IceRay:
an IceCube-Centered Radio GZK Array

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for Bob Morse and the IceRay collaboration
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Goals

• Extend IceCube into the EeV range via a radio array
  – 50 km² (initial phase) to 300-1000 km² (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 $\sqrt{\text{bandwidth}}$
- Go low freq., high bandwidth: 60-300 MHz
Depth

- Firn shadowing: shallow rays can’t get to surface

- Means deeper is better for \( V_{\text{eff}} \Omega \) (up to \(~200\text{m}\))

- 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

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

Final phase: ~100 ev/year
“Golden” Hybrid Events

- 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

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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 $T_{sys} \sim 360K$ (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 63.0 MHz
- Noise Floor 100.0 uV/m Volume: 6480266913.827240

50m

- Depth 200.0 meters Theta 0.00 to 180.00 degrees
- ShowerEnergy 18.00 (log10 eV) Freq 1000.0 to 63.0 MHz
- Noise Floor 100.0 uV/m Volume: 228248961621.893494

200m
Ray Tracing, cont.

400m

1 km