

Upward-reflected CR Signals: Backgrounds to neutrino searches for RNO-G and ICG2R

Shoukat Ali

October 15, 2026



Overview

- Reflection from an internal layer can cause the reconstructed arrival direction to point toward deeper ice.

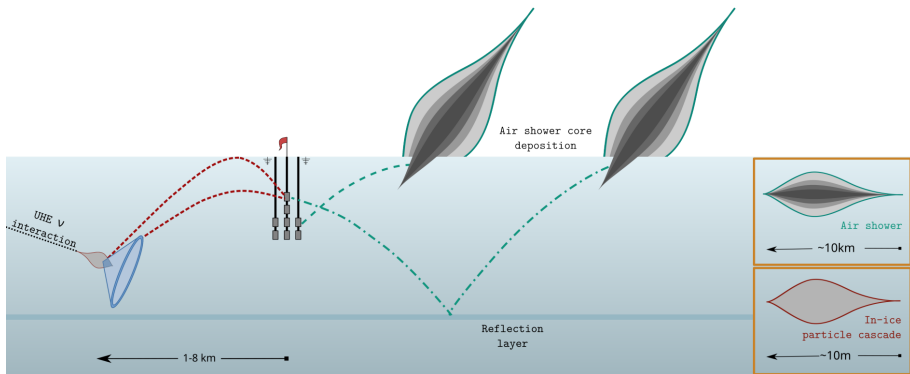


Figure: Coleman et al.

In-ice Askaryan Emission from Air Showers: Implications for Radio Neutrino Detectors

Alan Coleman^a, Christian Glaser^a, Ryan Rice-Smith^b, Steven Barwick^b, Dave Besson^c

^aUppsala University Department of Physics and Astronomy Uppsala SE-752 37 Sweden.

^bDept. of Physics and Astronomy University of California Irvine United States

^cUniversity of Kansas Dept. of Physics and Astronomy Lawrence KS 66045 USA

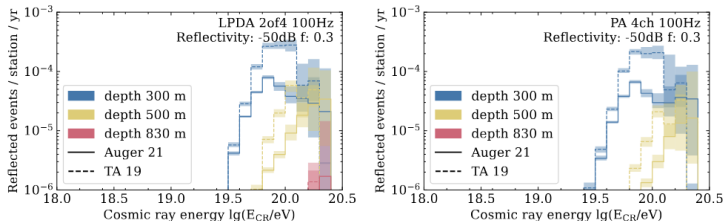


Figure: Coleman et al.

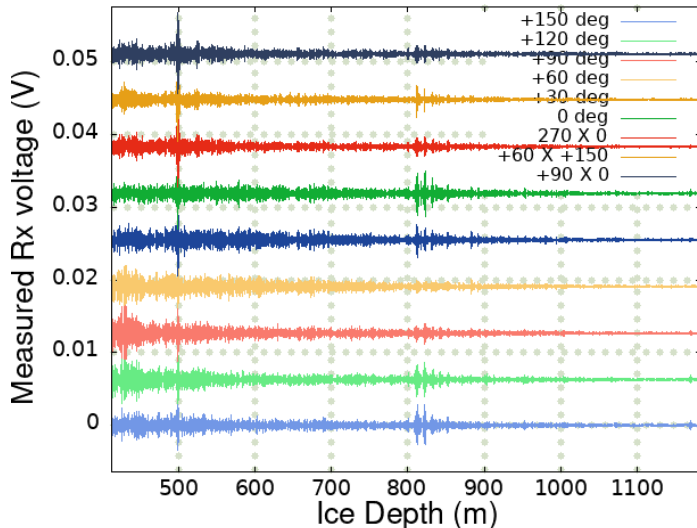
- Summary: For 300-m internal layer, if absolute reflectivity $\mathcal{R} > -50$ dB $\Rightarrow$ 0.01–0.1 evts in ICG2R; if ~ -60 dB $\Rightarrow$ negligible event rate.

Rates in IceCube Gen2-Radio depend on reflectivity R

Echo time	Depth	RICE 2007 $\mathcal{R}_{layer}/\mathcal{R}_{bed}$
6009 ns	521 ± 11.5 m	-48 ± 9
9674 ns	829 ± 17.4 m	-47 ± 8
9792 ns	840 ± 18 m	-46 ± 9
9905 ns	849 ± 18 m	-54 ± 12

$\mathcal{R}_{bed}$ typical value $\sim -6 \rightarrow -9$ dB

Layers from 2007 RICE data at South Pole: ($A=A(\phi)$)



CReSIS data

- Center for Remote Sensing of Integrated Systems (based at KU)
- Airborne radar sounding of Antarctica and Greenland
- Deduce ice thickness from travel time between surface radar echo and bedrock echo
- Also reveals internal layers within ice sheets

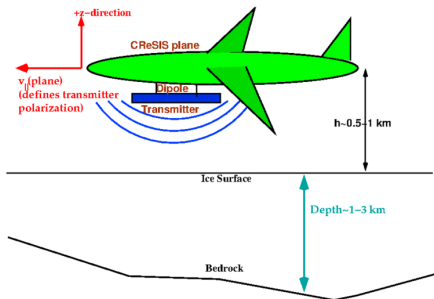
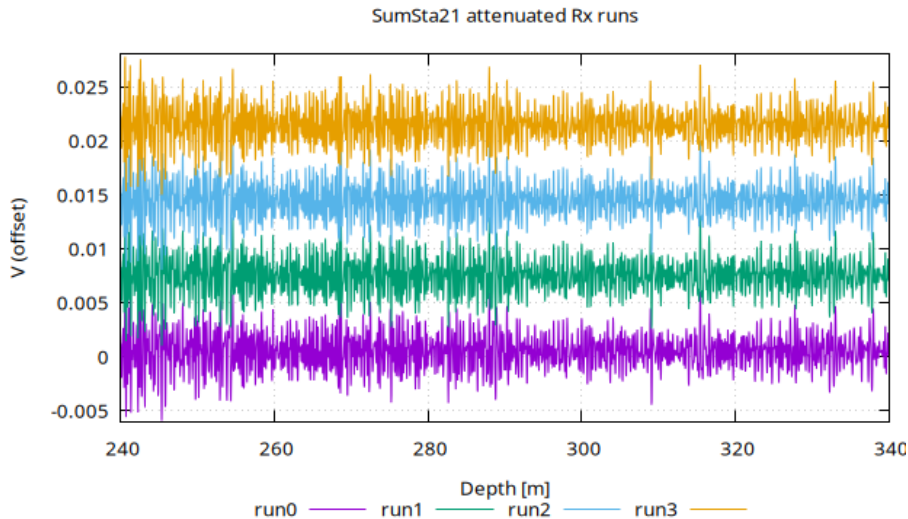


Figure: M. Stockham et al.

- 2021 Summit Station bed echo data (FID pulser)
 - LPDA Tx→LPDA Rx⇒nearby echoes 'bleed' together
 - surface LNA saturates on through-air signal for first 5-10 microseconds
- 2022 Summit Station bed echo data (LPDA replaced with horn)
- Contrast to CReSIS data: latter geographically extensive, also allows normalization to bed and surface echo, but coarser and requires SAR from 190 MHz 'tone' pulses

SumSta21 echograms ($2.5 \text{ GSa/s} \Rightarrow \delta(z) \sim 4 \text{ cm/sample}$)



cf: CReSIS: $16.6 \text{ ns} \Rightarrow \delta(z) \sim 1 \text{ m/sample}$

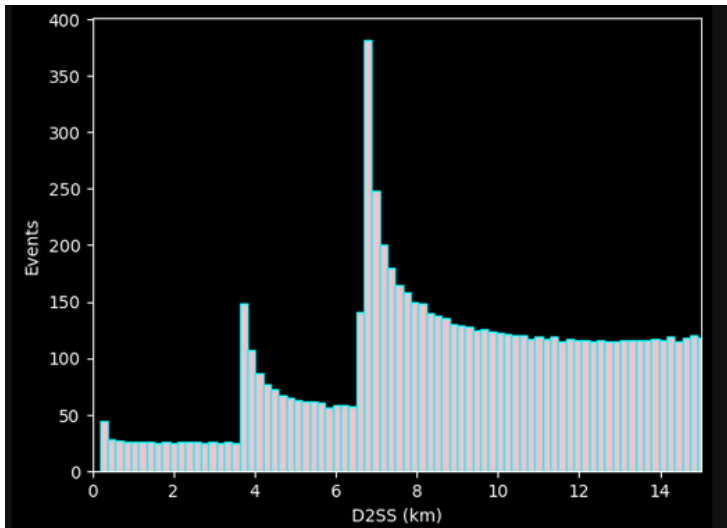
CReSIS Spatial Coverage

- Tx dipole/Rx dipole mounted on wings of plane (Basler); SAR for tones



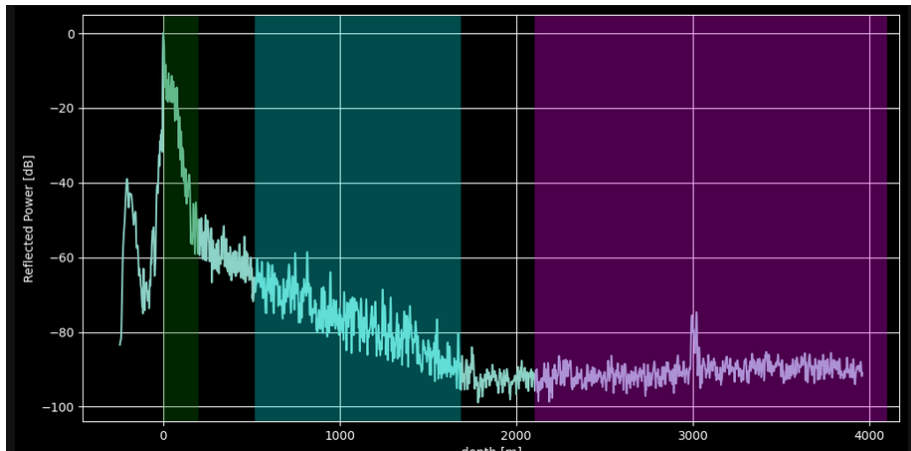
Echogram selection

- Sift through CReSIS data taken in the vicinity of Summit, and look at all echograms within 10 km of Summit:



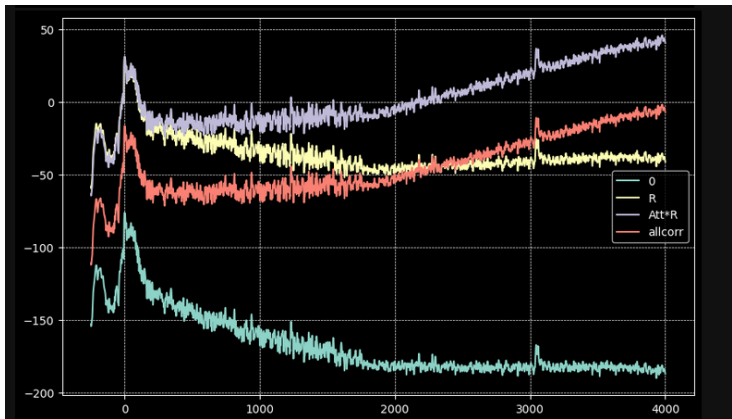
Typical Echogram

- Early: Surface echo/LNA saturation; Intermediate 'good' returns; 'Echo-Free-Zone': DAQ-noise dominated

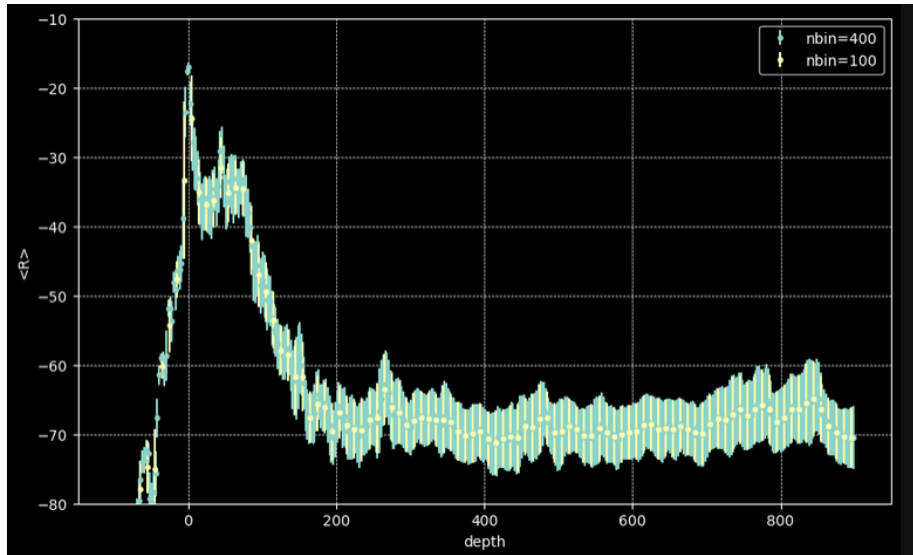


Corrections: $P \propto r^{-2}$; Attenuation; Focusing

1. $1/r^2$ in power; 2. $\langle L_{atten} \rangle \sim 400$ m; 3. $FF = (1.788/1.35)^2$
4. Since Tx power is unknown, normalize to surface echo: Elijah Paden measured $n_{surface} \sim 1.33$ by normalizing to over-ocean echo ($n \gg 1$) $\Rightarrow \mathcal{R}_{surf} \sim -17$ dB.

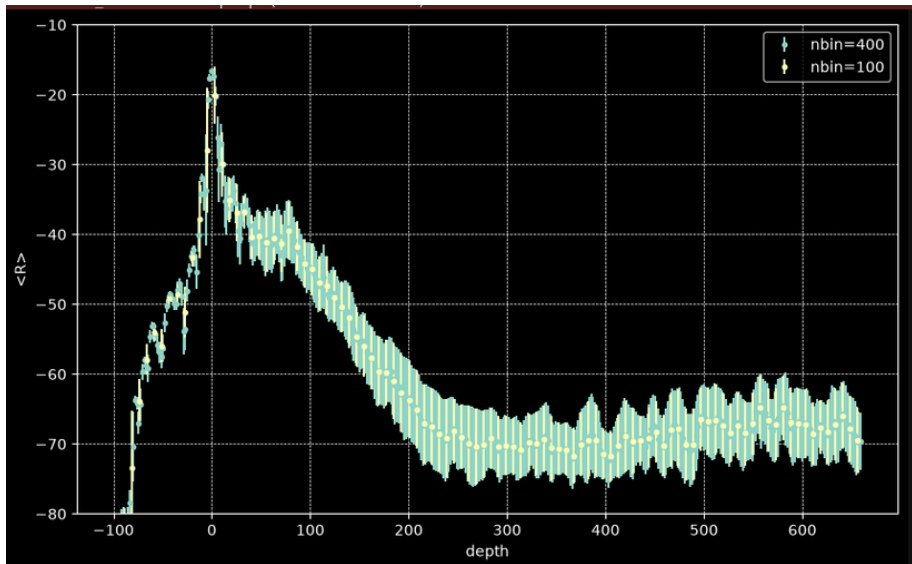


Post-corrections, 280 m layer (note $\mathcal{R}(z)$ flat)



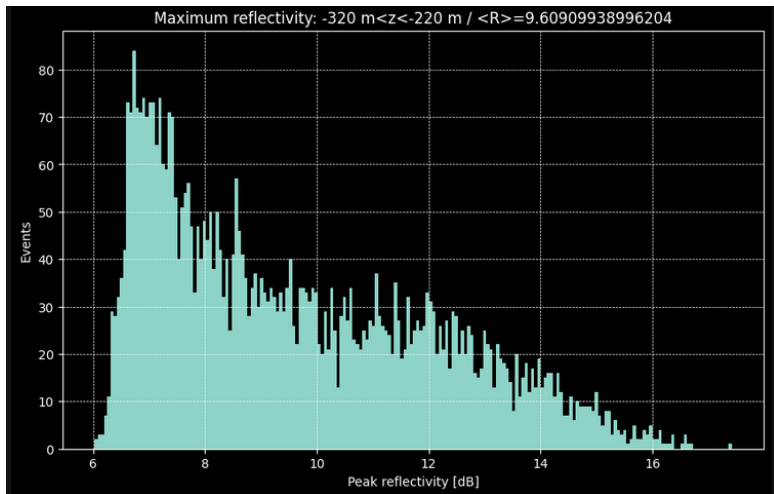
Raw $\langle R \rangle(280 \text{ m}) \sim -63.7 \pm 4.4 \text{ dB (stat)}$

South Pole



Depth variation of internal layers?

- Peak excess distribution over interval 220-320 m



Corrections/Systematics

- Normalization to surface echo:
 - Used $n_{surf}=1.35$; $n_{surf}=1.25 \Rightarrow$ reduces R by 2.6 dB
- Unfolding baseline power:
 - Signal ~ 5 dB above baseline $\Rightarrow$ reduce R by 0.5 dB
- Depth variation of reflector:
 - Suppose depth of echo changes by several meters $\Rightarrow$ averaging will reduce apparent peak value (also true of normalization echo) $\Rightarrow$ Upwards correction to $\langle R \rangle$ by 3.6 dB

$$\langle R \rangle \text{ (all corr)} = -62 \pm 4.4 \pm 4.1 \text{ dB}$$

Aside: consider normalizing to bedrock; Internal layer -52 dB wrt bed echo; if $\mathcal{R}_{bed} = -6$ dB $\Rightarrow \mathcal{R}_{bed} \sim -58$ dB

Summary and conclusions

- CReSIS measurements at both the South Pole and Greenland indicate that absolute reflectivity of internal layers $\sim -65 \rightarrow -60$ dB.
- So, upward reflections of Askaryan signals from impacting air shower cores, off internal layers not likely to be significant background for radio neutrino experiments.
- TBD and caveats
 - Are there reflectors shallower than 280 m?
 - Experimentally, typically 'lost' in surface echo. (may require dedicated data-taking; no Rx amplifier, FID $\rightarrow$ horn Tx; horn Rx)
 - Reflected Signal amplitude observed to vary with azimuth, and correlated with ice flow direction at South Pole. Here, have averaged over all directions.