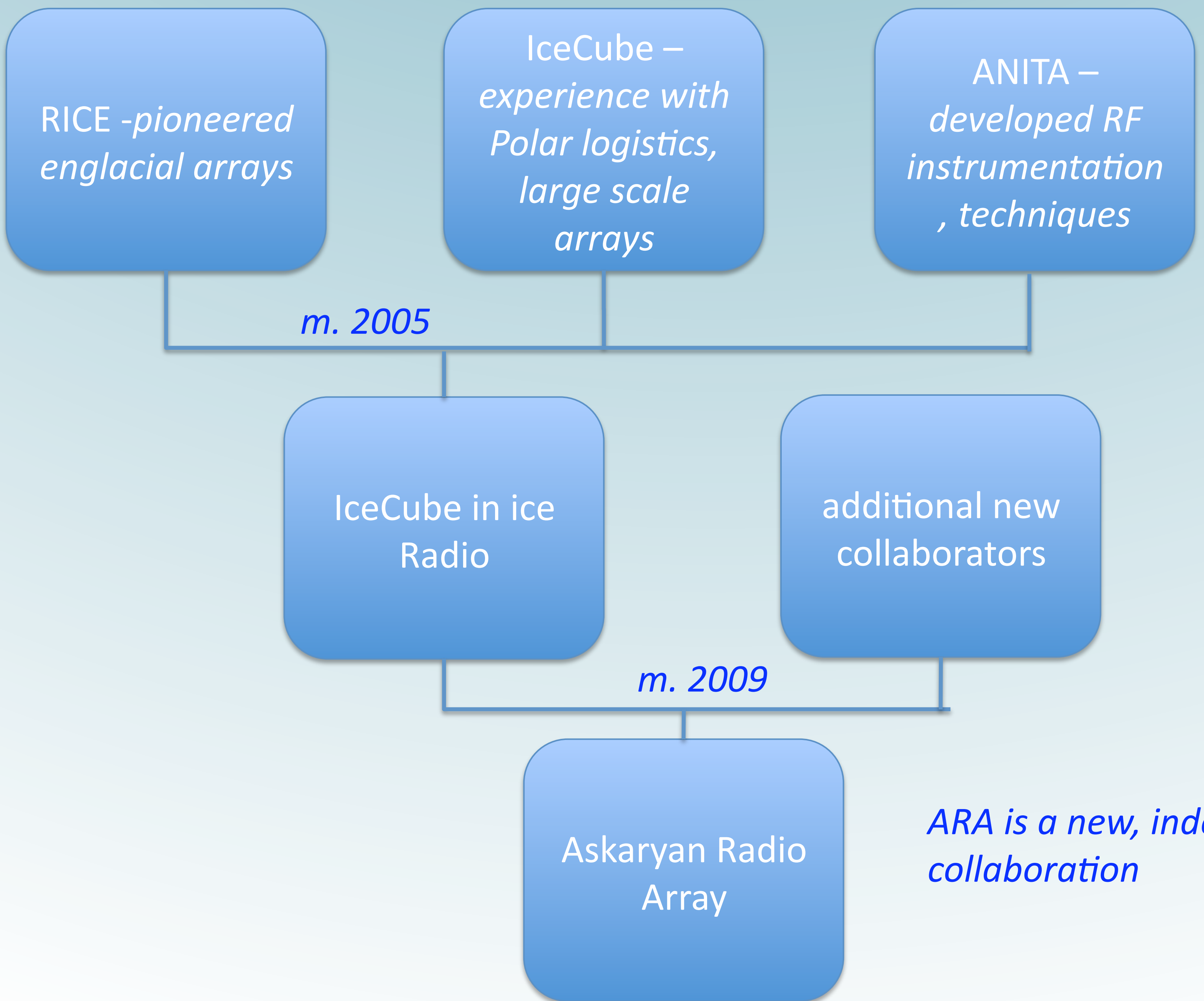
Kara Hoffman
University of Maryland
on behalf of the ARA collaboration

- the ARA concept and history
- ARA status
- plans for 10-11 austral summer



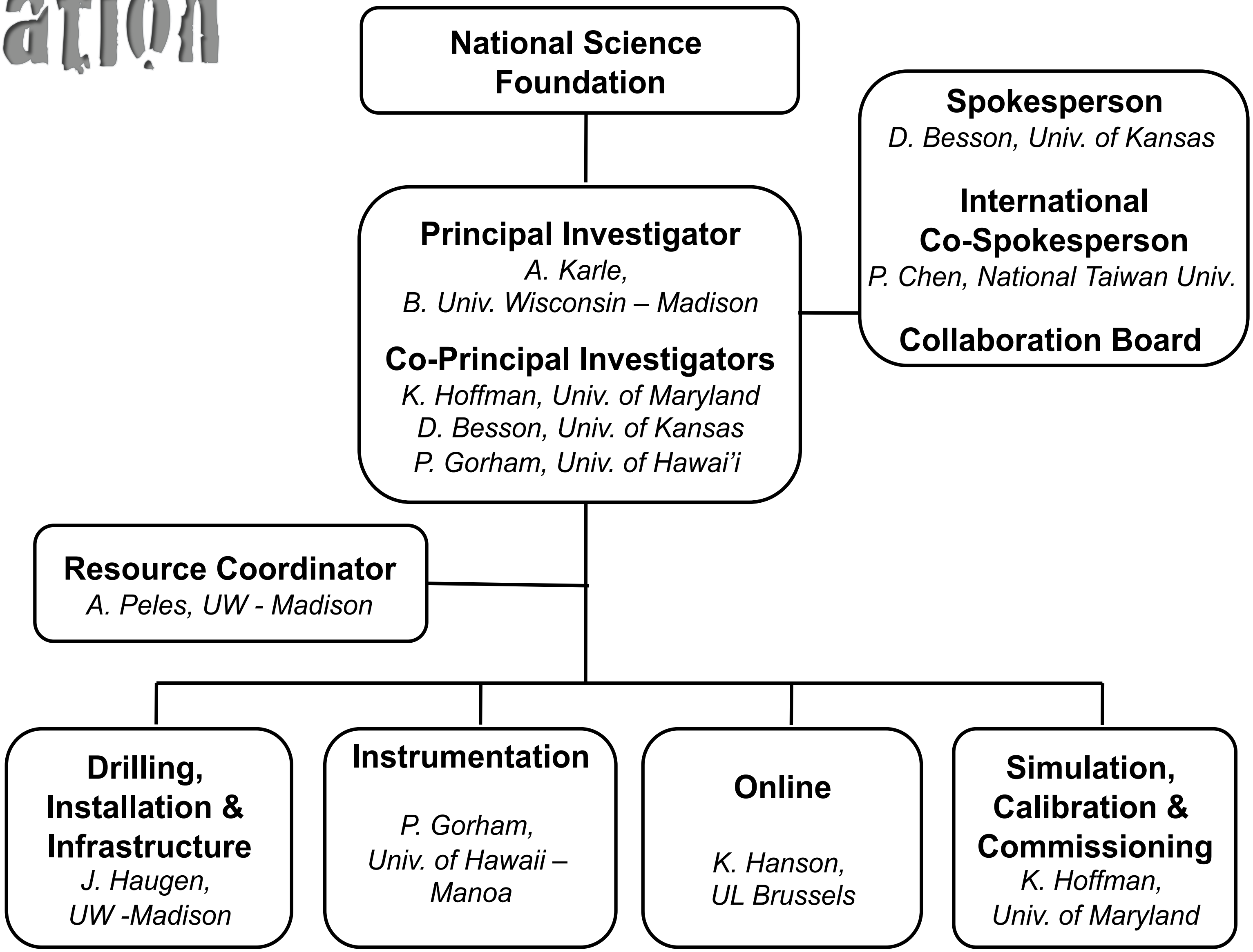
01.15.2006

ARA: a brief history (family tree)



ARA is a new, independent collaboration

Collaboration



Collaborating Institutions: University of Wisconsin*, University of Maryland*, University of Kansas, University of Hawaii, University of Delaware, Ohio State University, University of Alabama, University of Nebraska, National Taiwan University, Universite Libre de Bruxelles, University College London, Chiba University

* sponsoring institutions

ARA: Design and Concept

Goal: to design a cost effective englacial array large enough to observe cosmogenic neutrinos

Impact of ice properties and RF environment

Measurements from bottom reflections of surface broadcast signals. Reflection coefficient introduces uncertainty.

Radioglaciology studies

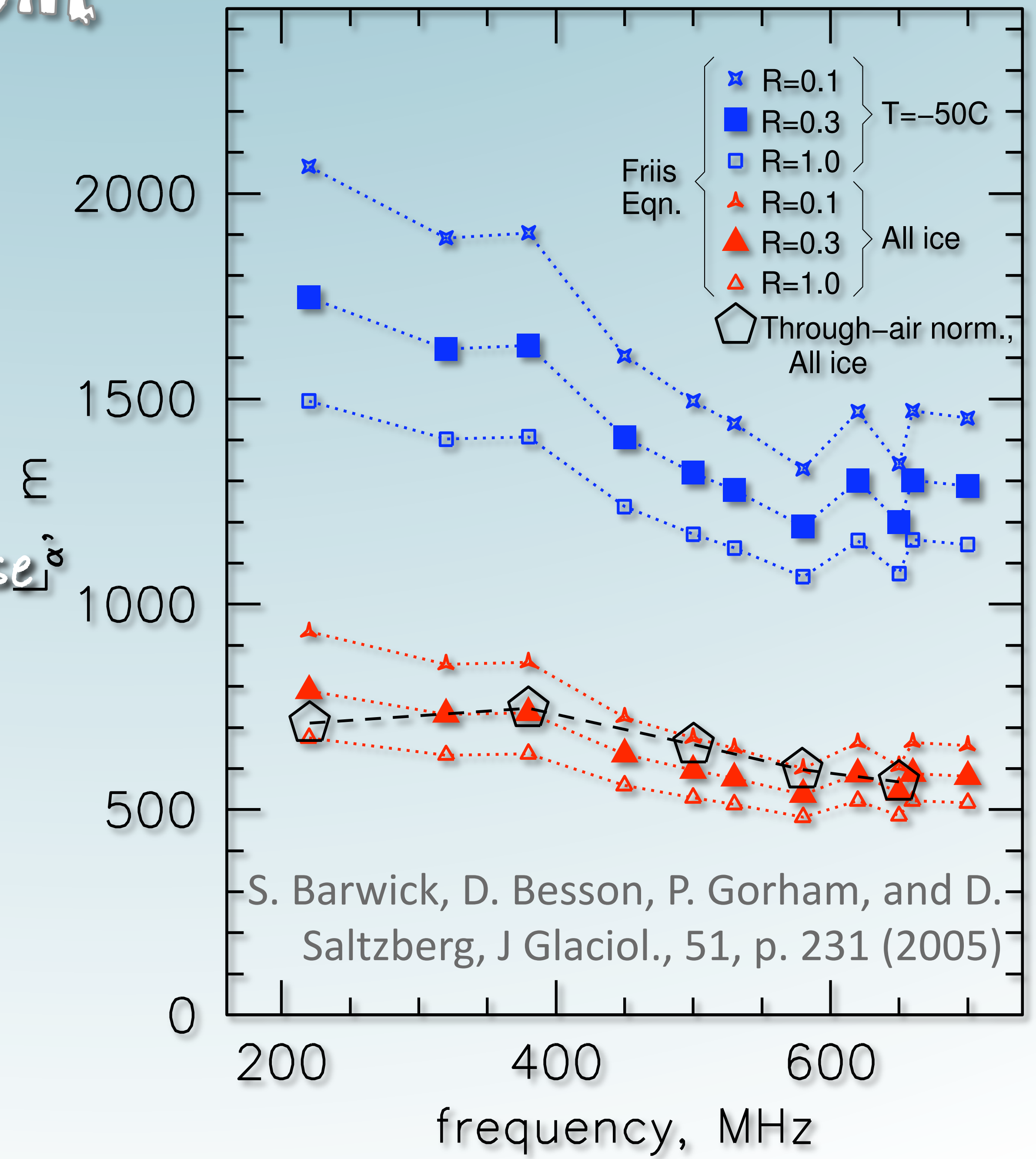
- Index of refraction
- Attenuation length
- birefringence

RF environment

- transient and ambient noise

Ongoing studies at the Pole

- see talks by I. Kravchenko (RICE) and H. Landsman (IceCube Radio)



Future Array Optimization

<u>Some considerations:</u>

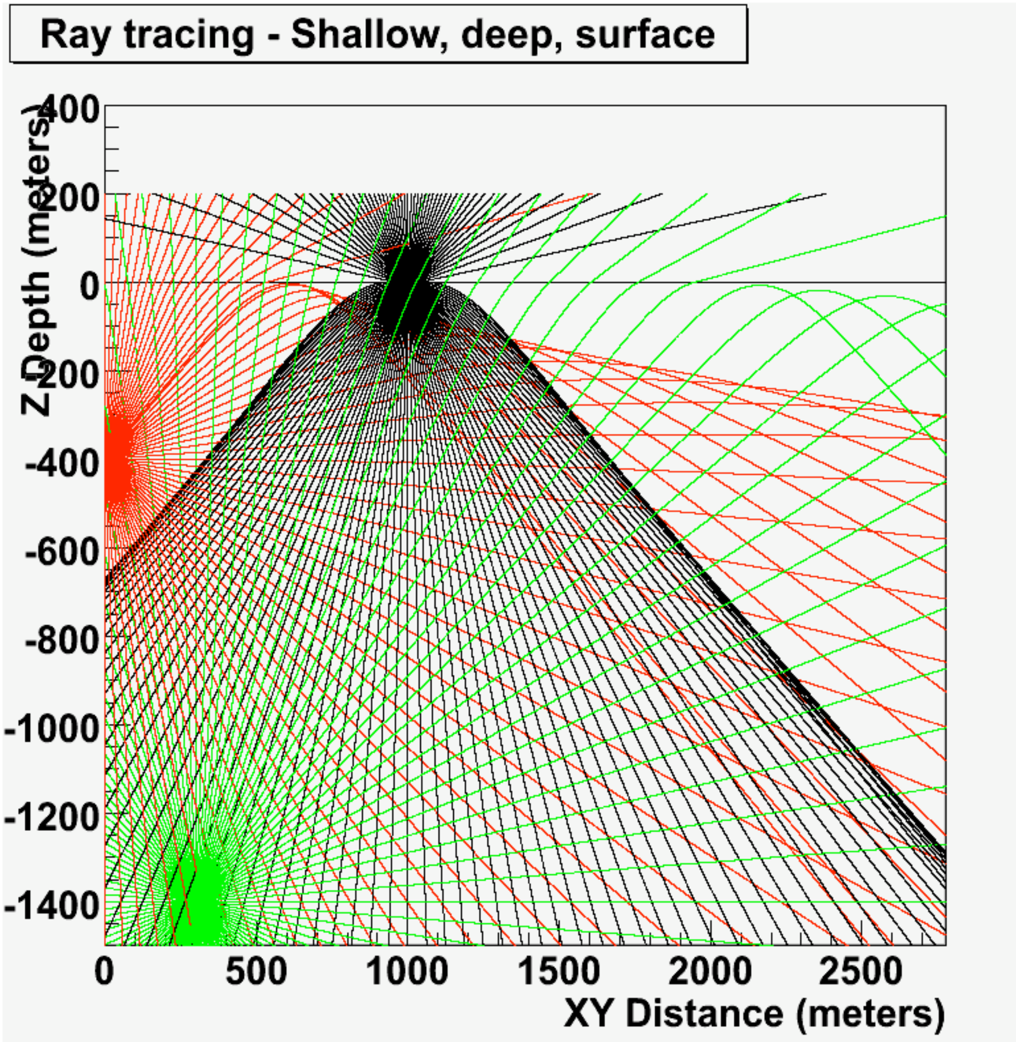
- Frequency range and band width.
- Antenna type

<u>Data type:</u>

- Full digitized WF
- Transient array

<u>Geometry (depth and spacing):</u>

- Spacing of antennas
- Shadowing effect → Deeper is better
- Ice Temperature → Shallower is better
- Drilling cost and time– Deep=expensive
- Hole diameter limits design of antennas
- Wet/dry hole (dry doesn't have to be sealed although holes may close anyway)

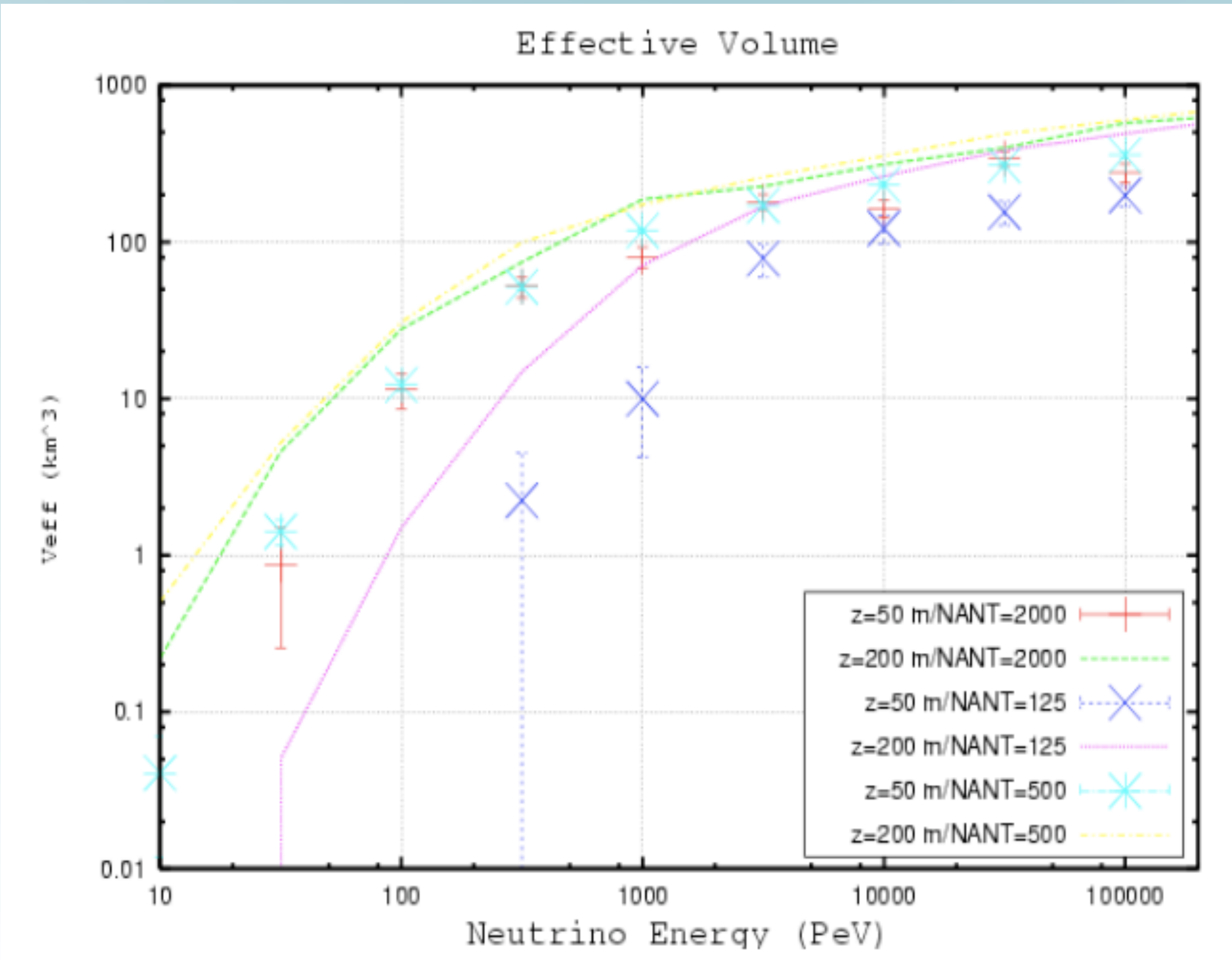


Ray tracing by H. Landsman

Index of refraction varies with depth for first 100-200 meters (known as "firn") due to compactification of snow.

MC studies

results from several independent codes were reconciled: Dave Besson, Amy Connolly, Peter Gorham, Dave Seckel



all agree you need to get below the firn, or you loose a lot of signal.

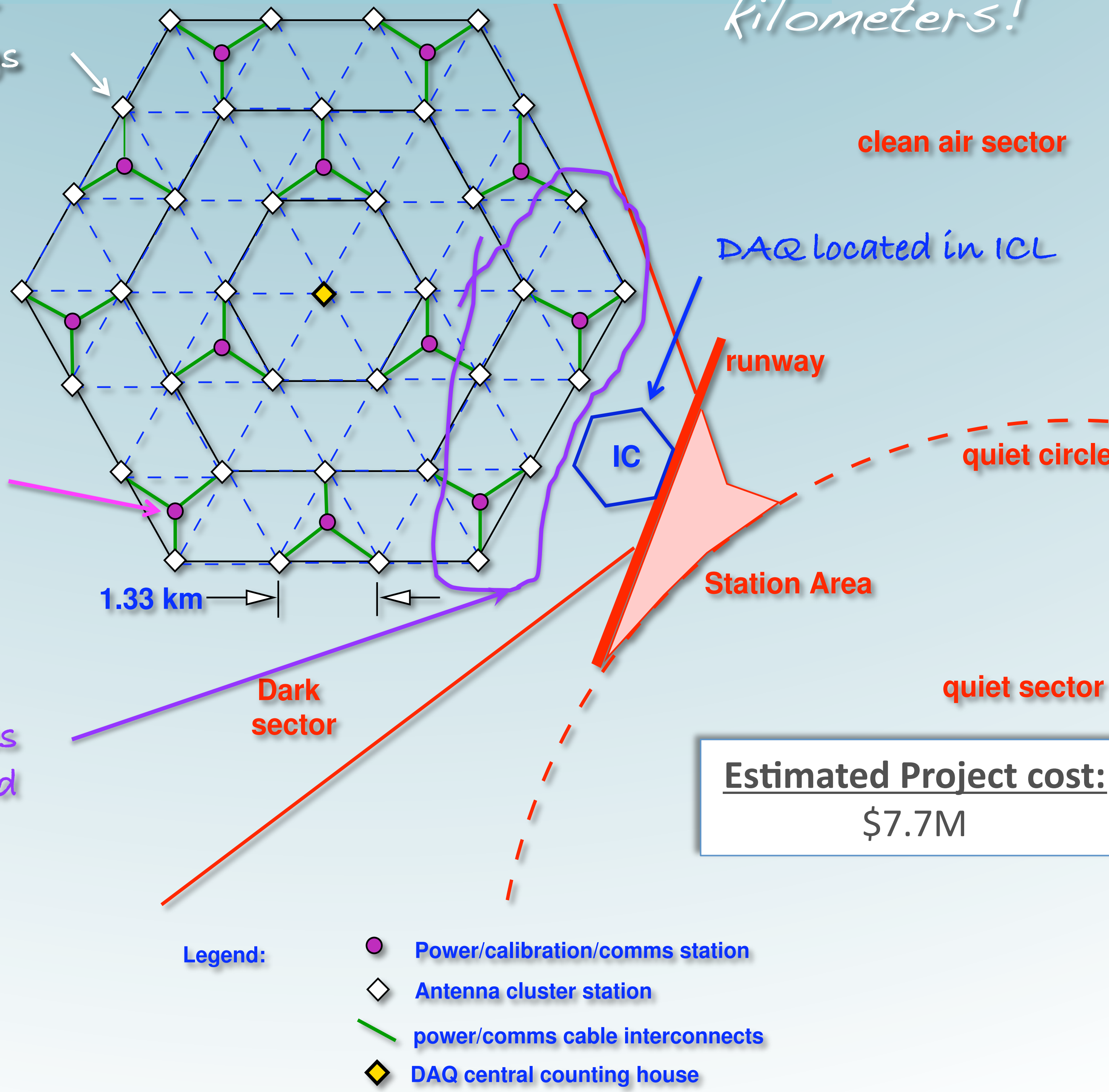
ARA Concept

~80 square kilometers!

each antenna cluster will contain 4 strings of receiver antennas

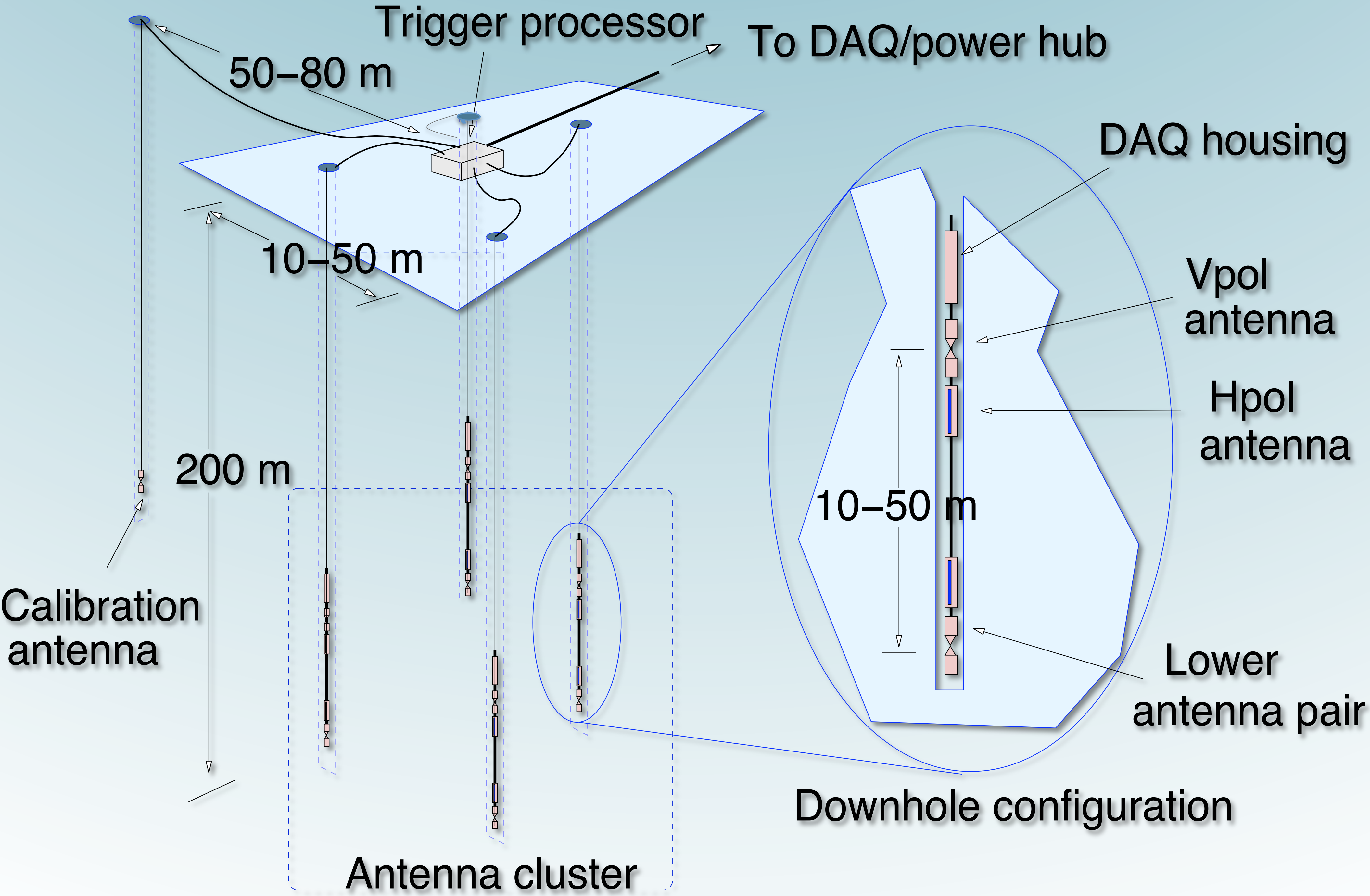
superclusters station consists of windmill, RF comms and in ice calibration pinger

first deployments will have trenched cables for power, comms.



Estimated Project cost:
$7.7M

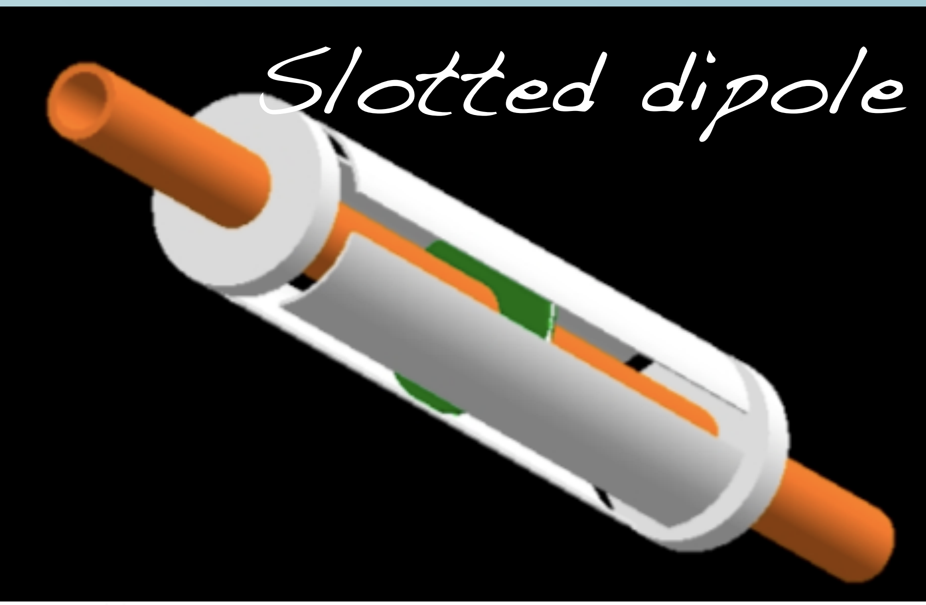
ARA station detail

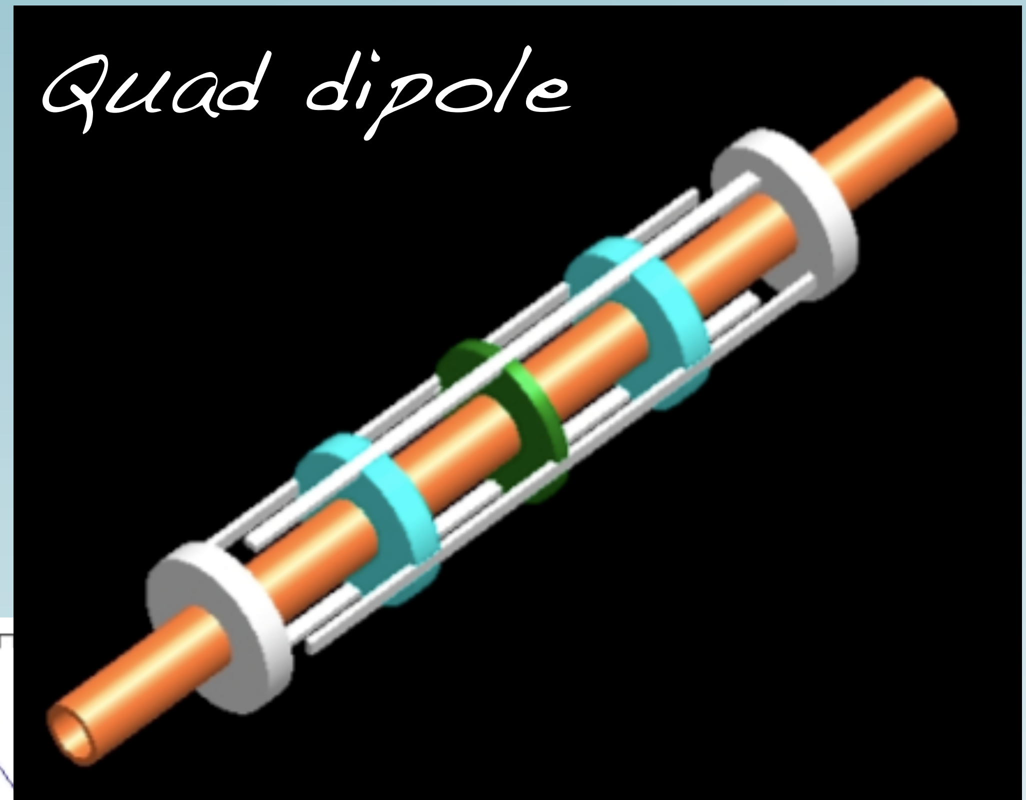


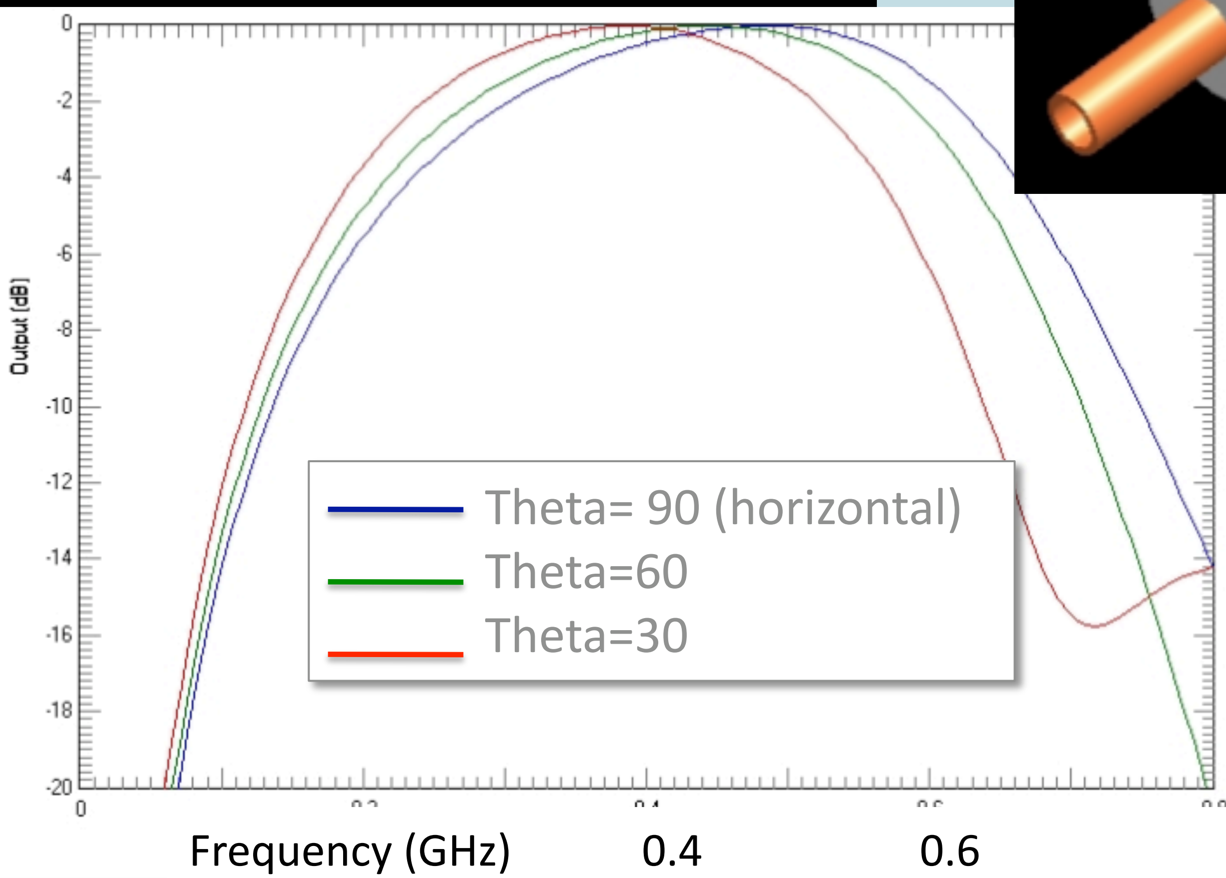
Why clusters?

- Goal is to count events, not reconstruct the angles as would be needed for observatory class instrument.
- A single station can provide a stand alone trigger -> trigger locally.
- Decreases trigger time window, lowering background and therefore thresholds.
- Lowers the energy threshold (lowest energies dominated by single string hits in a widely spaced grid).
- Exact spacing between clusters and within clusters to be determined by monte carlo.

Instrumentation: Antennas





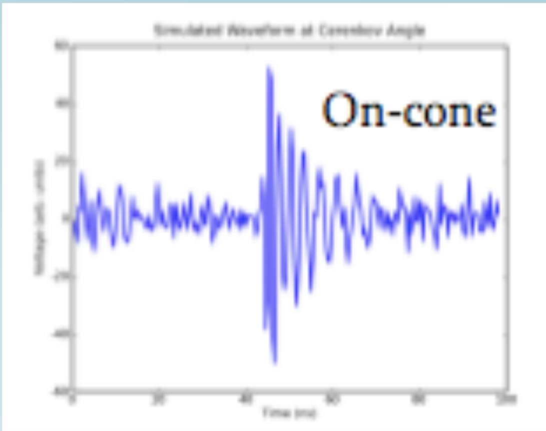


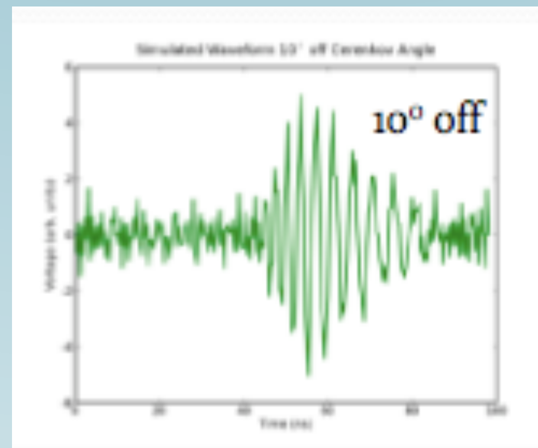
Only narrow holes (10-15 cm) are feasible:

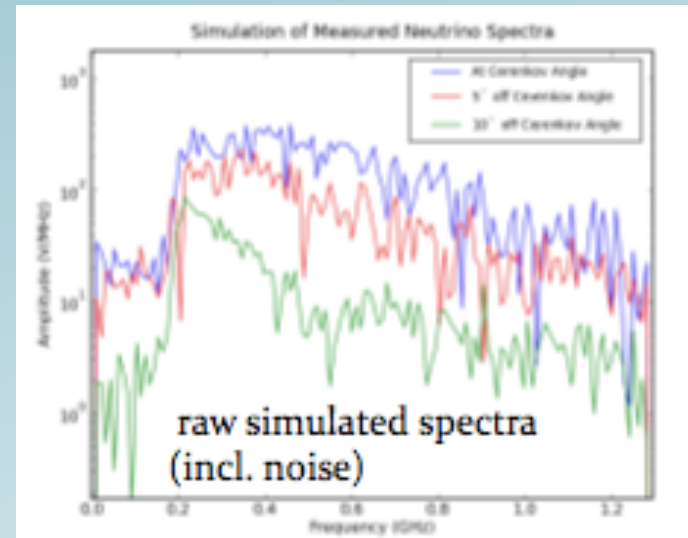
- need narrow antennas
- power and comms must pass through antenna to avoid cable shadowing
- Hpol information provided by slotted antenna
- frequencies 100-900MHz

Instrumentation: Transient vs. full waveform

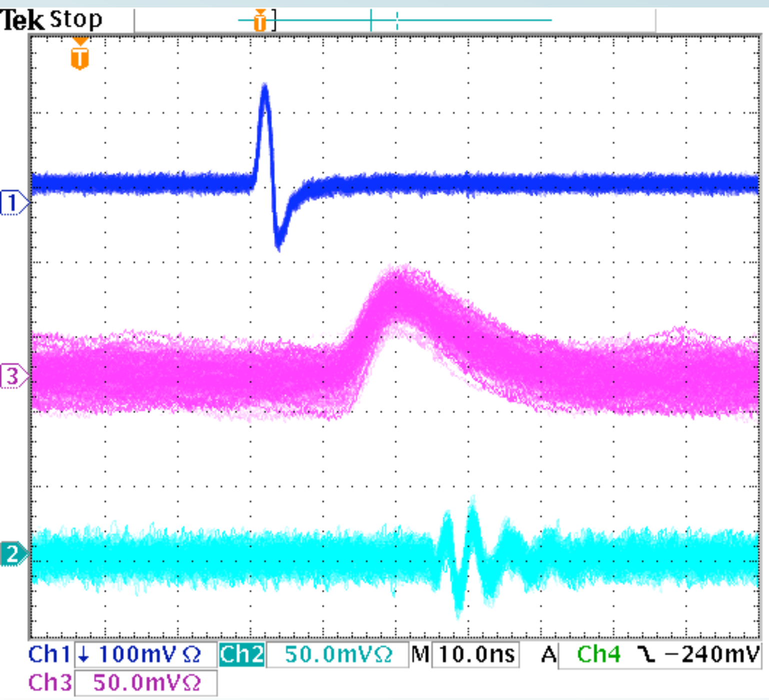
waveform information:







transients: see next talk by Kael Hanson



200uV$_{p\text{-}p}$ Stimulus

TDA Output

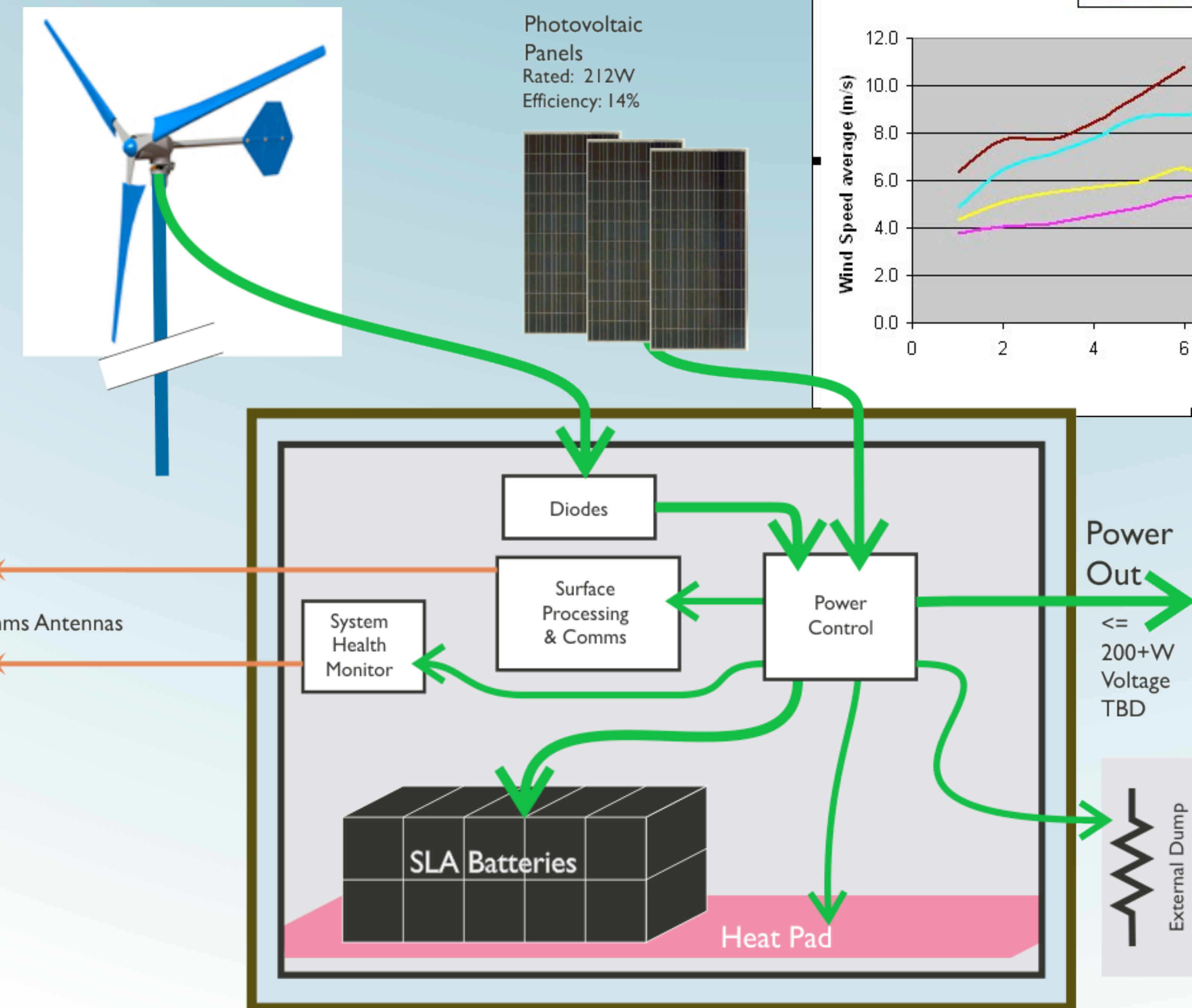
WFD Front End Output

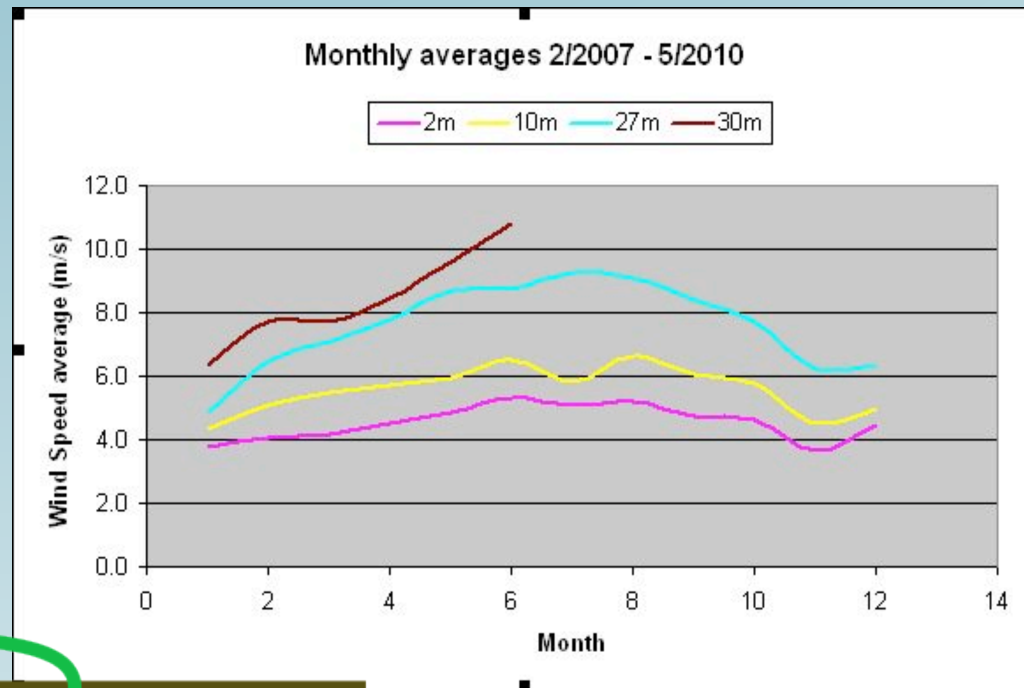
Build new array on "tried and true" waveform detection.

Include transient detectors in the trigger.

Once signal is observed and background well understood, re-evaluate before building 1000 km sq array.

"Supercluster" Instrumentation: Power

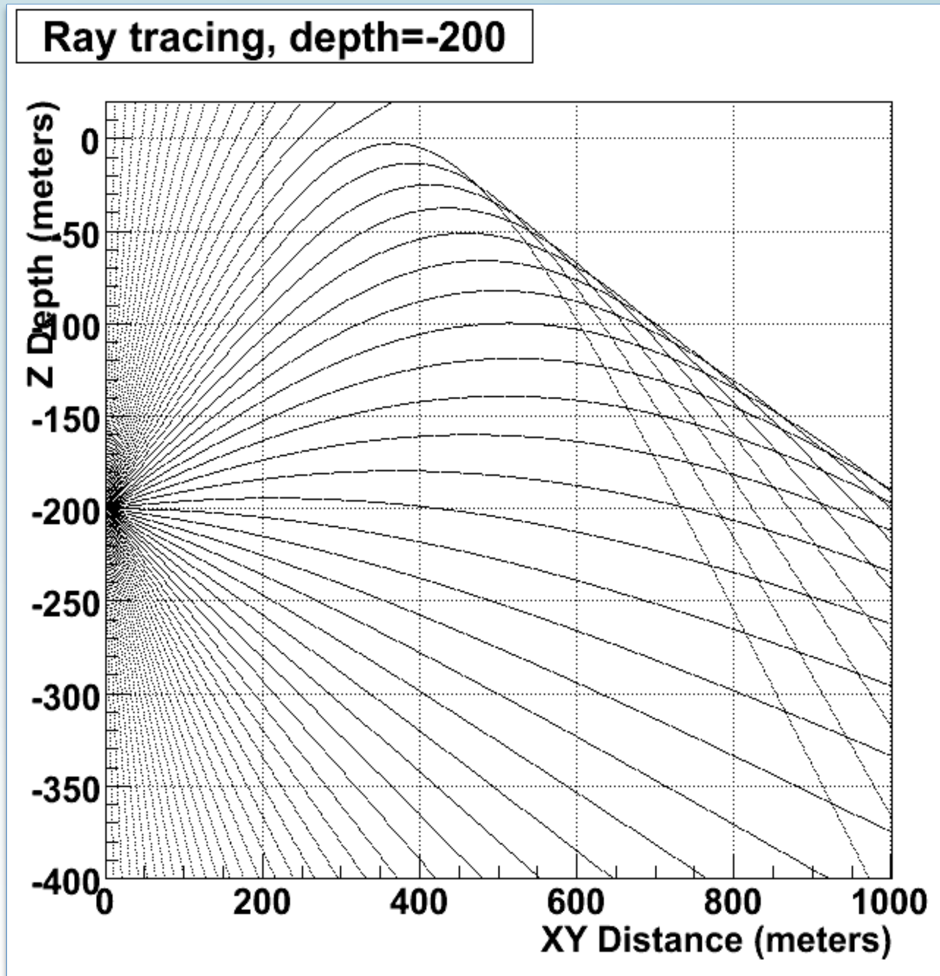




- A large scale array must be autonomously powered.
- Significant increase in wind speed with taller masts.
- Power scales as wind speed cubed.

"Supercluster" Instrumentation: Calibration and comms

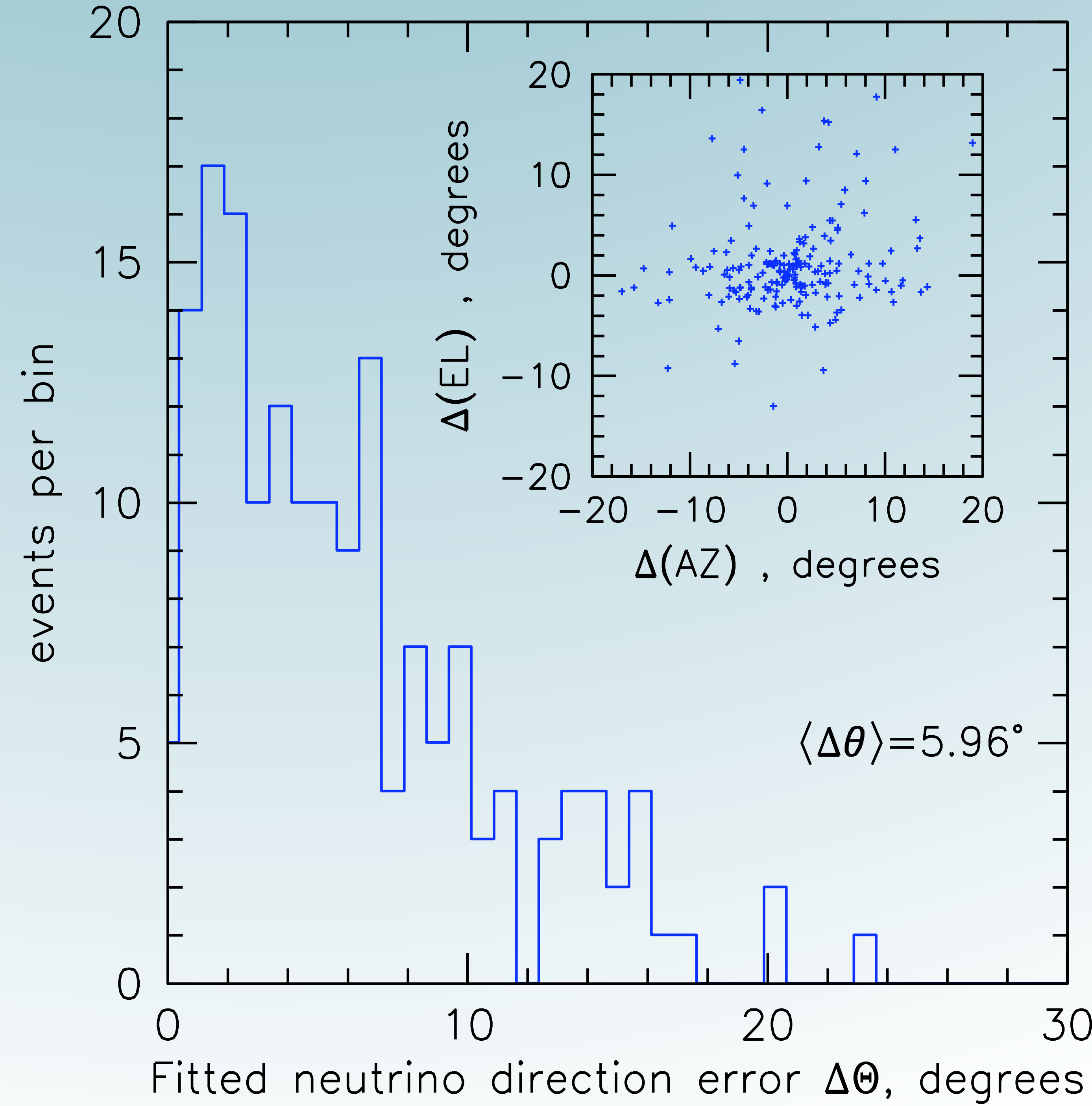
•*Communications to be provided by Zigbee RF- frequency TBD (must play well with other EMI sensitive endeavors at the South Pole).*



•*Supercluster will also contain a calibration antenna deep enough and strong enough to be seen by all antennas on neighboring clusters.*

Performance: Angular Resolution

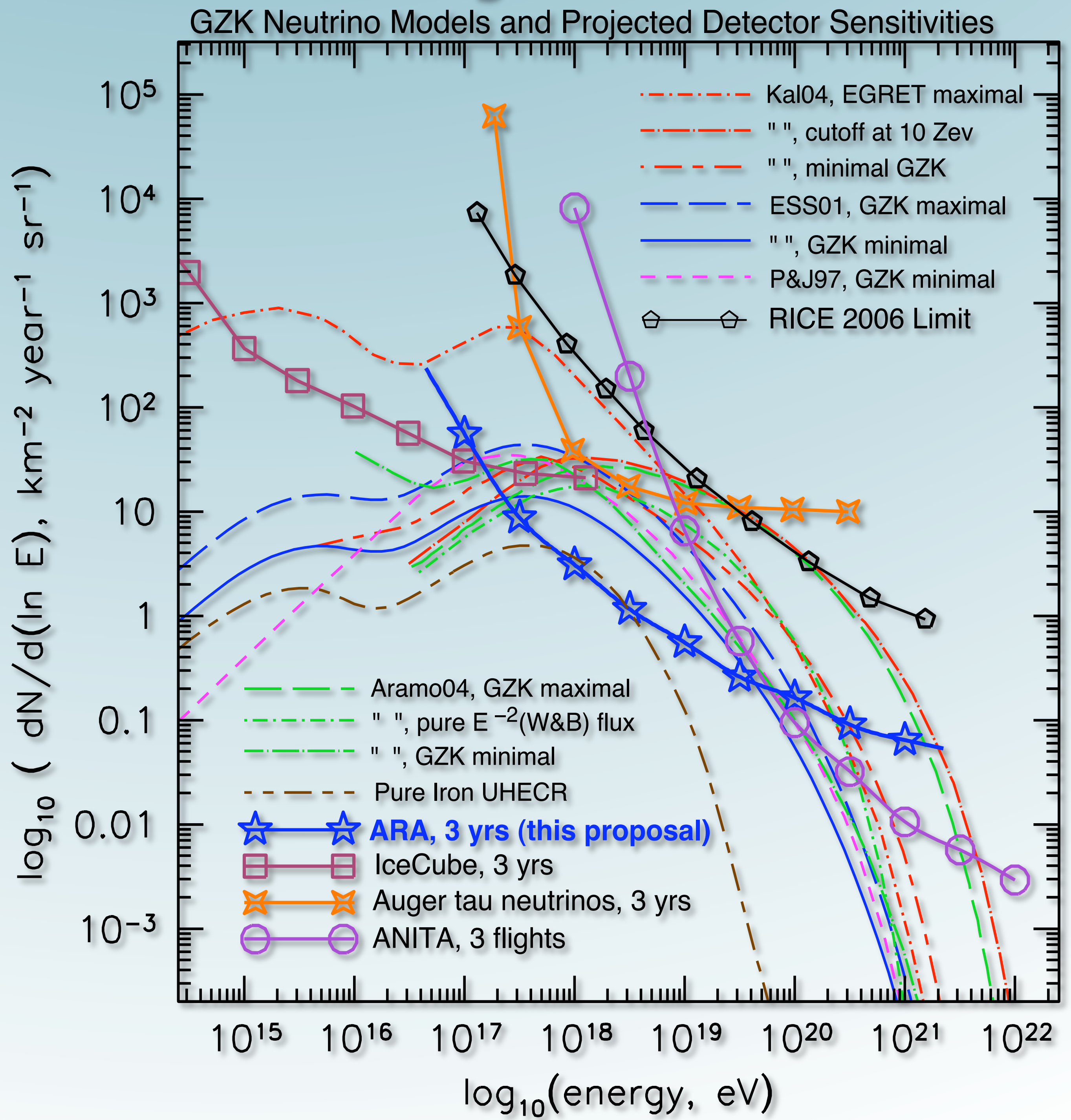
- array optimized for flux measurement, rather than angular resolution
- once flux is determined, a proposal for an "observatory class" instrument would follow



Performance: Sensitivity

ARA will be able to measure the flux of cosmogenic neutrinos even in more pessimistic scenarios.

Once the flux is known, we can design an astrophysical observatory for the GZK energy regime.



Performance: Event rates

…because none of us are in this business to set limits

Model & references N_ν:	ANITA, 1st flt	ARA, yr^{-1}
Baseline BZ models		
Protheroe & Johnson 1996	0.22	7.0
Engel, Seckel, Stanev 2001	0.12	3.5
Barger, Huber, & Marfatia 2006	0.38	4.9
Strong source evolution BZ models		
Engel, Seckel, Stanev 2001	0.39	11.1
Barger, Huber, & Marfatia 2006	0.89	17.6
Yuksel & Kistler 2007	0.56	26.4
Waxman-Bahcall (WB) fluxes:		
WB 1999, evolved sources	0.76	7.4
WB 1999, standard	0.27	2.6
All-Iron UHECR composition:		
Ave et al. 2005	0.00	0.74

References:

R. J. Protheroe and P. A. Johnson, Astropart. Phys. **4, 253 (1996)**

R. Engel, D. Seckel, and T. Stanev, Phys.Rev. **D64, 093010 (2001)**

V. Barger, P. Huber, and D. Marfatia, Phys. Lett. **B642, 333 (2006)**

H. Yuksel and M. D. Kistler, Phys. Rev. **D75, 083004 (2007)**

E. Waxman and J. N. Bahcall, Phys. Rev. **D59, 023002 (1999)**

M. Ave, N. Busca, A. V. Olinto, A. A. Watson, and T. Yamamoto, Astropart. Phys. **23, 19 (2005)**

Phase 1: funded

Phase 1 funding:
$4M USD

2010-2011
•install radio testbed system
•drill tests
•3 wind turbines installed for testing
•calibration activities

This year!

2012-2011
•install one ARA in ice station and one power/communications hub

2012-2013
•install one ARA in ice station and one autonomous power/communications hub

•Additional instrumentation will be built for laboratory study.

Work already begun! First collaboration meeting held in Madison, WI in March.

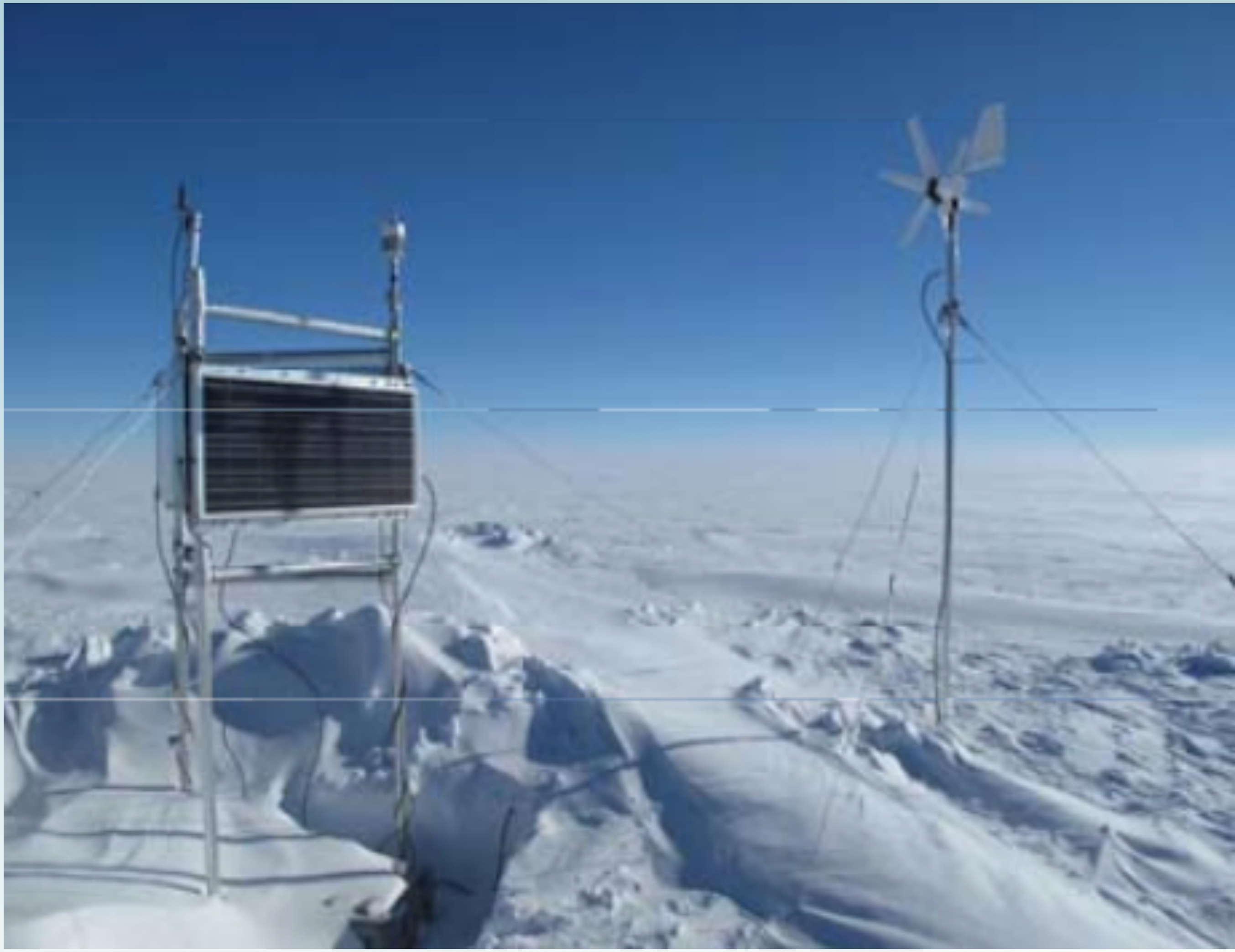
Plans for austral summer 2010-2011

Power and communications infrastructure

Over 80 km^2, communications and power distribution is a challenge!

Goals for 2010-2011

- Test candidate turbines.
- Look for rf interference.
- Evaluate a PhotoVoltaic system
- Monitor environmental and operational parameters
- Test independent health-monitoring system.



Drill Tests

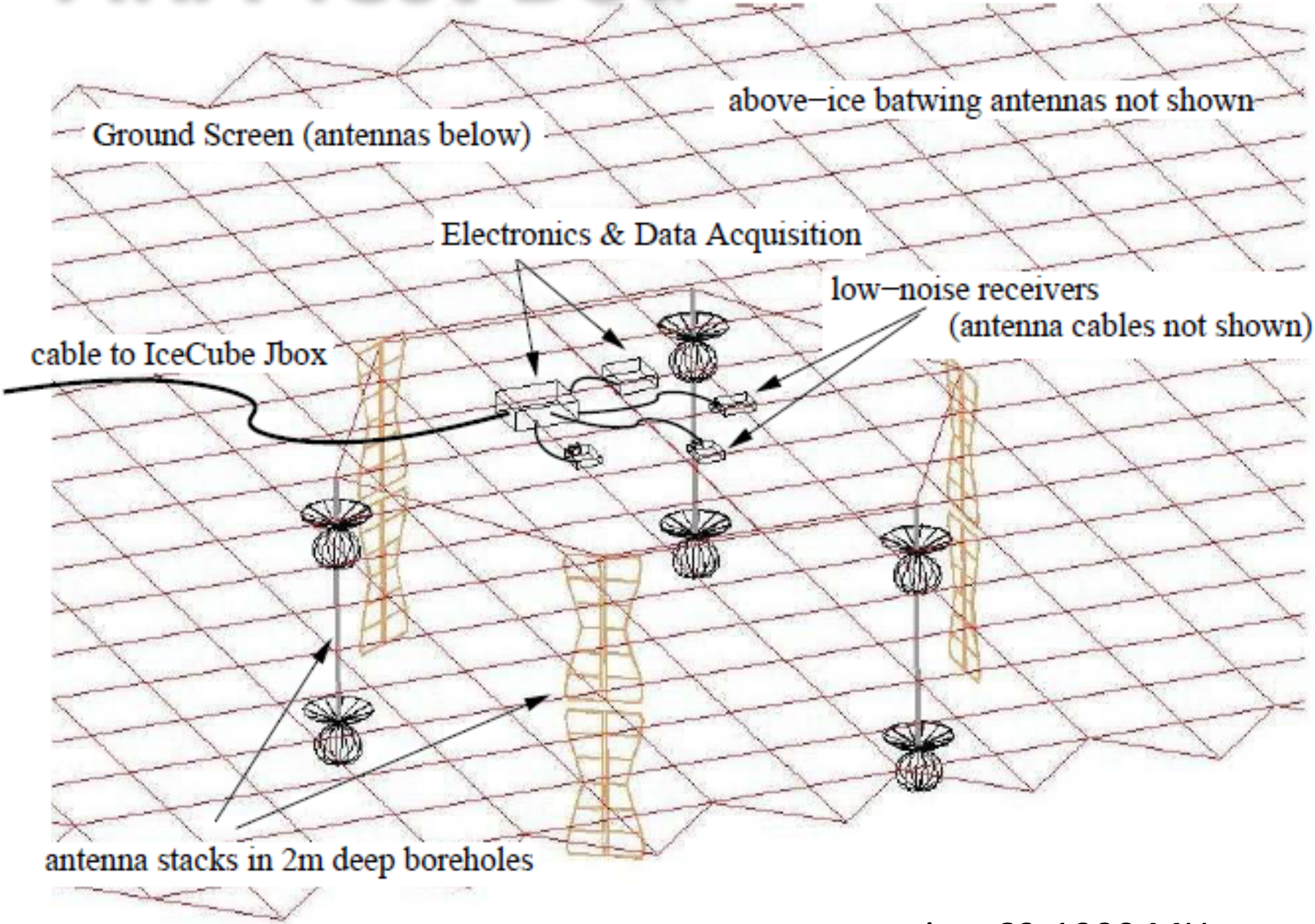
<u>RAM drill</u>

•200m hole in 60 min
•efficient 18 gallons for 200m hole
•lots of cargo to get it to the Pole
•extra compressors may be required
•dry hole

<u>Hot water drill</u>

•200m in 3 hours
•36 gallon per 200m 4" hole
•we have experience
•diameter is flexible
•most of the components already at the Pole
•wet or dry hole

ARA Test Bed

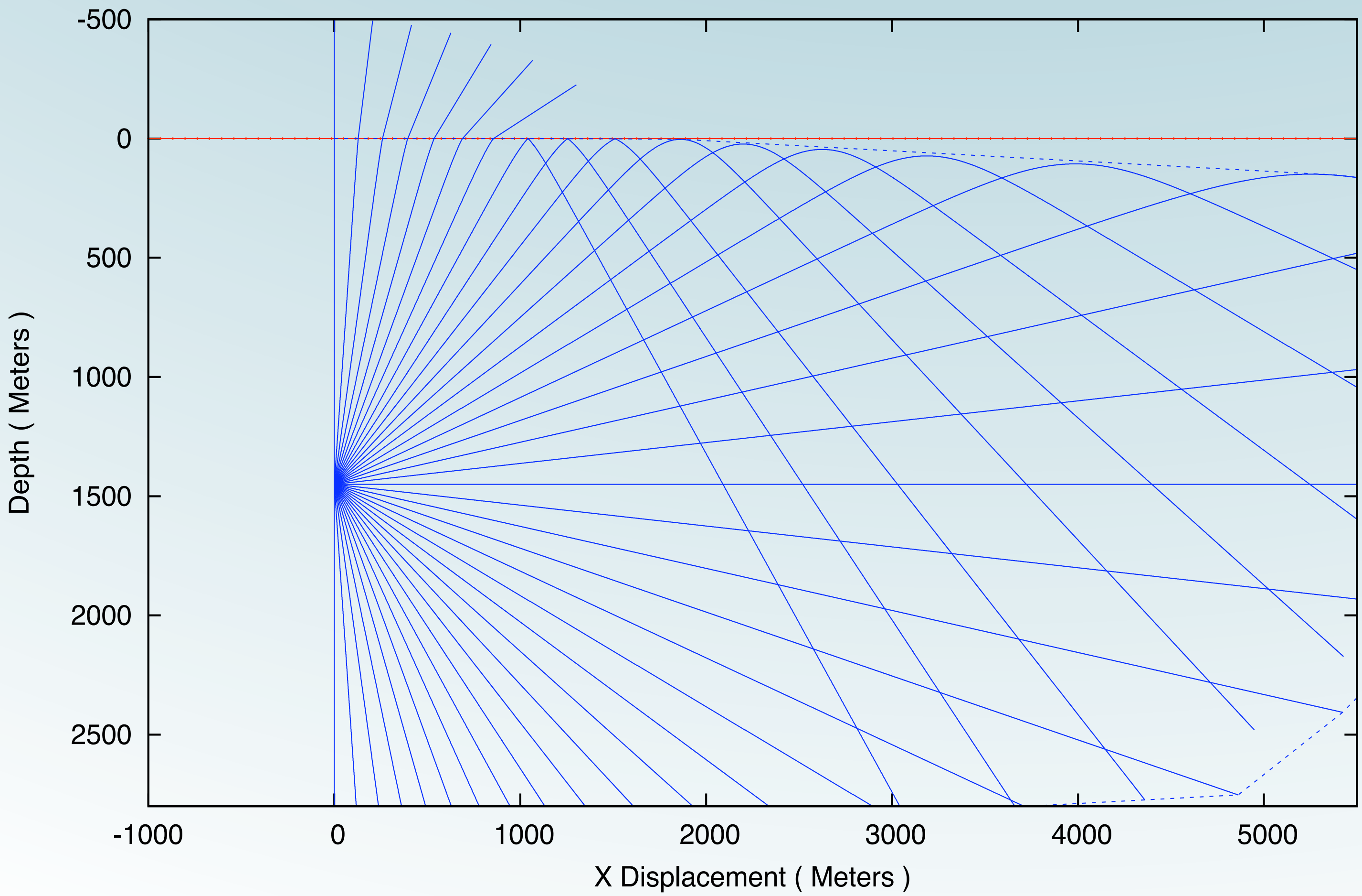


also, additional narrow antennas to be deployed deeper

monitor 60-1000 MHz at sensitivity levels of -110dB

Additional deep pulsers on IceCube strings

- last access to deep IceCube holes in 2010-2011
- 3 high voltage calibration transmitters will be installed on IceCube strings- 2 at 1450 m and 1 at 2450 meters



- Deep -can be seen at >km scale distances
- strong pulses ~5kV
- azimuthally symmetric bicone antenna - eliminates systematics from cable shadowing effects
- goals: radioglaciology and calibration

Final thoughts

- A collaboration has been formed to build an englacial array large enough to detect cosmogenic neutrinos
- An array concept has been proposed, with fine tuning of instrumentation and spacing to be optimized during the development phase
- Funding ($4M from U.S. NS and foreign agencies) has been granted for the development phase (since April 20, 2010)
- Work has commenced in preparation for the first Polar season (2010-2011)

Backup Slides

ARA proposal history

- August 2009: proposal submitted to NSF
- November 2009: favorable reviews received by NSF
- November 2009: with guidance from program officer, scope of work revised to be development oriented (operations requirements and funds request significantly reduced)
- November 2009: proposal is selected by panel
- December 2009- January 2010: operations review conducted by Raytheon Polar Services
- April 20, 2010: award received!

MRI R2 Proposal	NSF Funds Request	Cost Sharing	Total Project Cost
University of Wisconsin-Madison	$1,114,402	$248,121	**$1,362,523**
National Taiwan University		$419,322	**$419,322**
University of Delaware - Bartol	$203,483	$0	**$203,483**
UW-Madison Sub-Proposal Total	**$1,317,885**	**$667,443**	**$1,985,328**
University Of Maryland - College Park	$801,060	$179,680	**$980,740**
Kansas University - Lawrence	$292,519	$125,366	**$417,885**
Universite Libre De Bruxelles		$262,605	**$262,605**
University of Hawaii - Manoa	$384,171	$32,500	**$416,671**
UMD-College Park Sub-Proposal Total	**$1,477,750**	**$600,151**	**$2,077,900**
Total Project Cost	**$2,795,634**	**$1,267,594**	**$4,063,228**
Percentage of total Project Cost	**68.8%**	**31.2%**	**100.0%**

ARA Timeline

- SEP 2010 Preliminary System Design Review. Include all major subsystem assemblies.
- OCT 2010 Ship Testbed prototype instrumentation to Pole
- AUG 2011 Design, construct and ship to Pole the Ice Drill
- SEP 2011 Design, integrate, test and ship 4 pre- production In Ice Instrumentation clusters after Shipment Readiness Review.
- SEP 2011 Design, construct and test Remote Stations. Ship prototype to Pole after Shipment Readiness Review.
- DEC 2011 Commission Ice Drill
- FEB 2012 Install and Commission 4 Radio Stations at Pole
- APR 2012 Final Critical Design Review & Production Readiness Review
- SEP 2012 Instrumentation Shipment Readiness Review.
- SEP 2012 Initial verification of data stream showing detector will meet Science objectives
- SEP2013 Instrumentation Shipment Readiness Review.
- Final verification of data stream showing detector will meet Science objectives.
- SEP 2014 Integrated, test and ship 33 production In Ice Instrumentation clusters.

ARA effective volume