

Recent results from the RICE experiment at the South Pole

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for RICE/NARC collaboration

Talk outline

Part 1:

- New results from RICE on neutrino flux

Part 2:

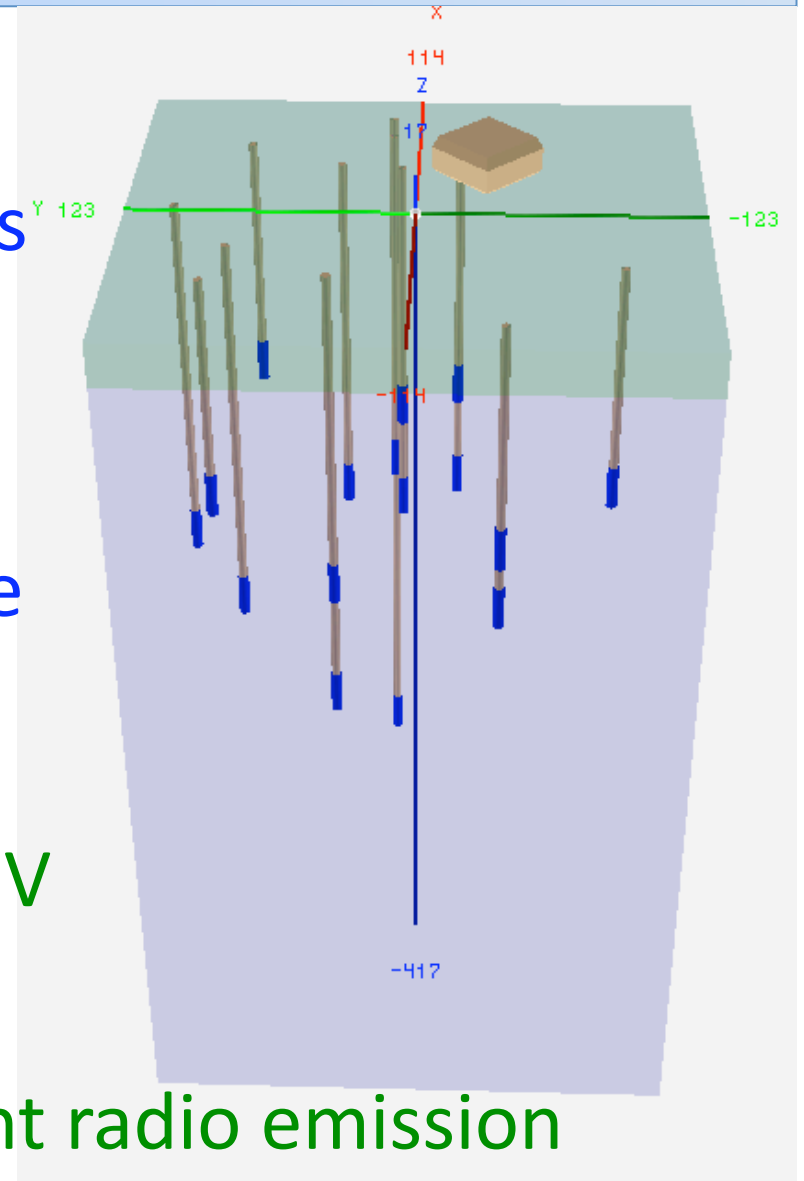
- Ice studies from RICE/NARC in preparation for ARA

Part 3:

- Environmental studies from RICE/NARC for RASTA

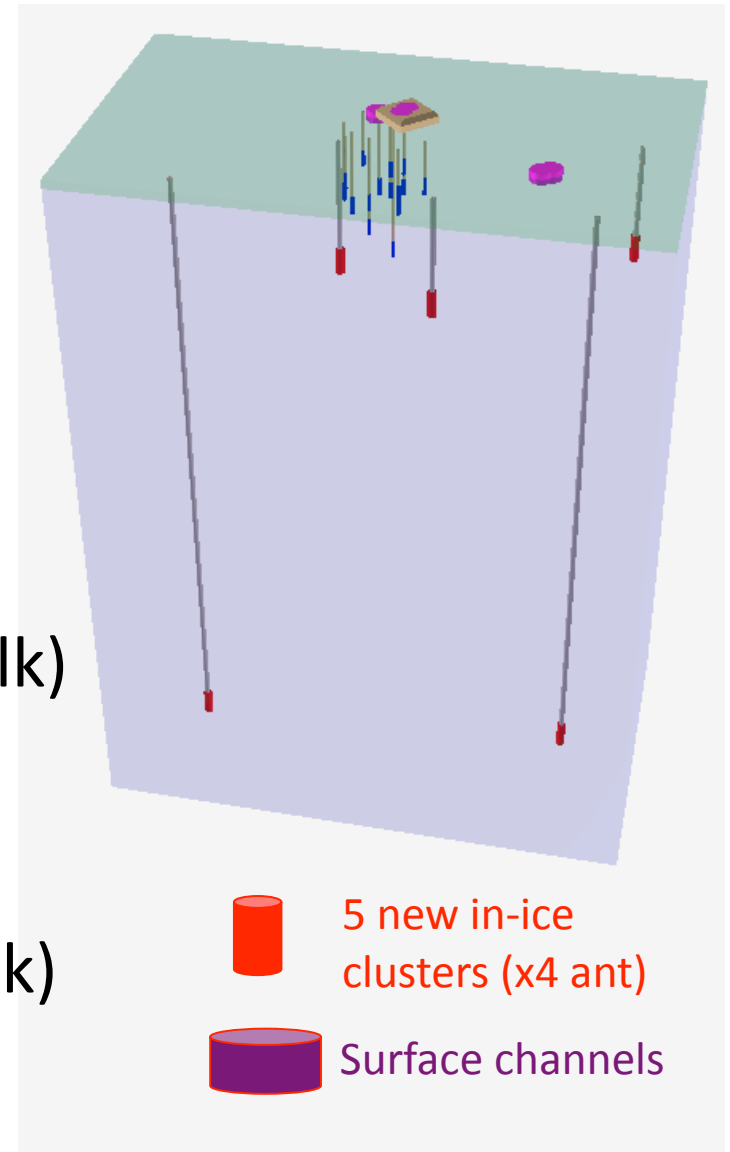
Nomenclature: RICE

- In-ice array of radio antennas
 - 20 channels, 200-500 MHz
 - Depths 100-300 meters
 - Signal digitized at the surface
-
- Sensitivity to $E_\nu \sim 10^{17}$ - 10^{20} eV
 - Running since 1996/1997
 - Detect neutrinos via coherent radio emission



Nomenclature: NARC

- Extension of original RICE
- 20 new in-ice channels
 - Attached to IceCube cables
 - Digitization in-ice
 - See H. Landsman's talk
 - Prelude to ARA, (K. Hoffman's talk)
- 4 new surface channels
 - Connected to RICE DAQ
 - Prelude to RASTA (S. Boeser's talk)



Part 1: new results on neutrino flux

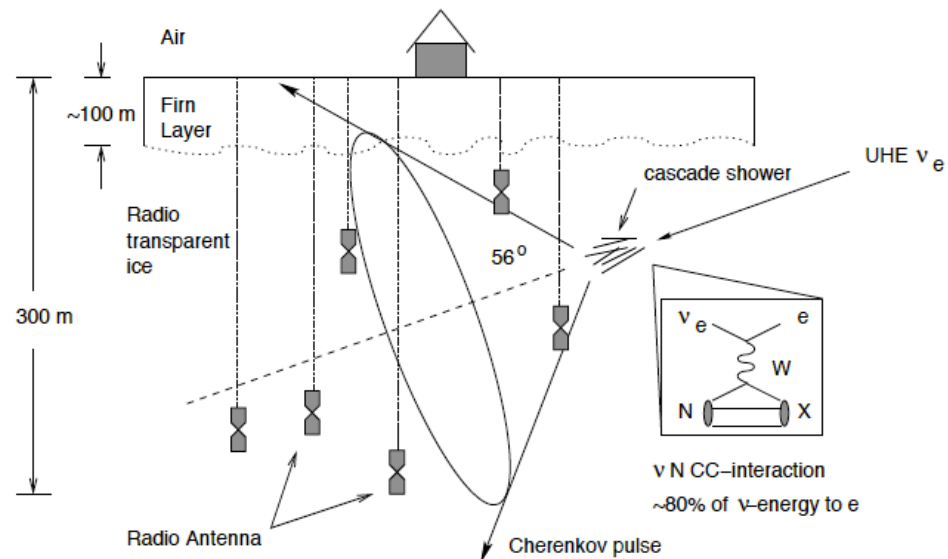
Event rate vs flux

$$N = V_{eff}(E) \sigma_{\nu N}(E) n \Phi \varepsilon L \Omega$$

- N - event count
- V - effective volume
- σ - neutrino-nucleon cross-section
- n - target density (nucleons per m³)
- Φ - neutrino flux (particles per GeV m² s sr)
- ε - efficiency to reconstruct an event
- L - livetime in seconds
- Ω - solid angle in steradians

Event definition and reconstruction

- **An event:** coincidence of a “hit” on ≥ 4 antennas within 1.25 μ s
- **Event source:** reconstruct vertex from relative times of the hits
- **Vertex reconstruction:** grid method or analytic solution method



Event selection

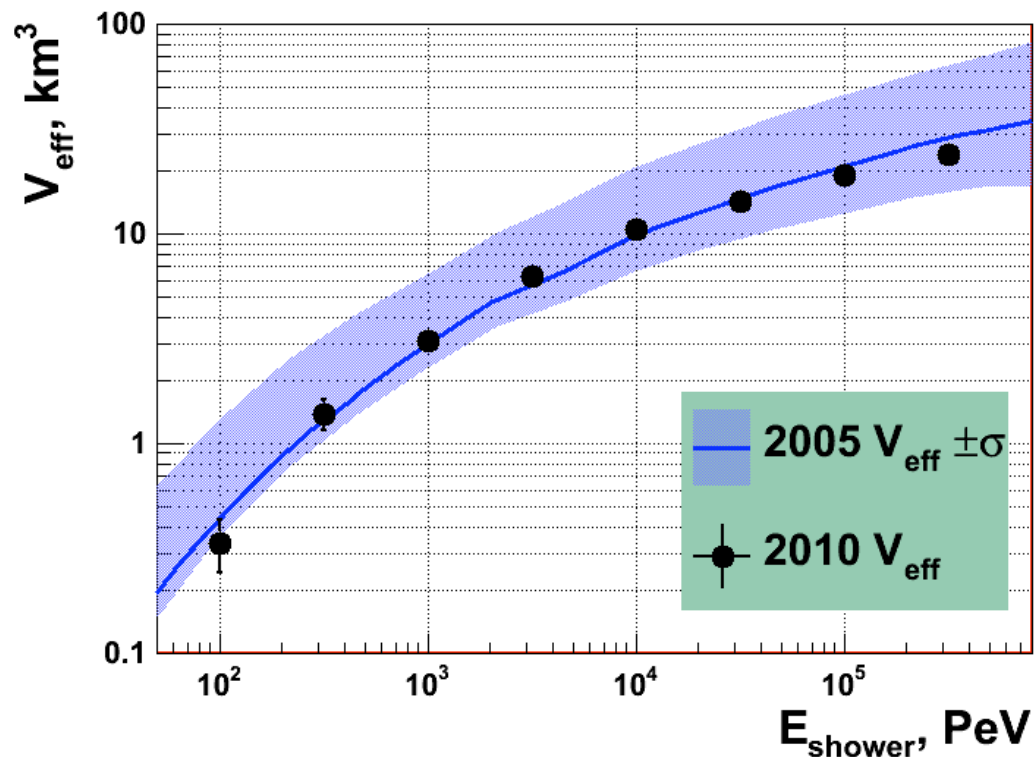
- Accumulated 1.78M events on disk
- Select events and reject backgrounds by:
 - Good source vertex: cut on time residuals
 - Consistency of 2 vertex finding algorithms
 - Time over threshold
 - Reconstructed source Z below 150 meters
 - Double pulse rejection

Zero surviving candidates

- upper limit 2.3 events @ 90% C.L.

Effective volume

- Estimated from simulation
- Similar to used in last publication: $V_{\text{eff}}(2000-2005) \approx V_{\text{eff}}(2006-2010)$
- Uneven: 2006 compromised by installation of 450 MHz Land Mobile Radio system at the Pole
- MC updated to include a better shower parameterization

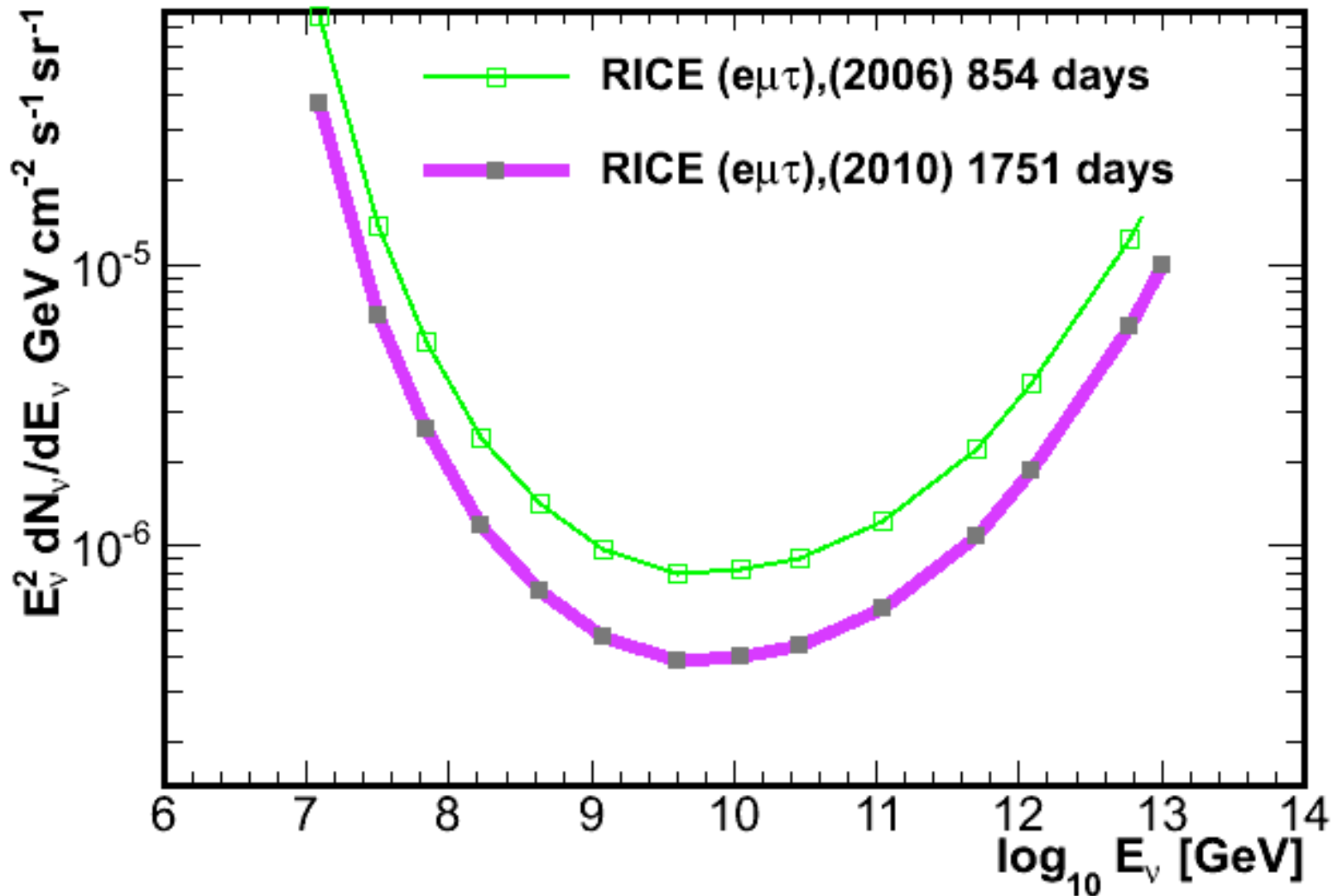


Other event rate pieces

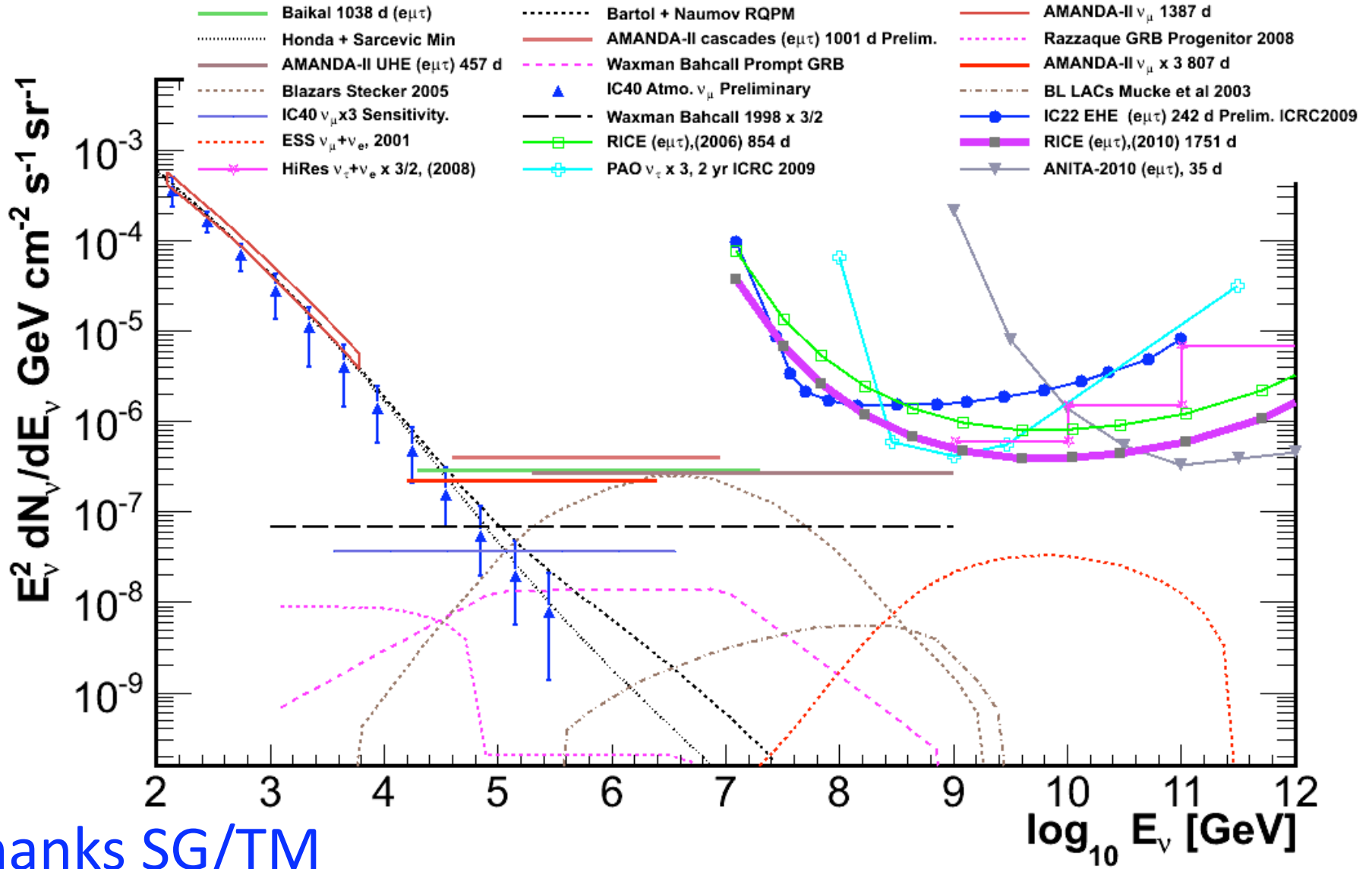
- **Livetime: ~ 1700 days**
 - Surface Veto board \rightarrow 7% livetime improvement
 - $L_{2000-2010} \sim 2.05 \times L_{2000-2005}$
- **Efficiency to pass selection:**
 - $71.4 \pm 1.0\%$ from MC
 - note: trigger efficiency is folded into V_{eff}
- **Solid angle: $\sim 2\pi$**

Upper limit on neutrino flux

RICE 2010 limits are $\times 2$ better than RICE 2006



Upper limit on neutrino flux



thanks SG/TM

Part 2: ice studies for ARA

Needed for ARA: full characterization of complex permittivity at all polarizations for propagation in both Z and phi.

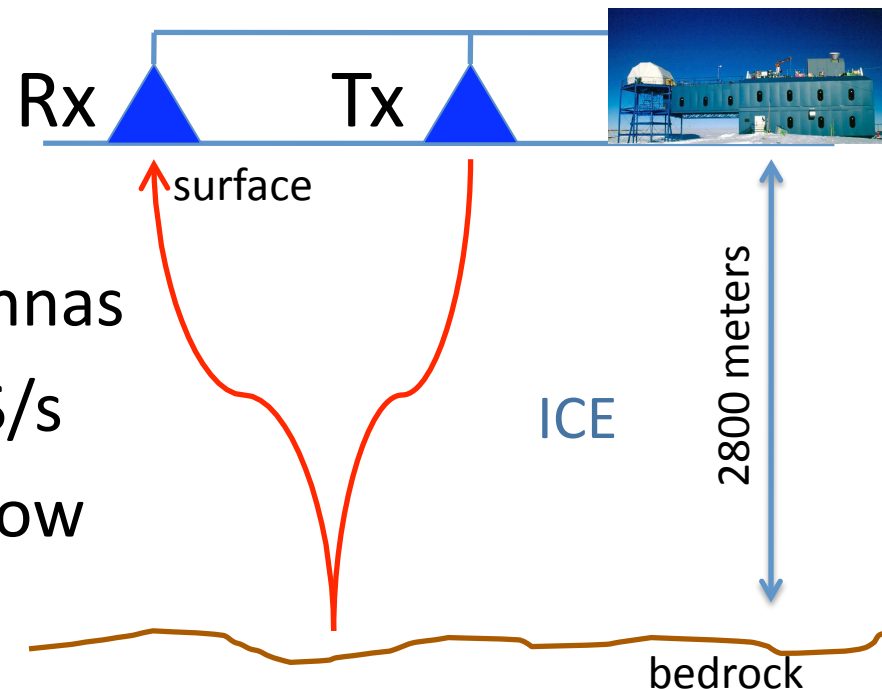
Known:

- $\langle L_{\text{atten}} \rangle \sim 600\text{m}$ for radar propagation along Z
- Index of refraction within 0.5-1.0%
- Birefringence indications: 0.3% in the upper 1.5km of ice at Dome Fuji

Jan 2010 studies: birefringence

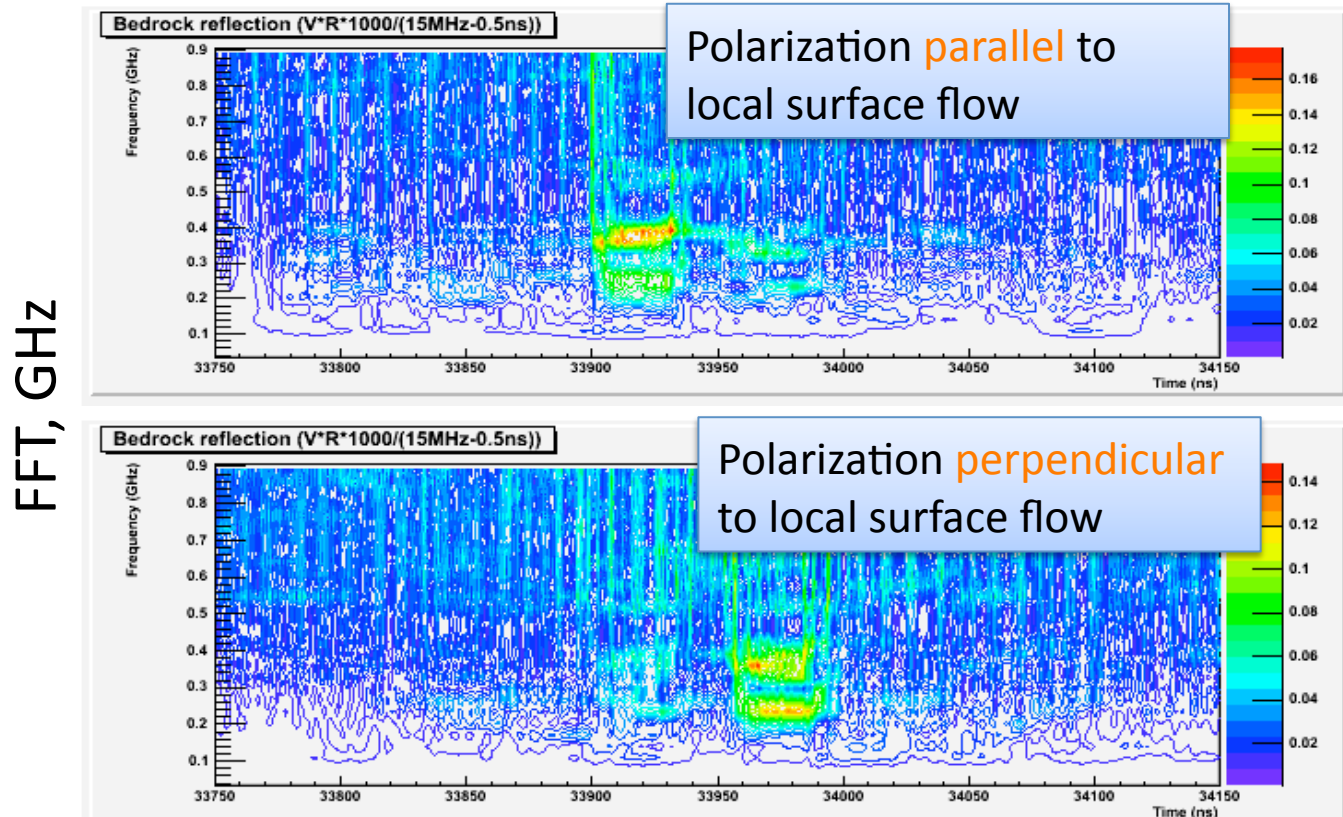
Direct time-domain measurement:

- Broadcast ns-duration pulses with surface horn antenna Tx broadcasting down through ice sheet and reflecting back up to receiver Rx



- Co-/cross-polarized antennas
- Record echograms @2GS/s
- Correlate with local ice flow

Birefringence results



Time shift => birefringence

Time, ns

- Average $(\Delta c/c) = 0.3\%$ (time shift 53 ns)
- Echoes to 1.5km are in sync, effect only in lower half of ice-sheet

Other ice studies from Jan 2010

- **Dispersive effects:**
 - Diff. frequency components for bedrock reflection simultaneous within 4ns
 - Limits dispersion to $<10^{-4}$ for 100-1000 MHz
- **Estimation of bedrock depth via roundtrip time**
 - Measured $2857 \pm 5\text{m} \pm 30\text{ m}$
 - Systematics from uncertainty of $n(Z)$
 - NO existing long-baseline radio transit measurements between known source/receiver locations
 - ARA will reduce this systematics by x5

Implications for ARA

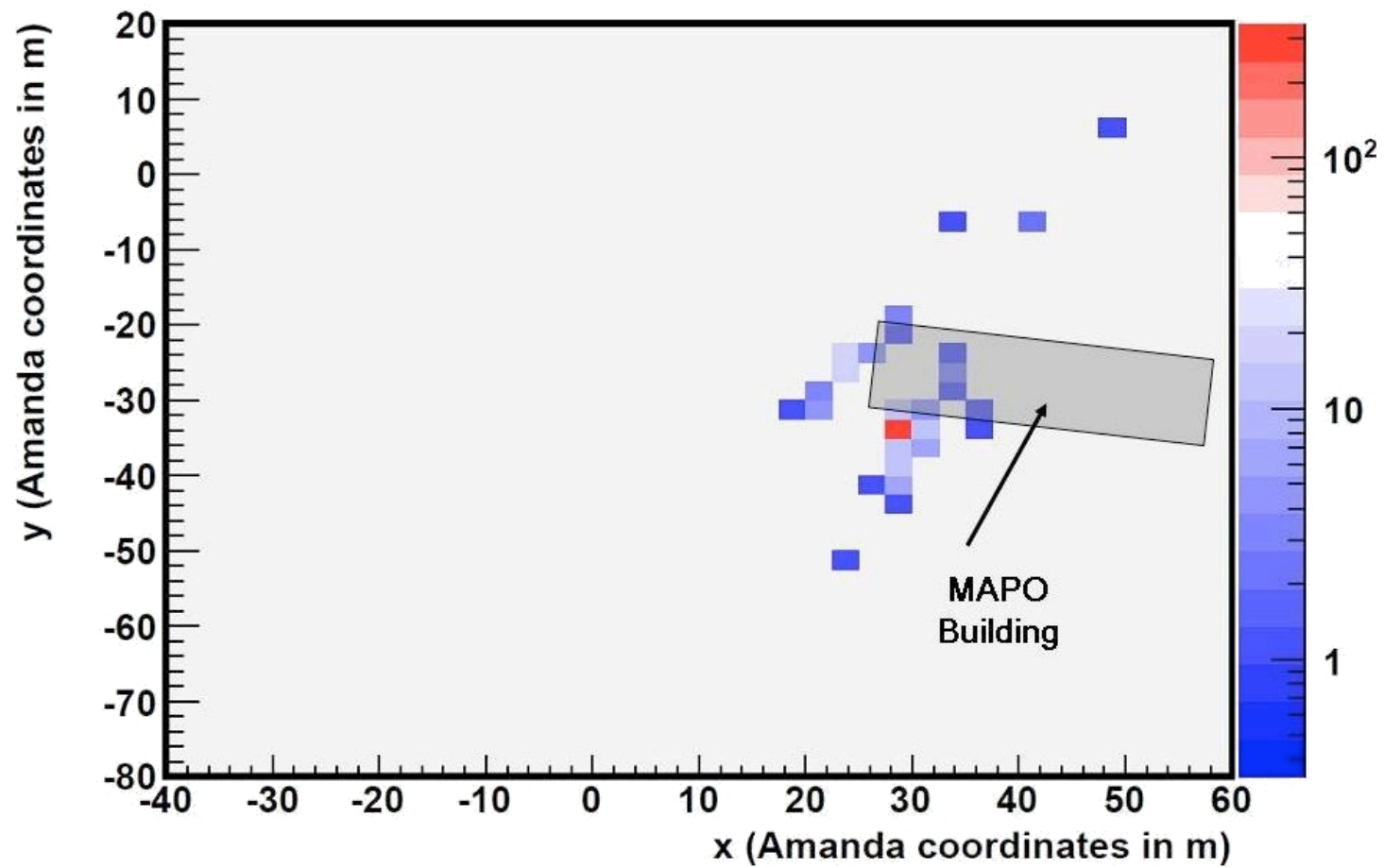
- No dispersion over long baselines (good!)
- Birefringence limited to lower portion of ice sheet (higher RF attenuation, anyway)
- A side note: ARA will be an instrument for forefront radioglaciology, as well as Astroparticle Physics!

Part 3: surface environmental studies

- RASTA strives to measure radio emission from air showers (see talk by S. Boeser)
- With NARC Jan 2009 – present studied the environment at the Pole:
 - 4 surface antennas from Wuppertal added to RICE
 - Similar to RICE dipoles, but x10 in scale
- Investigated:
 - Reconstruction of surface pinger
 - Calibration of frequency response to galaxy
 - Identification of background sources

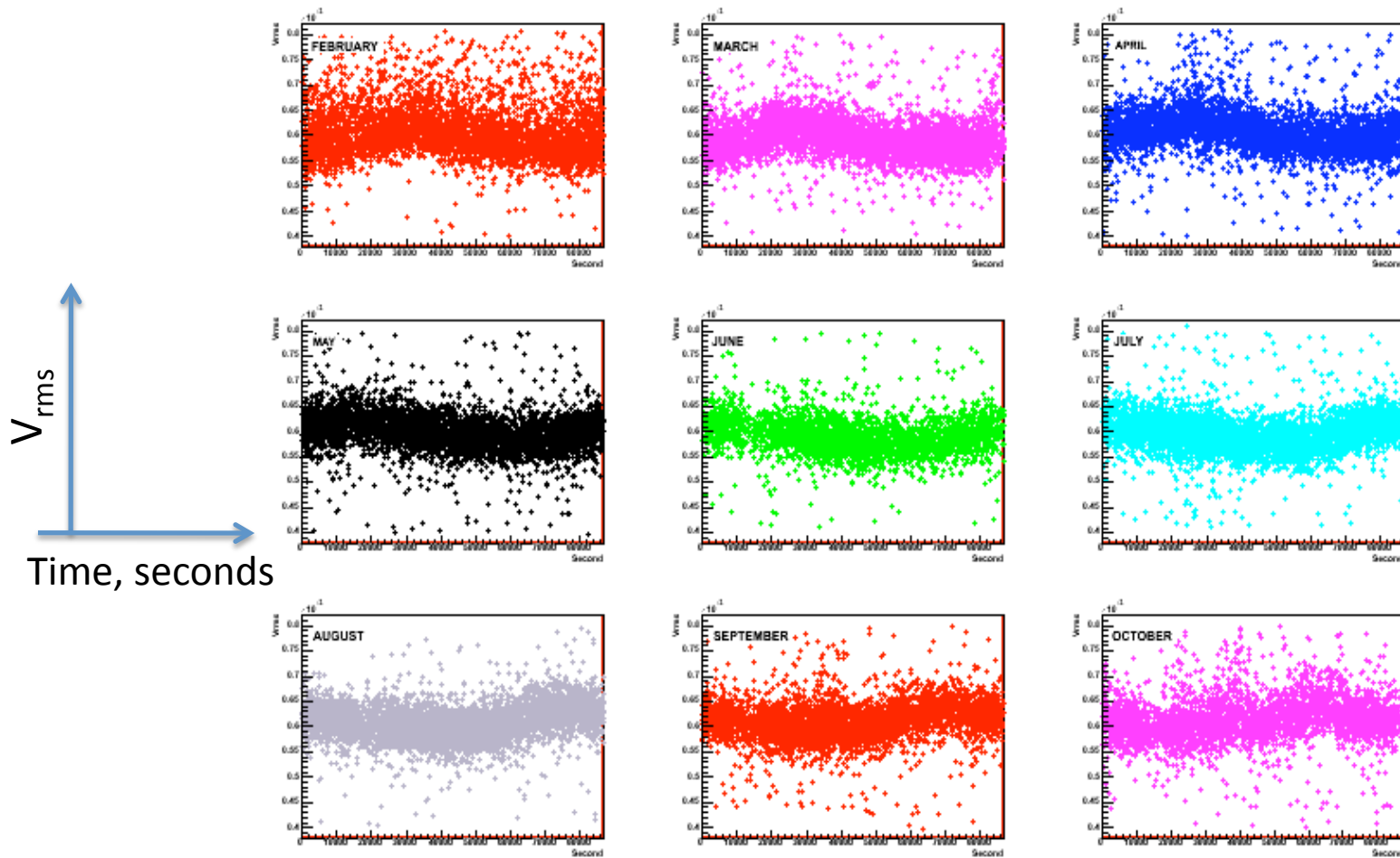
Reconstruction of known source

- Find pinger position in xy:



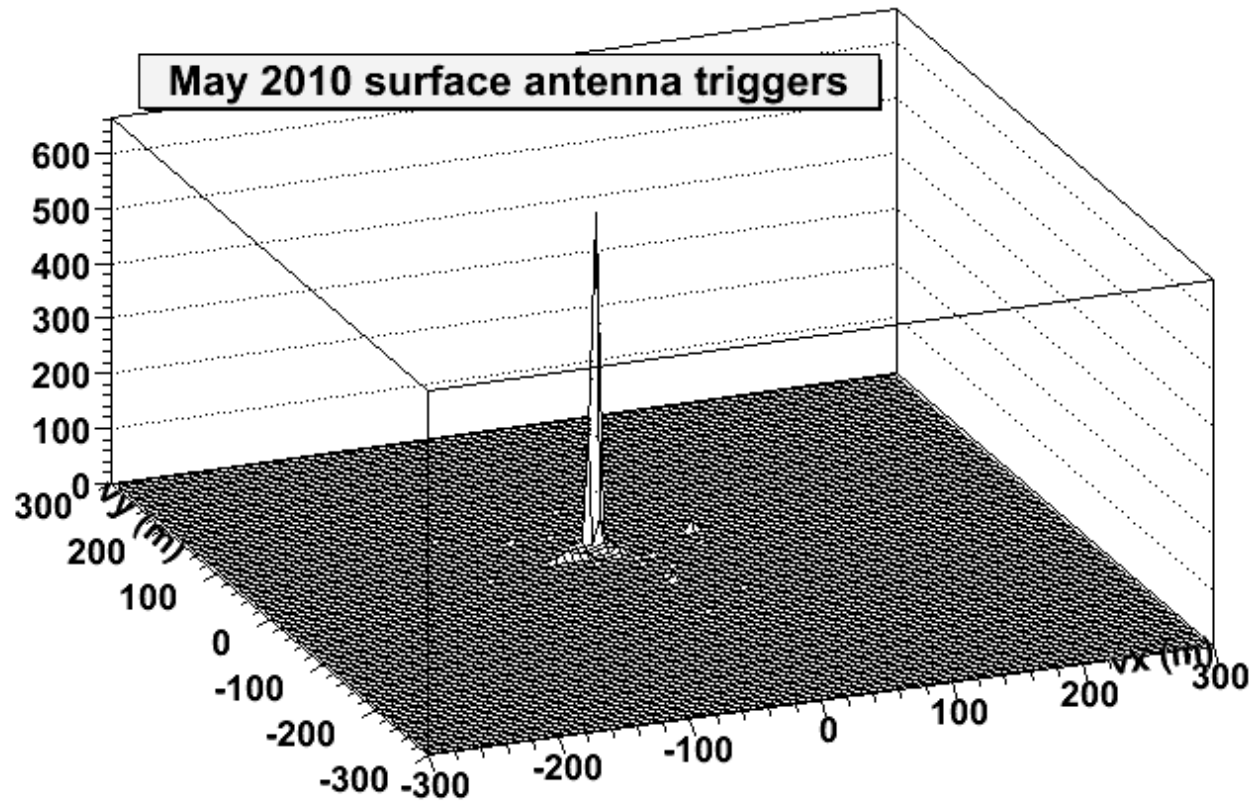
Frequency response to galaxy

V_{rms} for unbiased triggers: note $V(t)$ variation vs. second – sine wave advances with time=> inconsistent with Solar source; phase consistent with SgrA* source at “infinity”



Identification of backgrounds

- ICL building is the dominant source of background to surface triggers



Summary

- New RICE neutrino flux limits derived
 - About x2 better than previously published RICE
- Several studies done last year are useful for ARA R&D
- Recent measurements with surface channels are relevant for RASTA planning