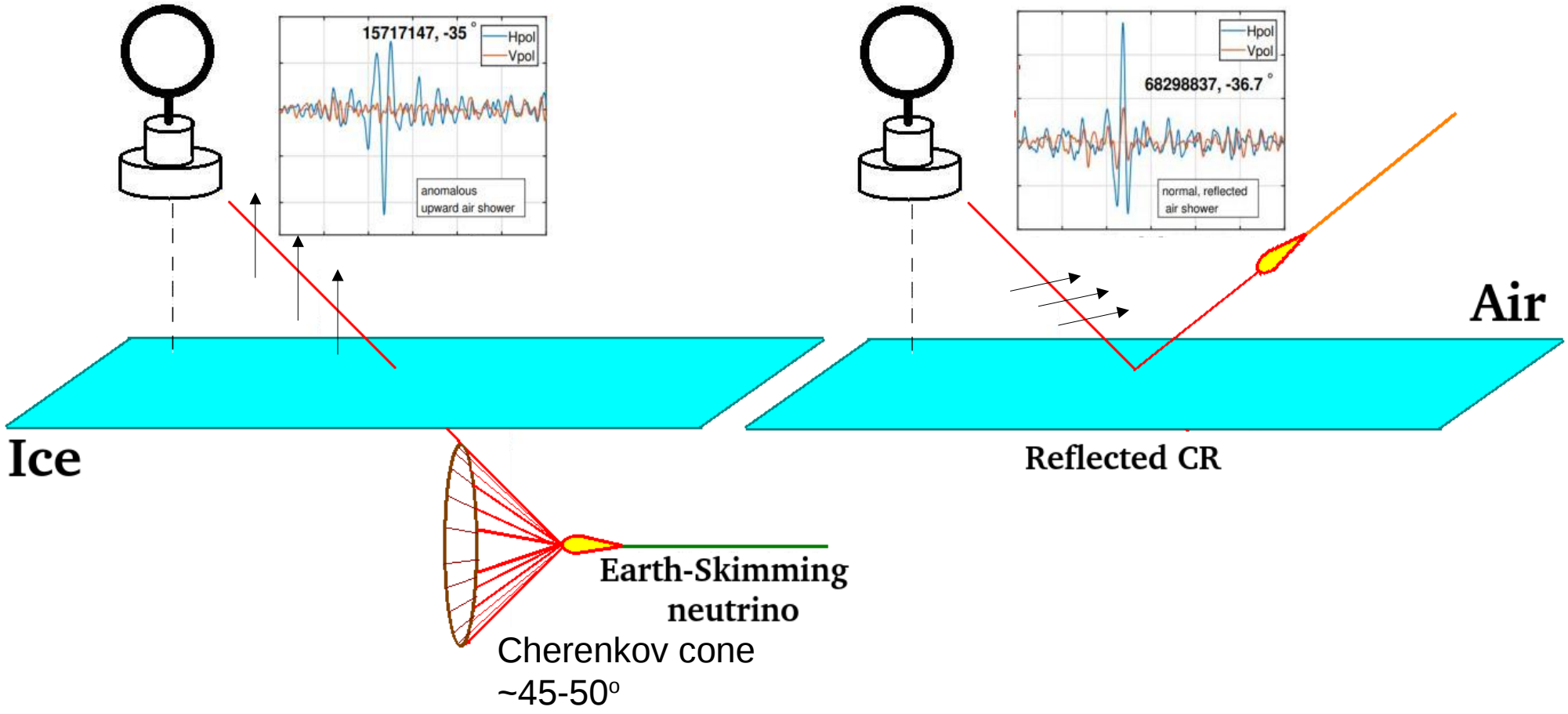
Status of ANITA and HiCal Experiments

- Brief introduction to science:
  - Ultra-High Energy Cosmic Rays and UHECR neutrinos
    - Yakutsk/TA/Auger-energy scales
- Experimental Scheme:
  - Detection of collective coherent radio waves emitted by particles in electromagnetic in-ice cascade
    - Gürgen Askaryan (1961, INR Moscow)
- ANITA Neutrino Search for signals from balloon in Antarctica
  - zero neutrinos observed, but best limits for $E > 10^{19}$ EeV (beyond cosmogenic peak)
- UHECR Search: approximately 100 UHECR observed to date via radio
  - Two reported 'Mystery Events' with 'wrong polarity'
  - HiCal experiment (MEPhI/KU) designed to calibrate ANITA Mystery Events
  - Maybe not-so-mysterious after all...

Signal Type (Neutrino VS. EAS)

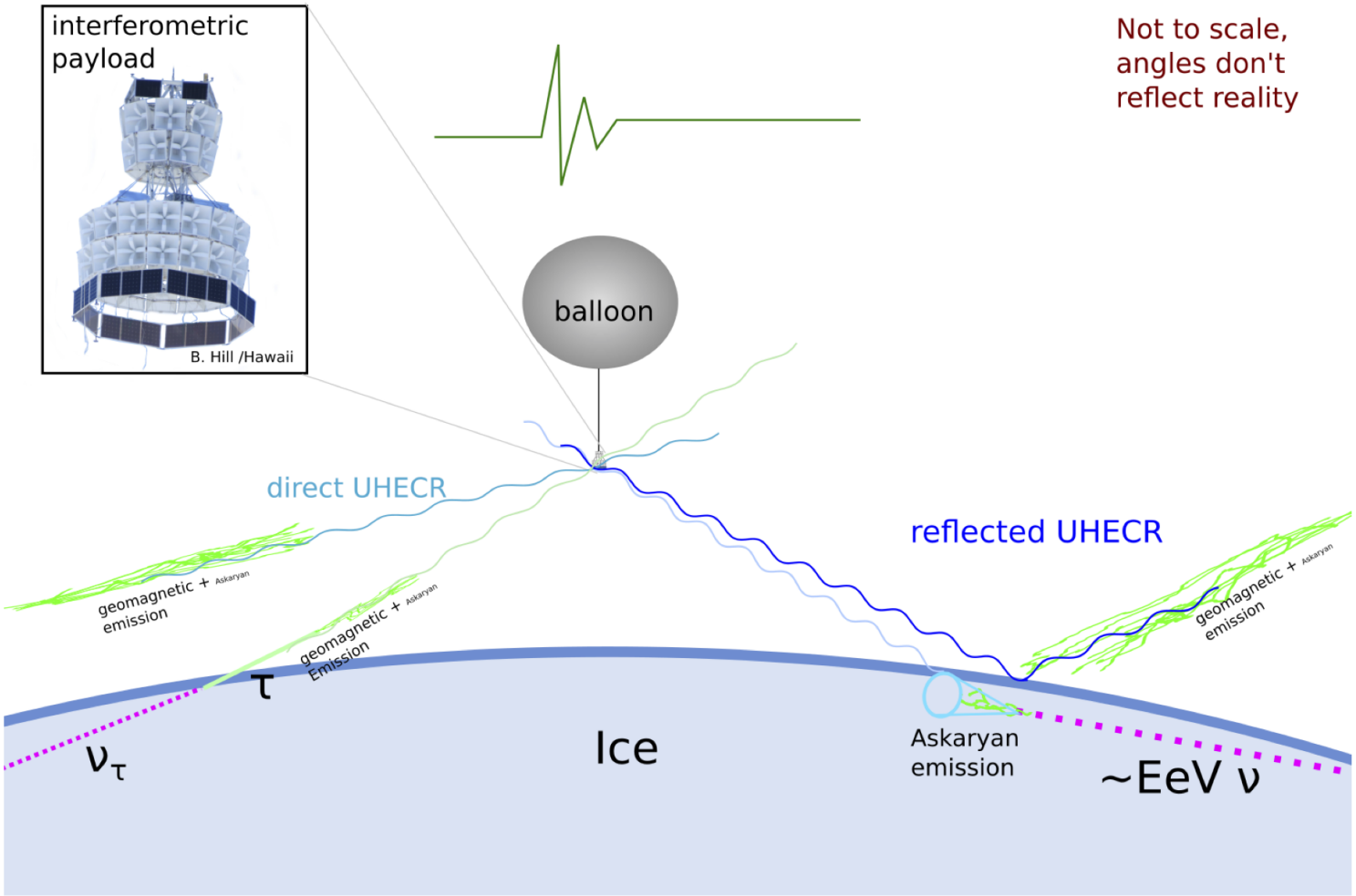


Askaryan radiation

Geomagntic radiation

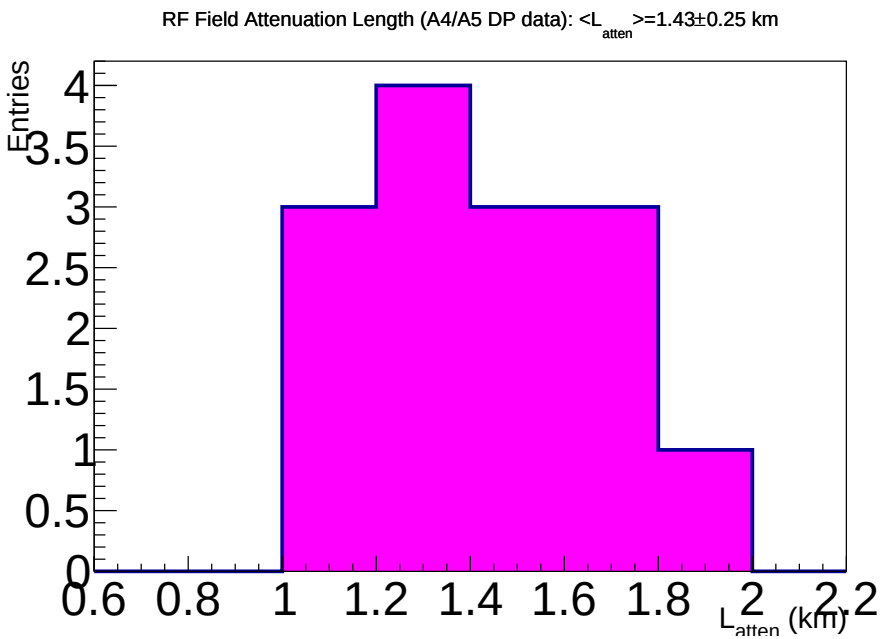
UHECR and ν have opposite signal polarity!

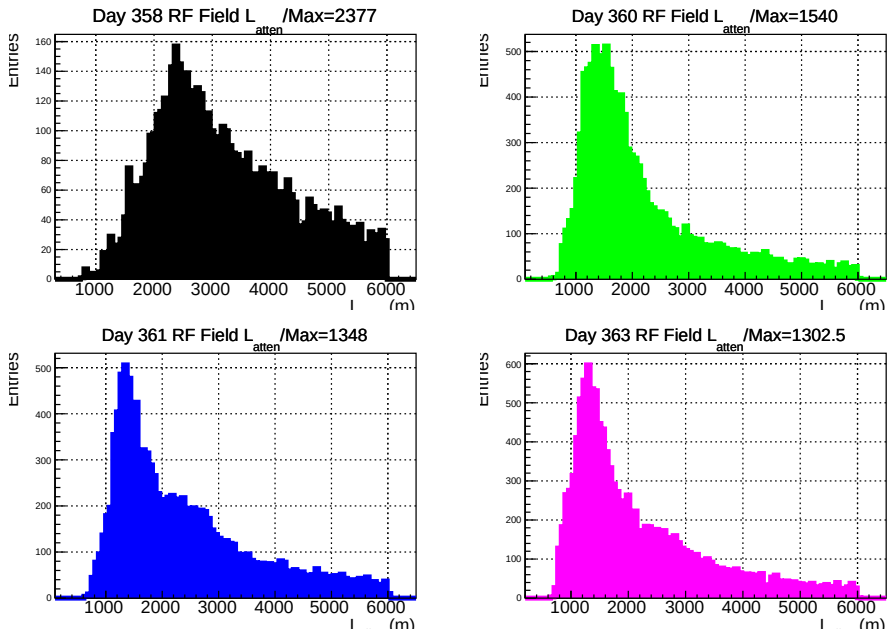
(due to inversion after surface reflection of UHECR)



Scan Antarctic ice (low-noise environment)

1–2 km RF attenuation length!

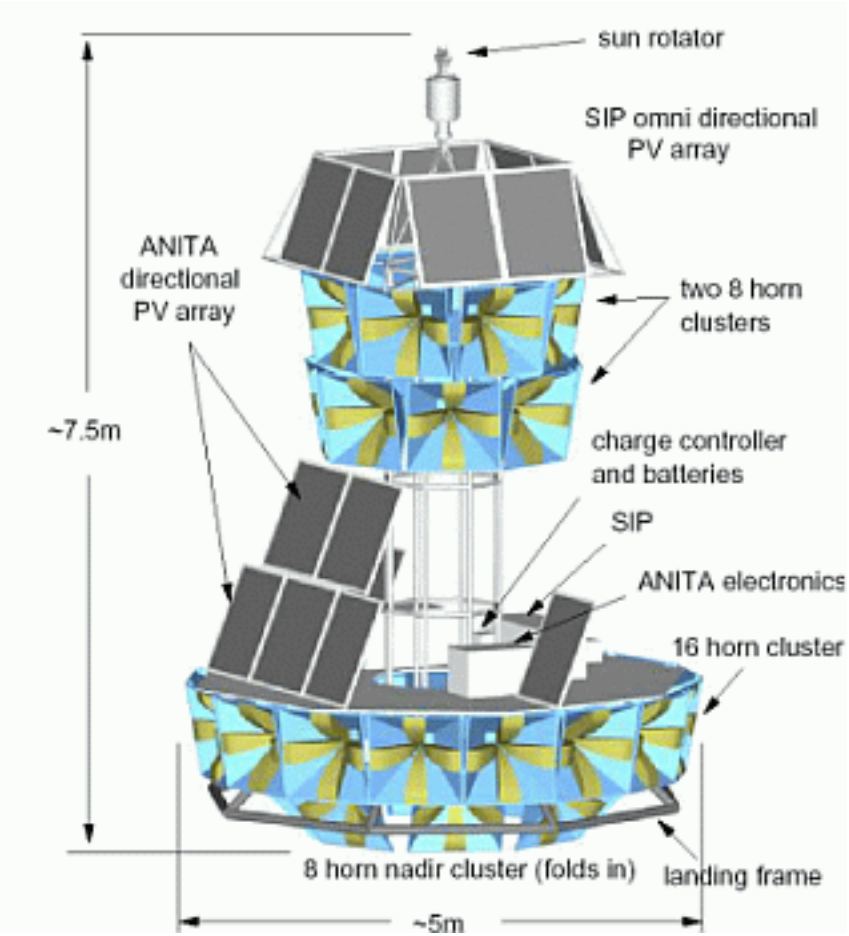




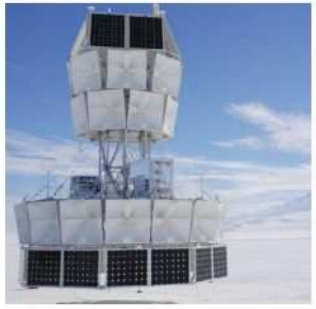
Measurements made at South Pole in December, 2018 using MEPhI/KU-built radio-frequency transmitter (SPUNK) - observed after traversing 4 km of solid ice!

Compare near-station signal to far-station signal amplitude

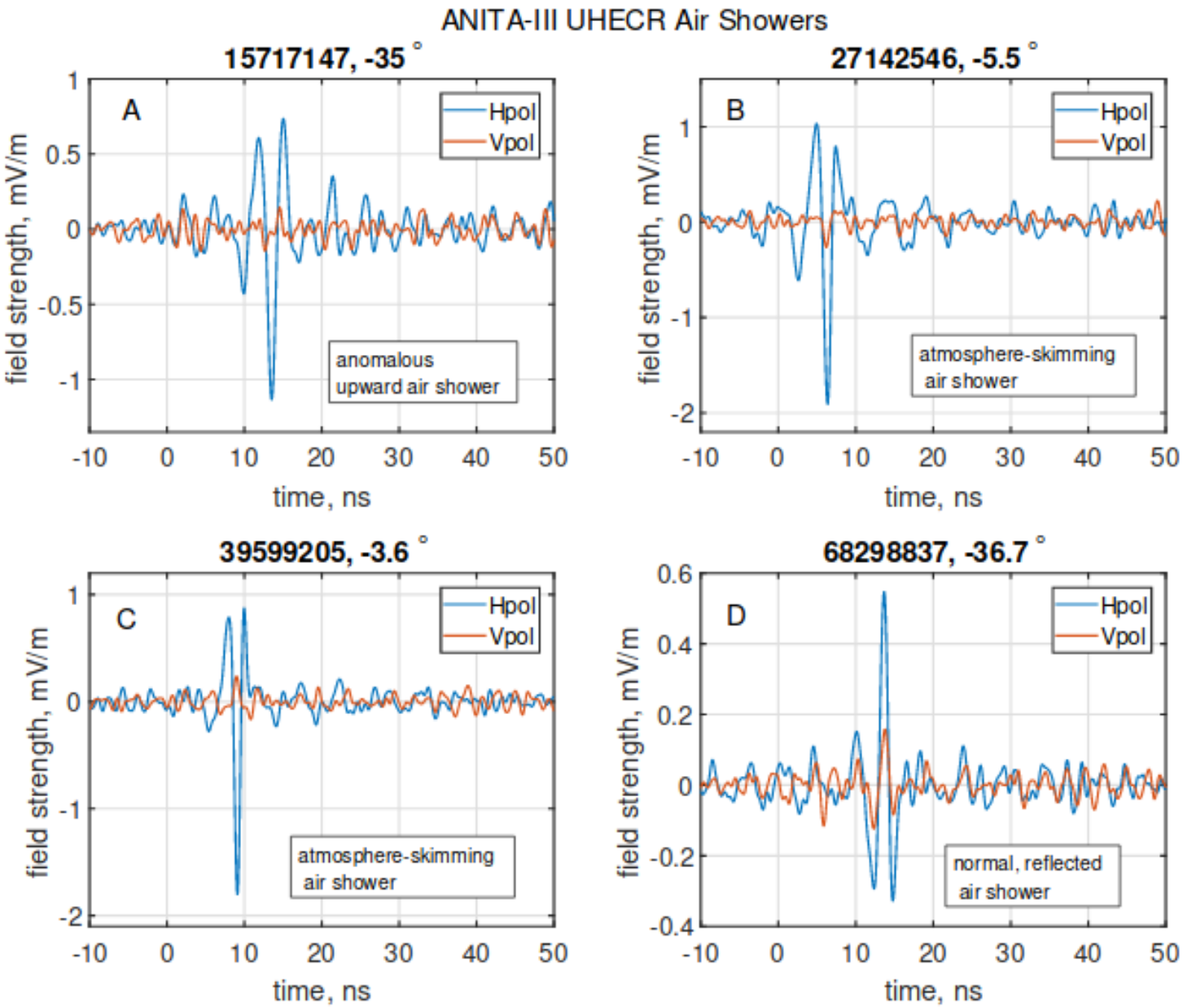
The ANITA Instrument



ANITAs

ANITA-Lite	ANITA-I	ANITA-II	**ANITA-III**	ANITA-IV
				
2003-2004	2006-2007	2008-2009	2014-2015	2016
18 days, 2 antennas	35 days, 32 antennas	30 days, 40 antennas	22 days, 48 antennas	29 days, 48 antennas
Piggy-back on TIGER	Multi-band, Pol-independent trigger	Multi-band, VPol trigger	Full-band HPol + VPol trigger	Full-band, Lin-Pol trigger
Analyzed	Analyzed	Analyzed	**Recently analyzed**	Analysis Ongoing

A3 Mystery Evt (15717147 vs. 68298837)



Explanations (last 6 mos. only!)

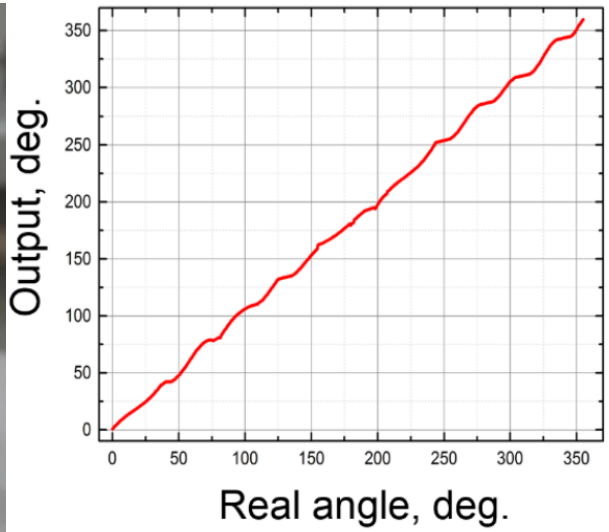
arXiv:1905.13223: Explaining the ANITA Anomaly with Inelastic Boosted Dark Matter, Lucien Heurtier et al
arXiv:1905.02846: Reflections On the Anomalous ANITA Events: The Antarctic Subsurface as a Possible Explanation, Andrew Romero-Wolf et al
arXiv:1904.13396: Can the ANITA anomalous events be due to new physics? J. Cline et al
arXiv:1904.12865: Superheavy Dark Matter and ANITA's Anomalous Events, D. Hooper et al
arXiv:1903.08750: Coherent transition radiation from the geomagnetically-induced current in cosmic-ray air showers: Implications for the anomalous events observed by ANITA, K. deVries and S. Prohira
arXiv:1902.04584: A Dark Matter Interpretation of the ANITA Anomalous Events, L. Heurtier et al
arXiv:1812.01520: Supersymmetric sphaleron configurations as the origin of the perplexing ANITA events, L. Anchordoqui et al

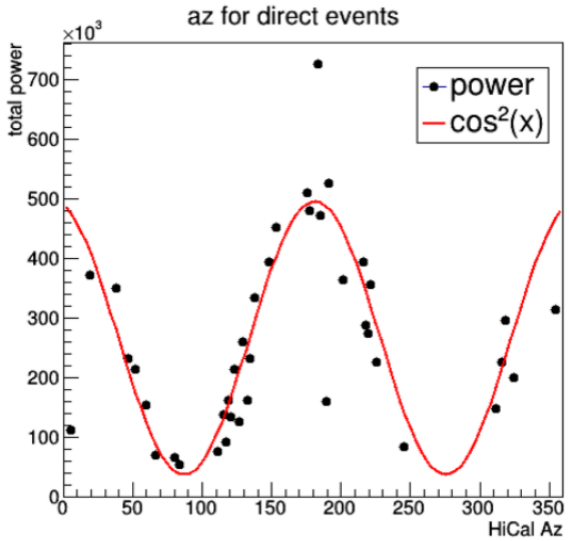
CAUTION!!

- 'Mystery' based on only one observable (POLARITY)!
- Waveforms are shown to public only after unfolding ANITA detector response
  - All band-limited signals look identical!
  - Mystery events otherwise indistinguishable from UHECR in FFT, etc.
- Antarctic surface (and sub-surface) not monolithic!
  - Ridges, crevasses, etc.
- Radio from UHECR hitting surface is also accompanied by
  - "Transition radiation"
  - "Stopping radiation"
  - "There are more things in heaven and Earth than are dreamed of in your philosophy" (Hamlet)

HiCal (MEPhI/KU) calibrates surface reflections

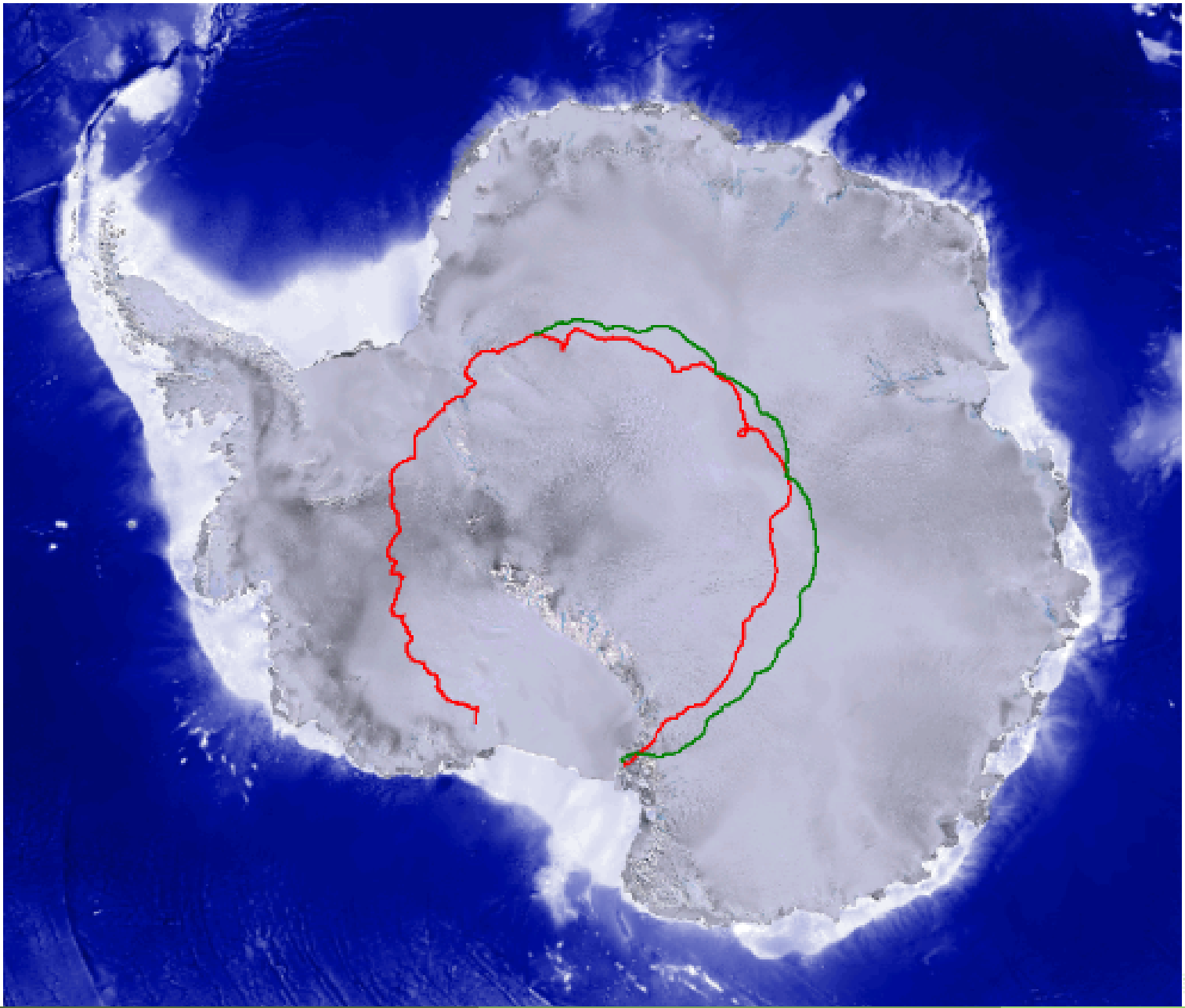
Balloon-borne (barbeque-lighter) transmitter separated from ANITA by 200–800 km.



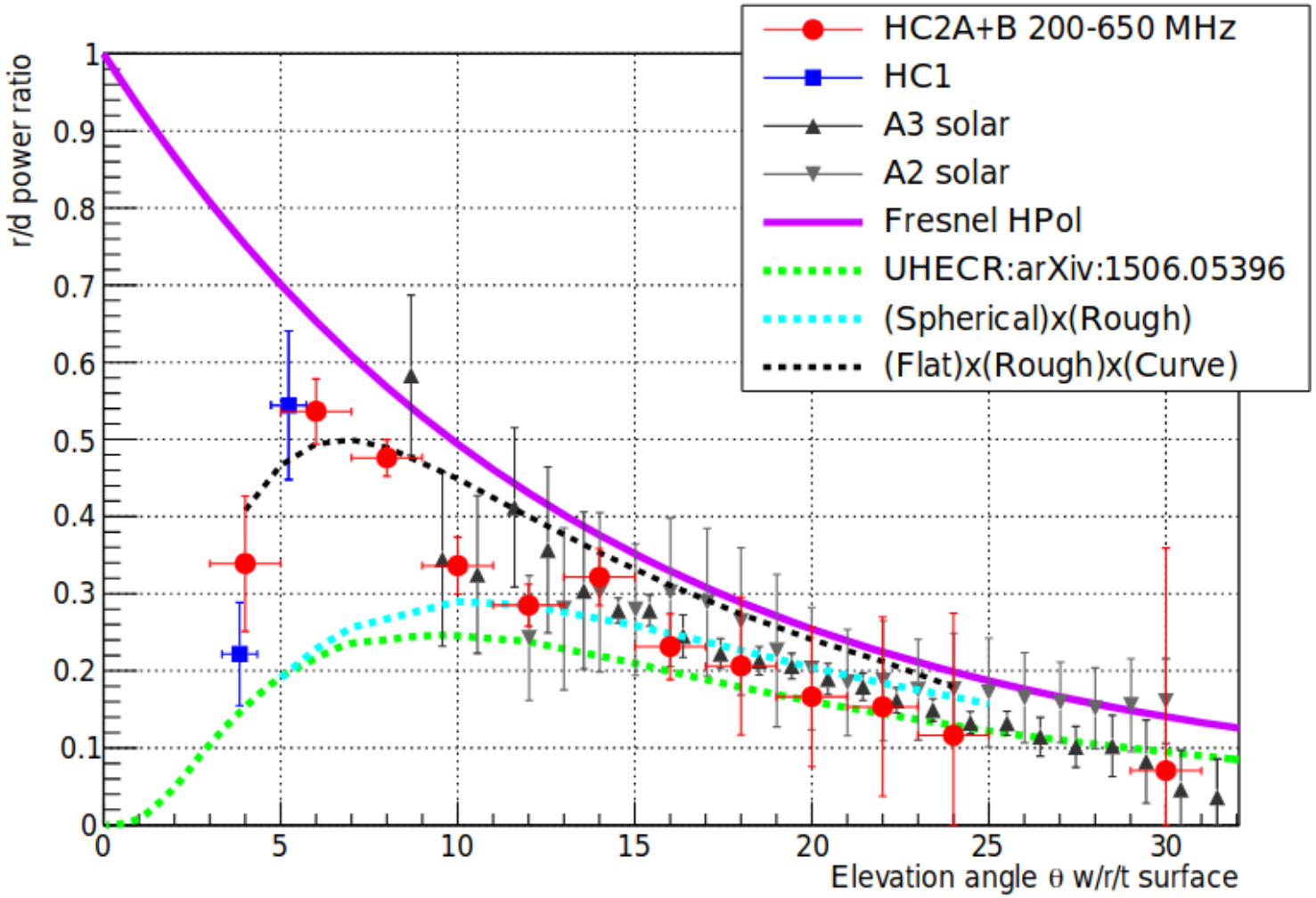


SPUNK Transmitter orientation measurements

HiCal-A and -B 38 km altitude flights (Dec, 2016)



Calibrate surface reflectivity to Expectation

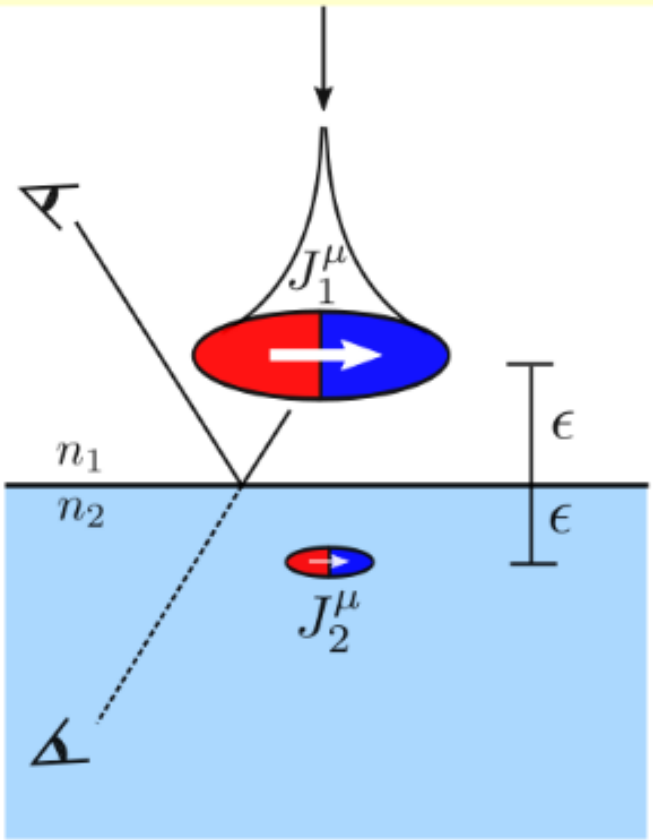


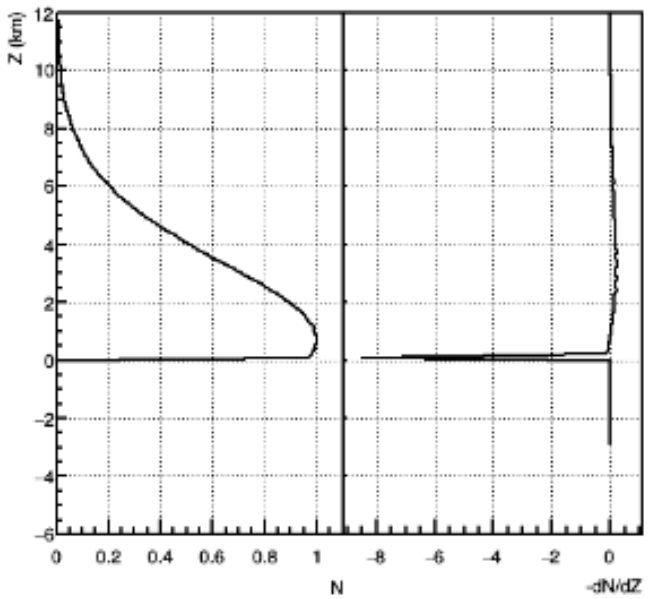
Tagline: Wrong polarity likelihood $<1\%$ per CR

Conventional explanation for mystery events

transverse current

- significant current arrives at air/ice boundary if:
  - energies >= 1e17 eV and
  - zenith angles < 70 degees
- AND amount of charge increases dramatically with high surface elevations





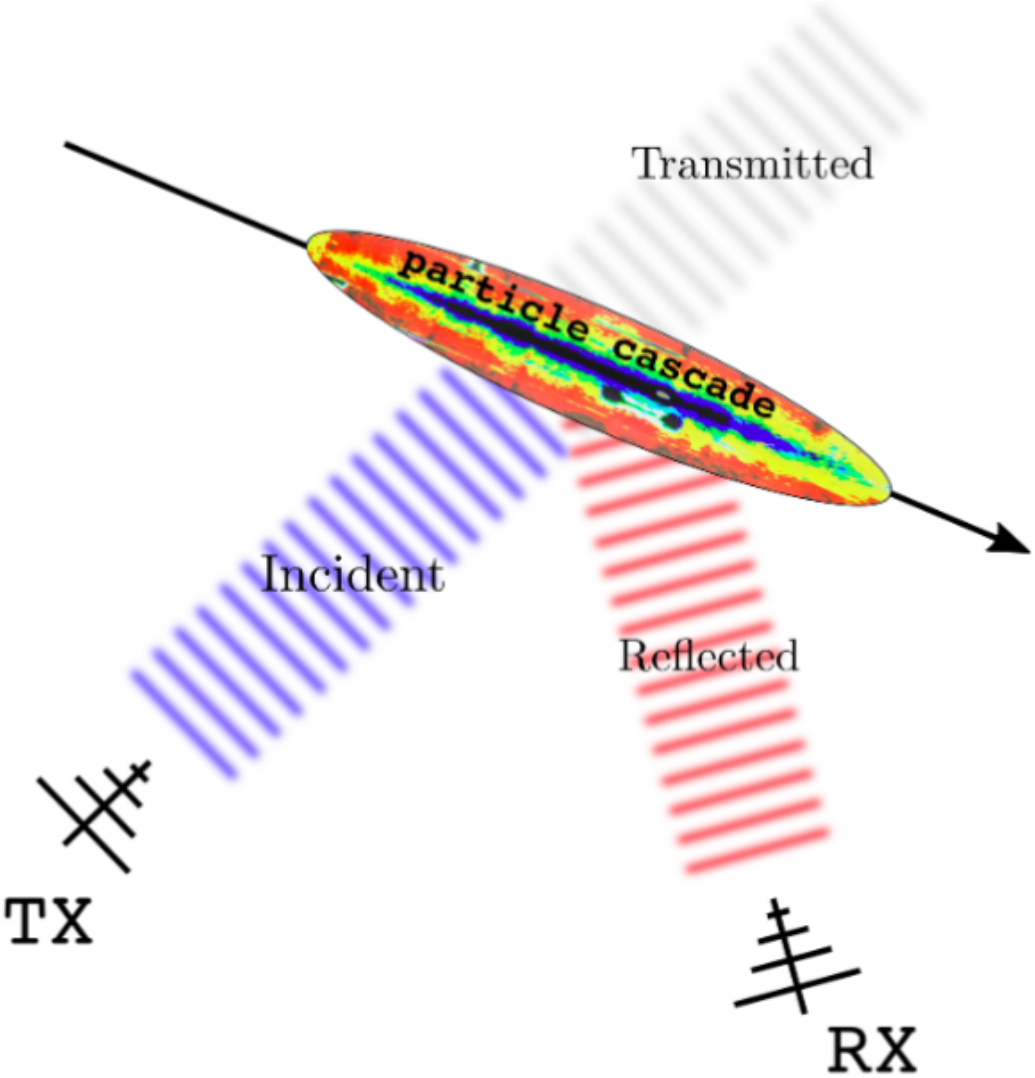
ex: 50 deg shower @ 3km elevation

- the transverse current, as well as the path itself *vanishes* resulting in a strong shock in the potential
  - producing the corresponding E-field
  - polarized along geomagnetic

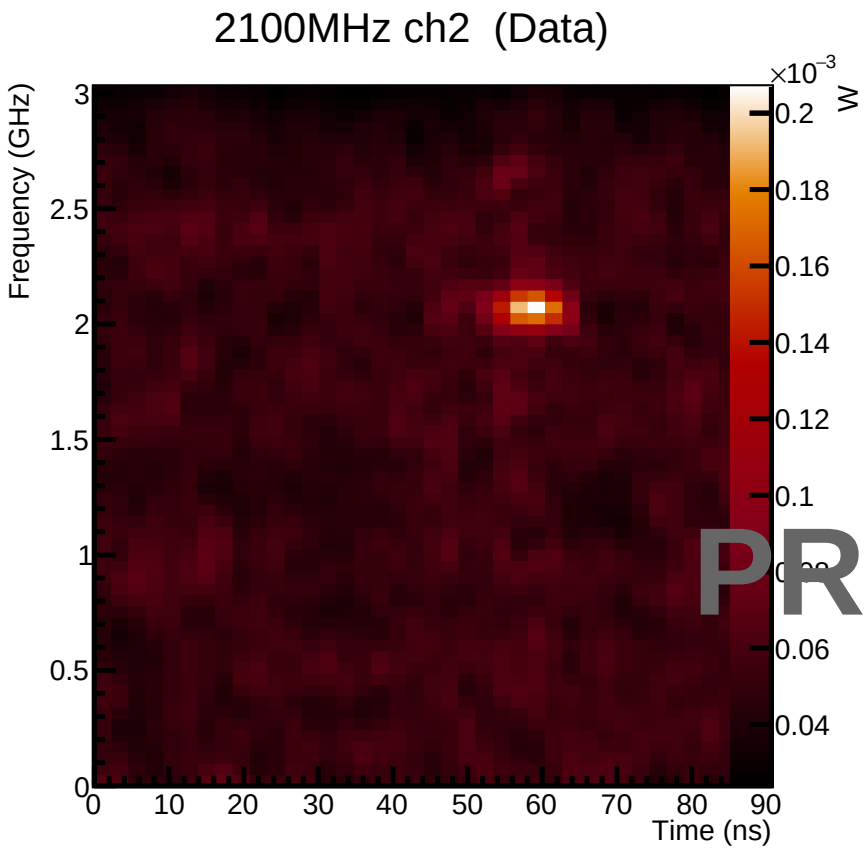
4 March 19 coherent TR--S Prohira--K.D. de Vries

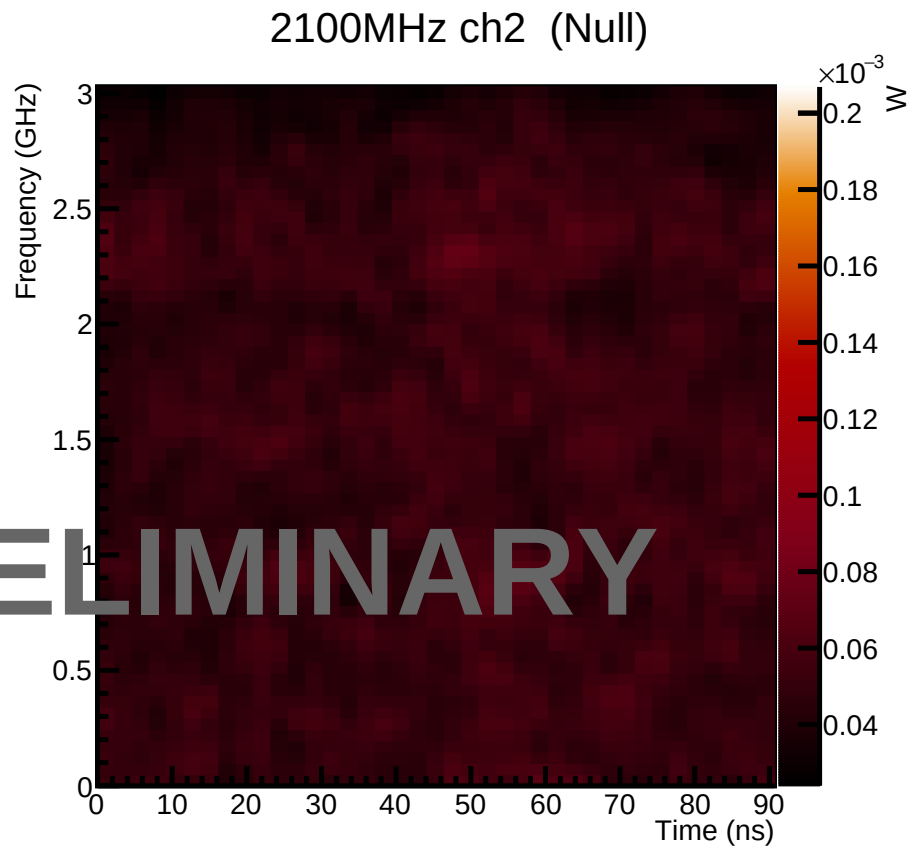
Future techniques: Reflect RF off in-ice shower plasma

RF from transmitter→in-ice shower→receiver (see Alisa Nozdrina poster)



October, 2018 SLAC TestBeam Results: Left: Tx On & Beam On/Right: Control Sample





Summary and Plans

- ANITA-IV = last flight in ANITA series
- Next-generation = PUEO ("Payload for Ultrahigh Energy Observations")
  - Interferometric beam-forming at trigger level
    - Reduce trigger threshold from SNR$\sim$6$\rightarrow$SNR$\sim$2 based on ARA experimence
- In concert - HiCal-3
  - Emphasize high-fidelity transmitter signal to provide high-statistics test of inversion probability
- Ancillary science: cross-correlation of Direct and Surface-reflected signals allows precision test of possible sub-surface reflectors
- Future techniques (radar, possible TR signals) also being explored