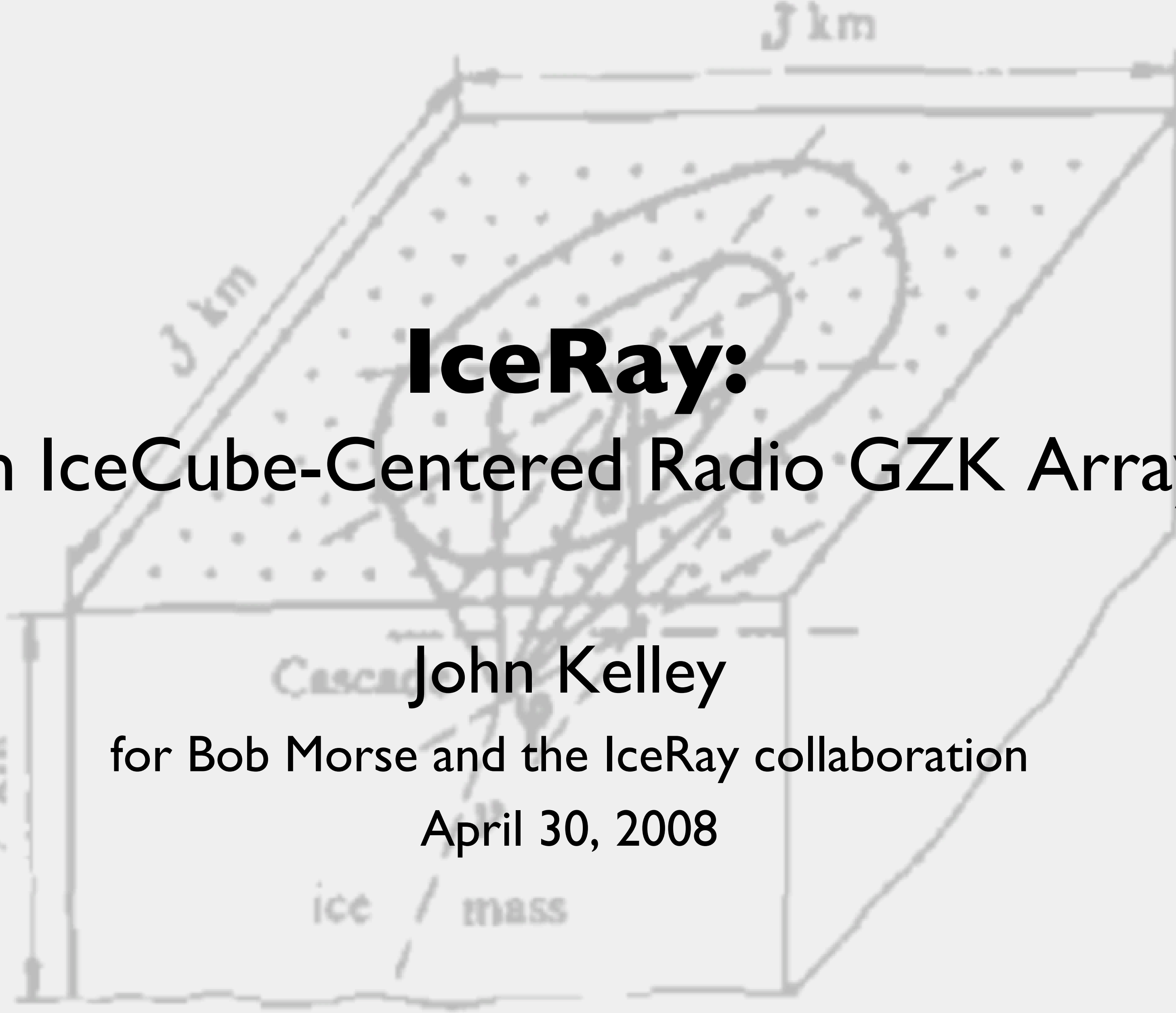
IceRay:

an IceCube-Centered Radio GZK Array

John Kelley

for Bob Morse and the IceRay collaboration

April 30, 2008



Goals

- Extend IceCube into the EeV range via a radio array
  - 50 km^2 (initial phase) to 300-1000 km^2 (final target)
  - substantial rates of GZK ν / year
- O(1°) angular resolution
- Subset of events which trigger both radio and optical arrays
  - Allows calorimetry of both shower and outgoing lepton
- Low cost (<$10M)

The IceRay Collaboration

Hawai'i: B. Morse, P. Allison, M. DuVernois, P. Gorham, J. Learned, and G. Varner

Kansas: D. Besson

Wisconsin: A. Karle, F. Halzen, and H. Landsman

Ohio State: J. Beatty

Maryland: K. Hoffman

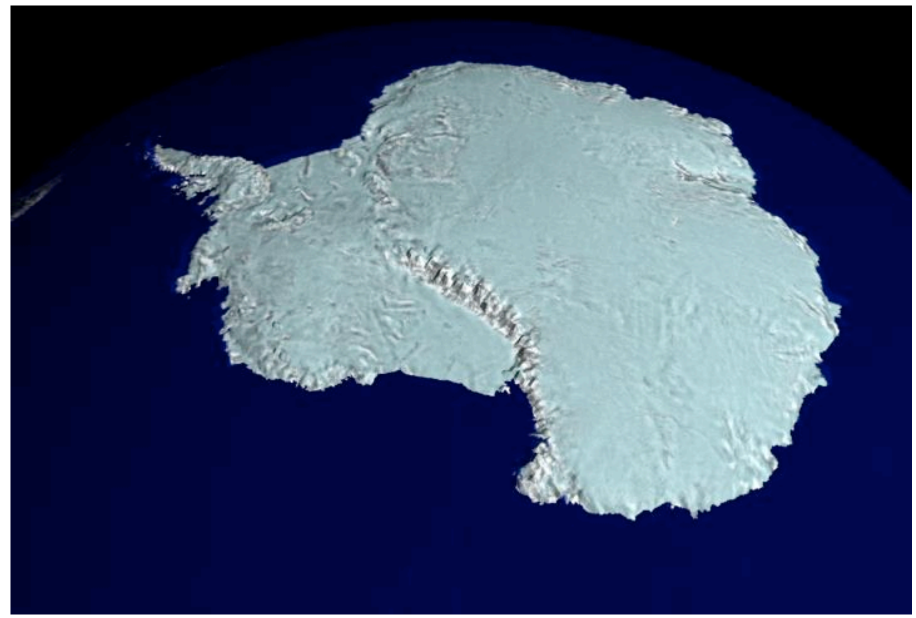
Delaware: D. Seckel

Penn State: D. Cowen and D. Williams

MIT: I. Kravchenko

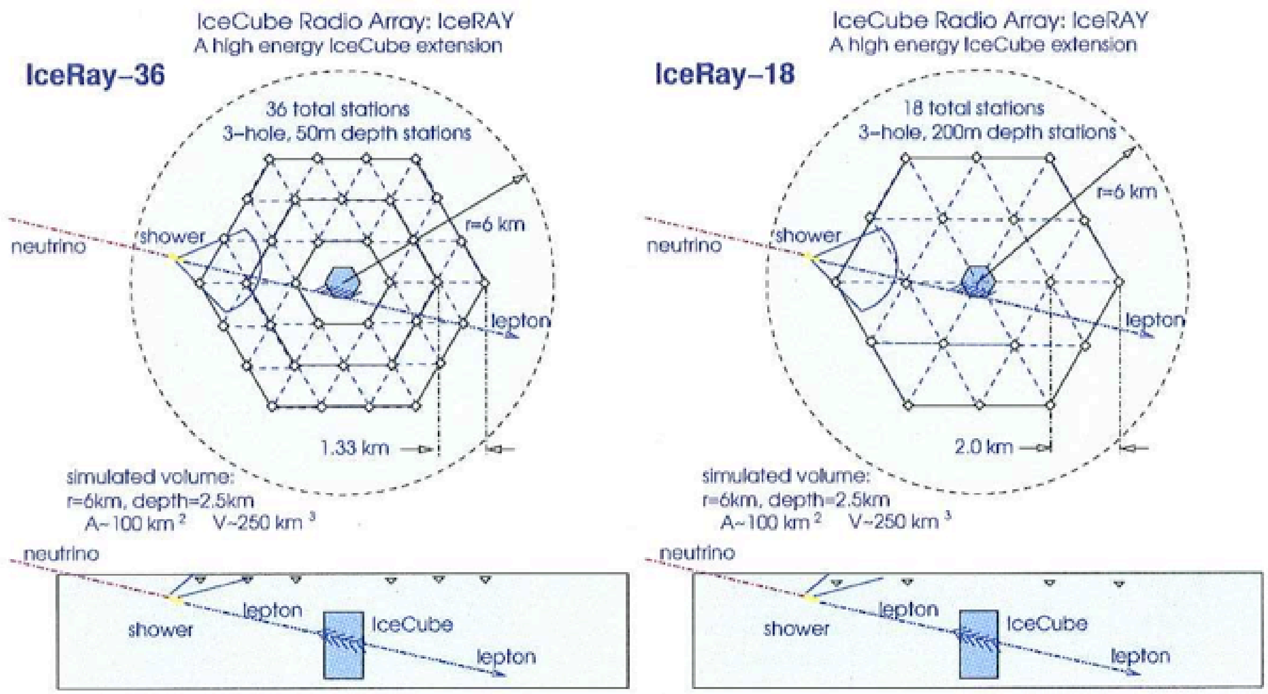
Taiwan: P. Chen

UCL: R. Nichol and A. Connolly



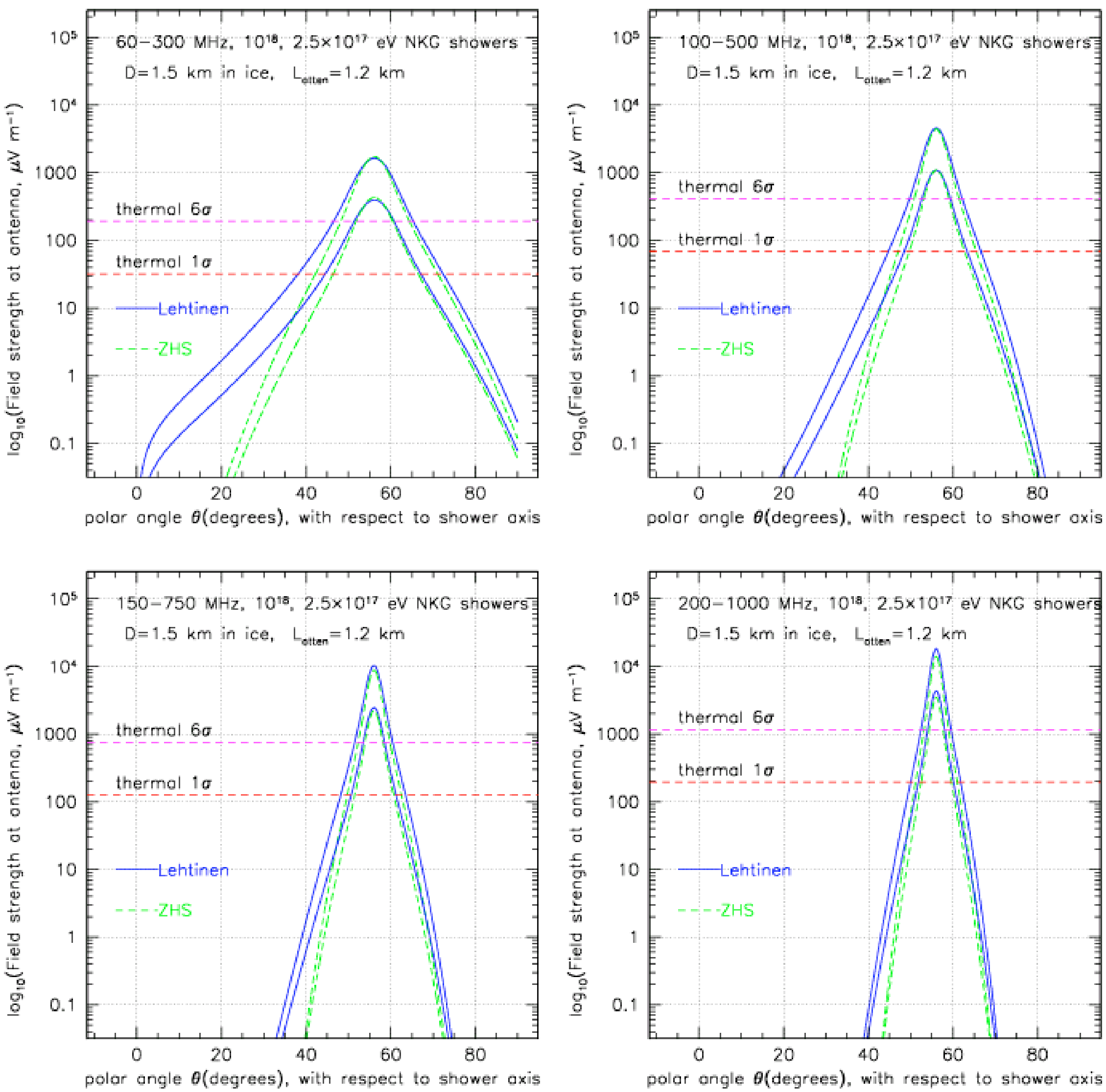
50 km^2 Baseline Studies

(the “AMANDA” of radio)



Higher density, shallow (50m) vs. sparse, deep (200m)

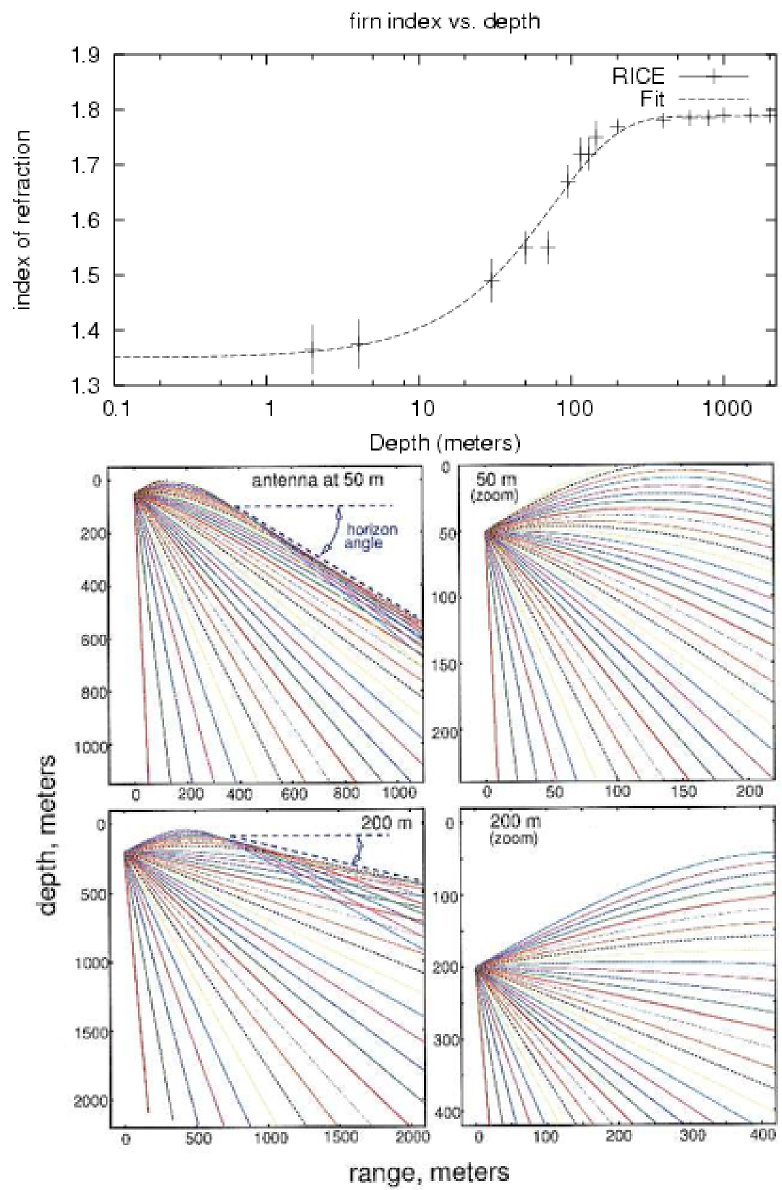
Frequency Range



- Ice is better at low frequency (< 500 MHz)
- Solid angle also better at low freq.
- SNR goes as sqrt(bandwidth)
- Go low freq., high bandwidth: 60-300 MHz

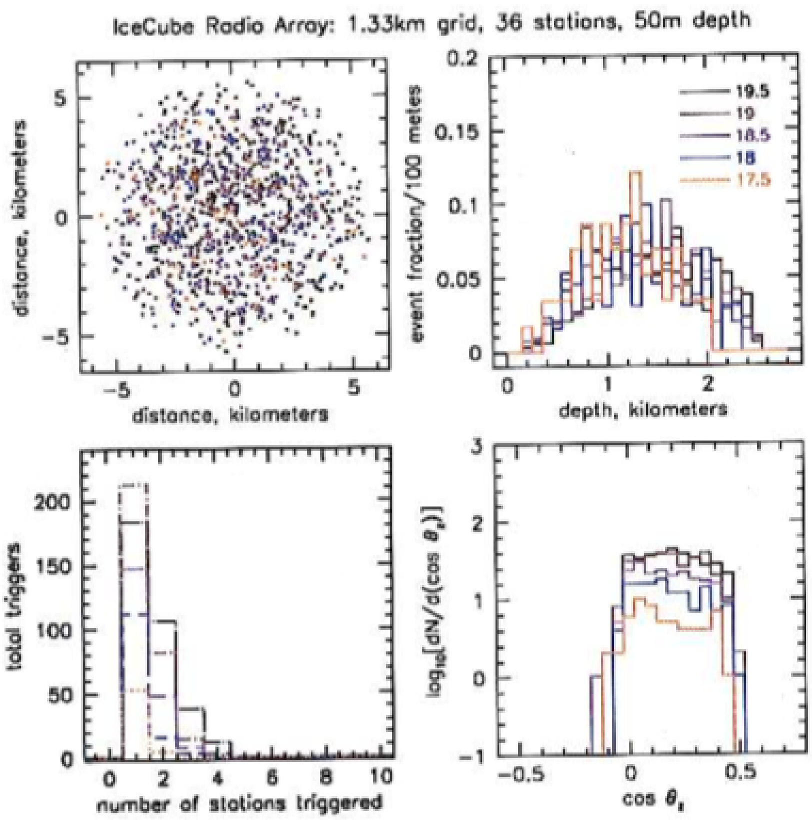
Depth

- Firn shadowing: shallow rays can't get to surface
- Means deeper is better for $V_{eff}\Omega$ (up to ~200m)
- Cost is the real issue
  - Deep firn drill?

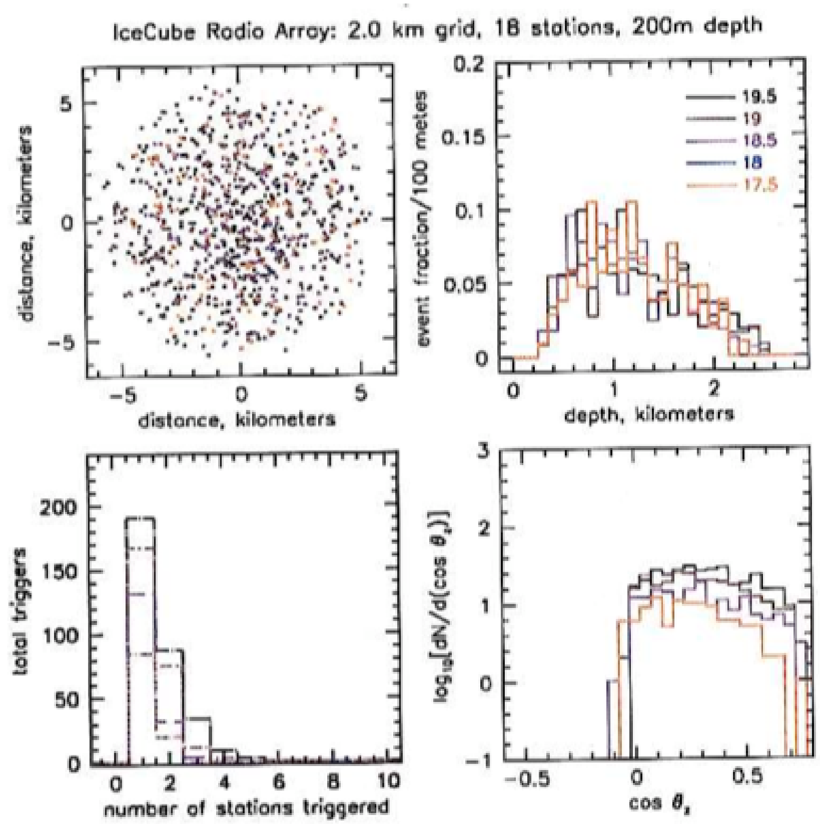


Simulation Results

IceRay-36 / shallow

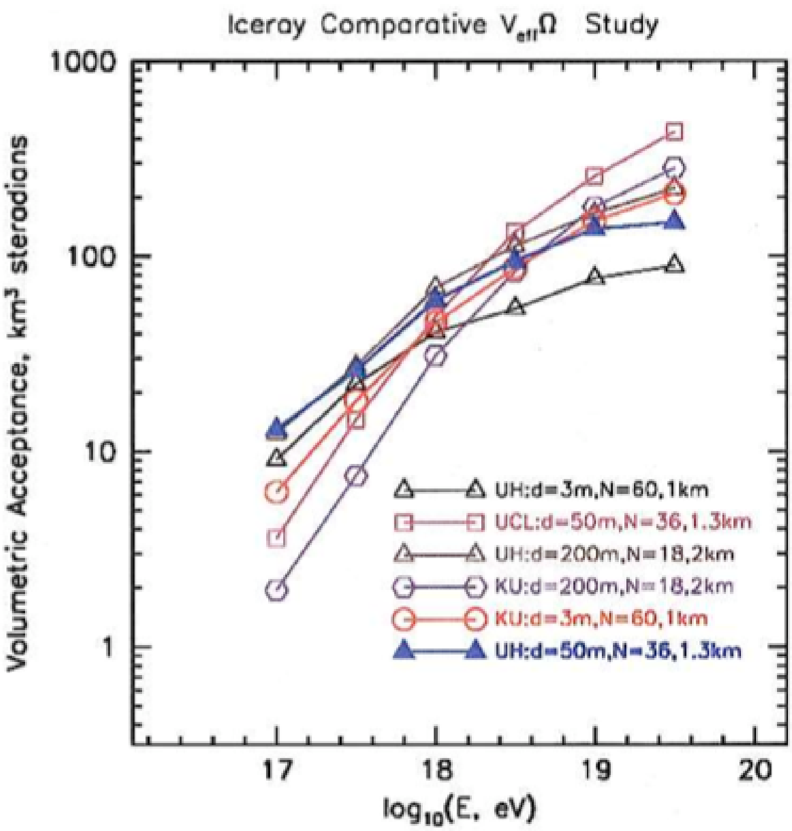


IceRay-18 / deep



Mostly via SalSA MC; crosschecked with Bartol, RICE MC, and ARIANNA MC

Acceptance and Event Rates

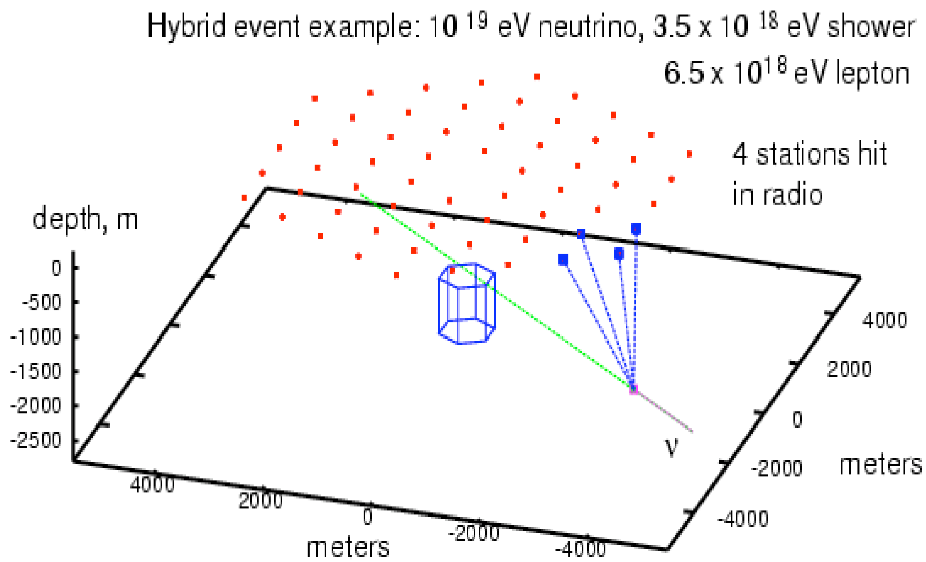


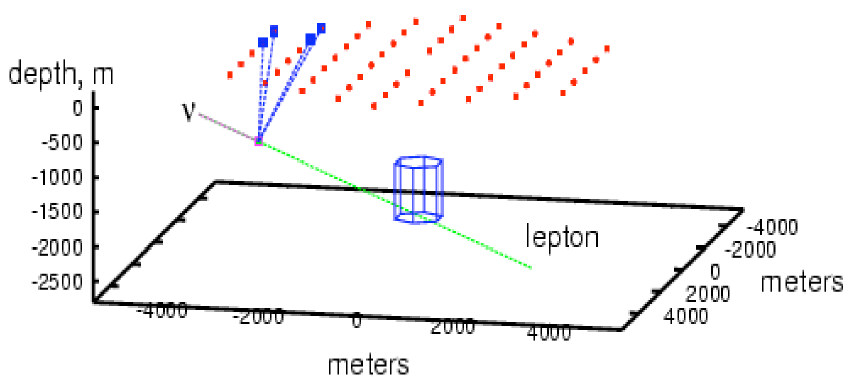
Cosmogenic neutrino model	36sta/50m events/yr	18sta/200m events/yr
Fe UHECR, std. evolution	0.50	0.60
Fe UHECR strong src. evol.	1.6	1.8
ESS 2001, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$	3.5	4.4
Waxman-Bahcall-based GZK-ν flux	4.2	4.8
Protheroe and other standard models	4.2-7.8	5.5-9.1
Strong-source evolution (ESS,others)	12-21	13.8-28
Maximal, saturate all bounds	24-40	32-47

Initial phase achieves 3-9 ev/year for "standard" fluxes

Final phase: ~100 ev/year

“Golden” Hybrid Events





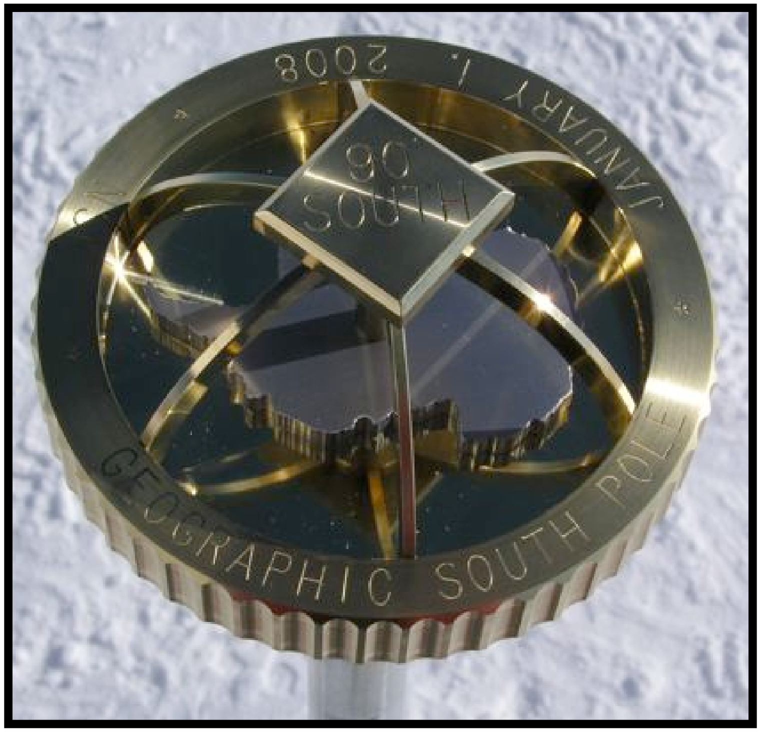
IceRay-36 / shallow

Cosmogenic neutrino model	IceCube 10 yrs	IceCube+ 10 yrs
ESS 2001 $\Omega_m = 0.3,\ \Omega_\Lambda = 0.7$	3.2	6.4
Waxman-Bahcall-based GZK-ν flux	3.8	7.6
Protheroe and other standard models	3.8-7.1	5.0-8.2
Strong-source evolution (ESS,others)	10-19	13-25
Maximal fluxes, saturate all bounds	22-36	30-44

- Triggering both IceRay and IceCube: rates are low, but extremely valuable for calibration
- High-energy extension (IceCube+ above) with 1.5km ring helps a lot
- Sub-threshold cross-triggering can also help

Proposed Schedule

- 2008-09: IceRay-0
  - surface testbed… see next talk!
- 2009-10: Two surface substations, 50-80m with existing or slightly modified firn drill
- 2010-2011+: Start installation of initial-phase array as IceCube ramps down



Extra Slides

Simulation Details

– Throw events over **6 km radius disk**, 300m to 2500m depth

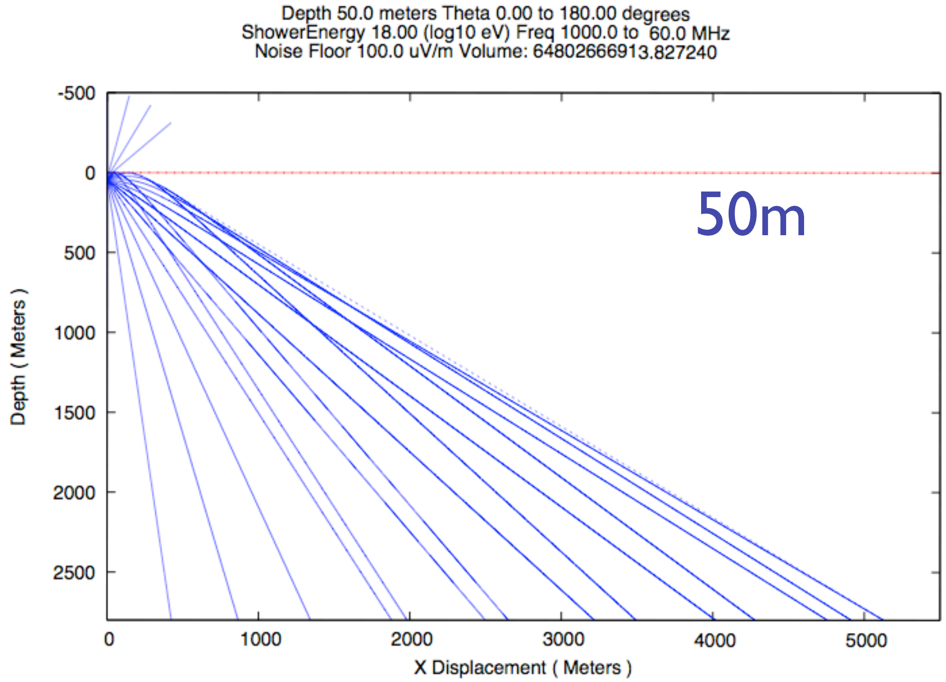
– **60-300 MHz** bandwidth for each antenna, low gain (dipole-like response)

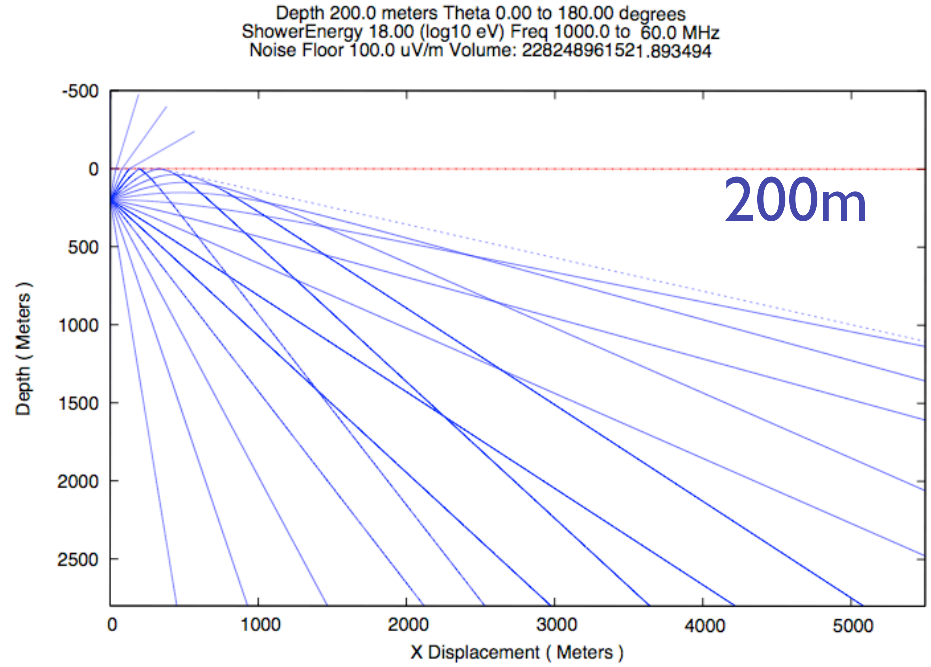
– **12 antennas** (6 H_{pol}, 6 V_{pol}) per station

– > **4σ on 5 antennas** required to trigger (to ensure near 100% reconstruction efficiency), use T_{sys} ~ 360K (230K ice +130K receiver)

– **Exclude shallow zenith angles** due to firn refraction shadowing

Ray Tracing


Depth 50.0 meters Theta 0.00 to 180.00 degrees
ShowerEnergy 18.00 (log10 eV) Freq 1000.0 to 60.0 MHz
Noise Floor 100.0 uV/m Volume: 64802666913.827240
50m
Depth (Meters)
X Displacement (Meters)
-500
0
500
1000
1500
2000
2500
0
1000
2000
3000
4000
5000


Depth 200.0 meters Theta 0.00 to 180.00 degrees
ShowerEnergy 18.00 (log10 eV) Freq 1000.0 to 60.0 MHz
Noise Floor 100.0 uV/m Volume: 228248961521.893494
200m
Depth (Meters)
X Displacement (Meters)
-500
0
500
1000
1500
2000
2500
0
1000
2000
3000
4000
5000

Ray Tracing, cont.