

RNO-G

Radio Neutrino Observatory - Greenland

RADAR ECHO TELESCOPE



ASKARYAN RADIO ARRAY

Highlights from the Radio Neutrino group

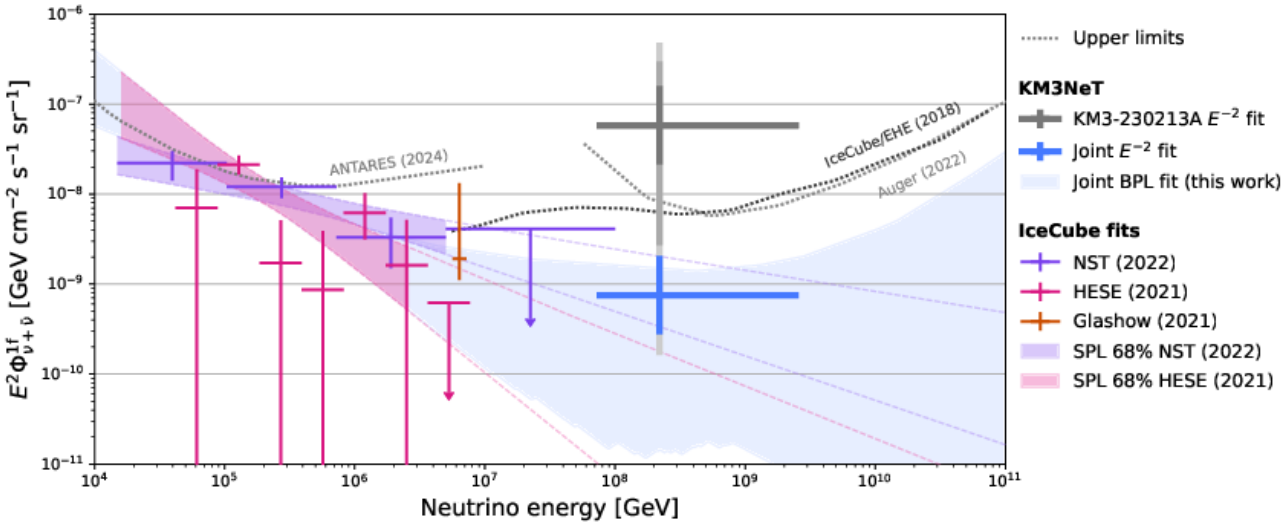
Dylan Frikken

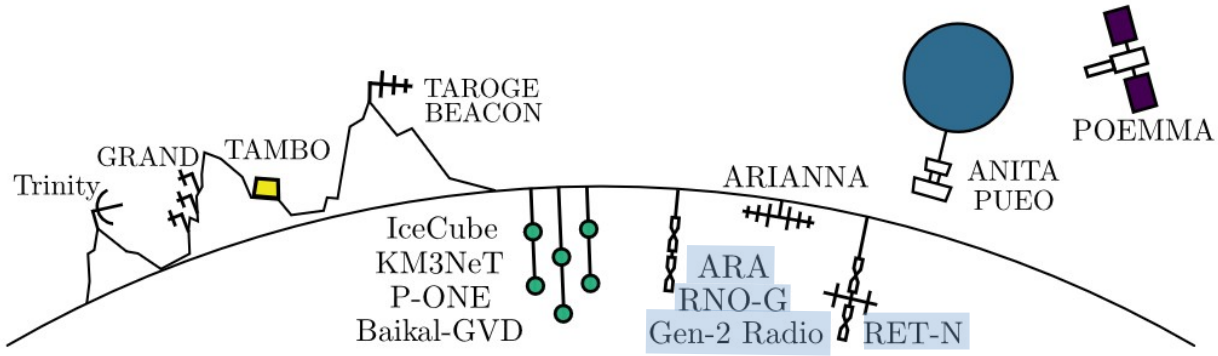
IIHE annual meeting 2026

iihe BRUXELLES BRUSSEL

Ultra-High-Energy (UHE) Neutrino Detectors

- **The neutrino flux drops rapidly with energy, so we need to build larger detectors to start detecting UHE neutrinos**
- **KM3-230213A broke the previous neutrino energy, but one single event is not enough to determine a flux above 10 PeV**
-

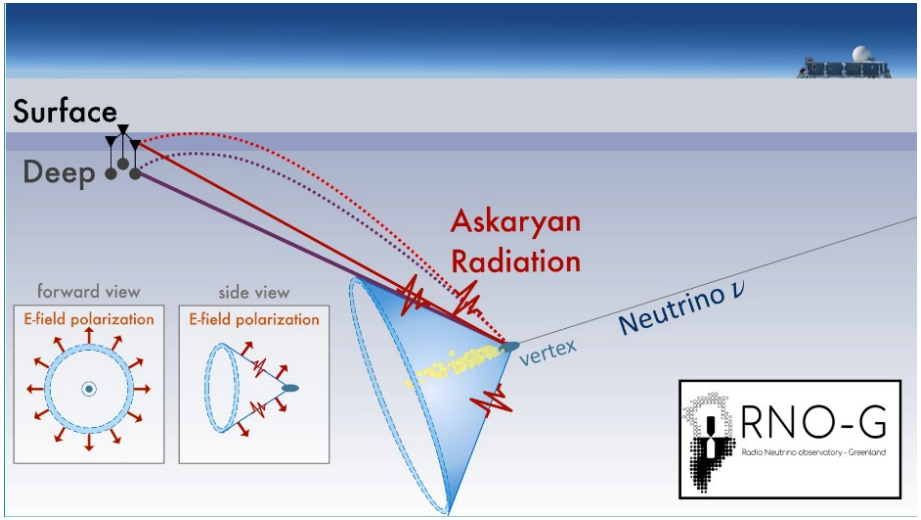




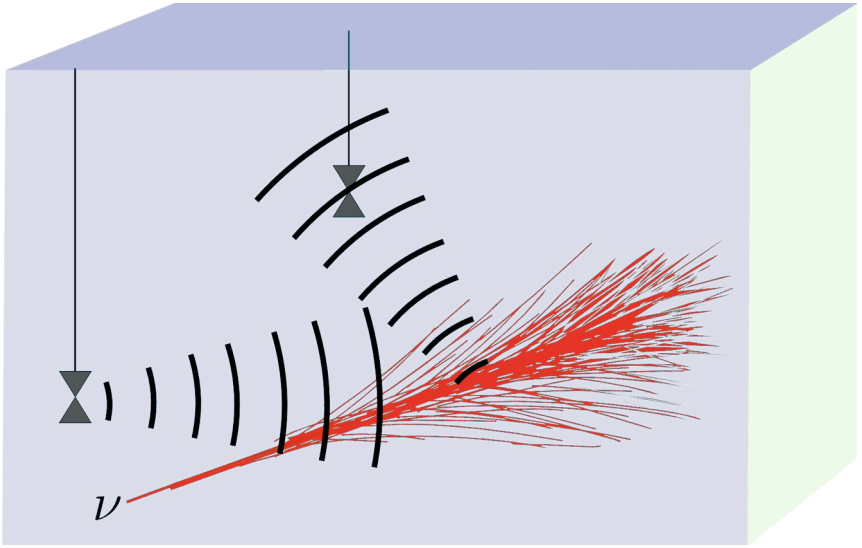
Ultra-High-Energy (UHE) Neutrino Detectors

- **Here in the IIHE, we employ two radio-based methods to instrument huge volumes of polar ice**
-

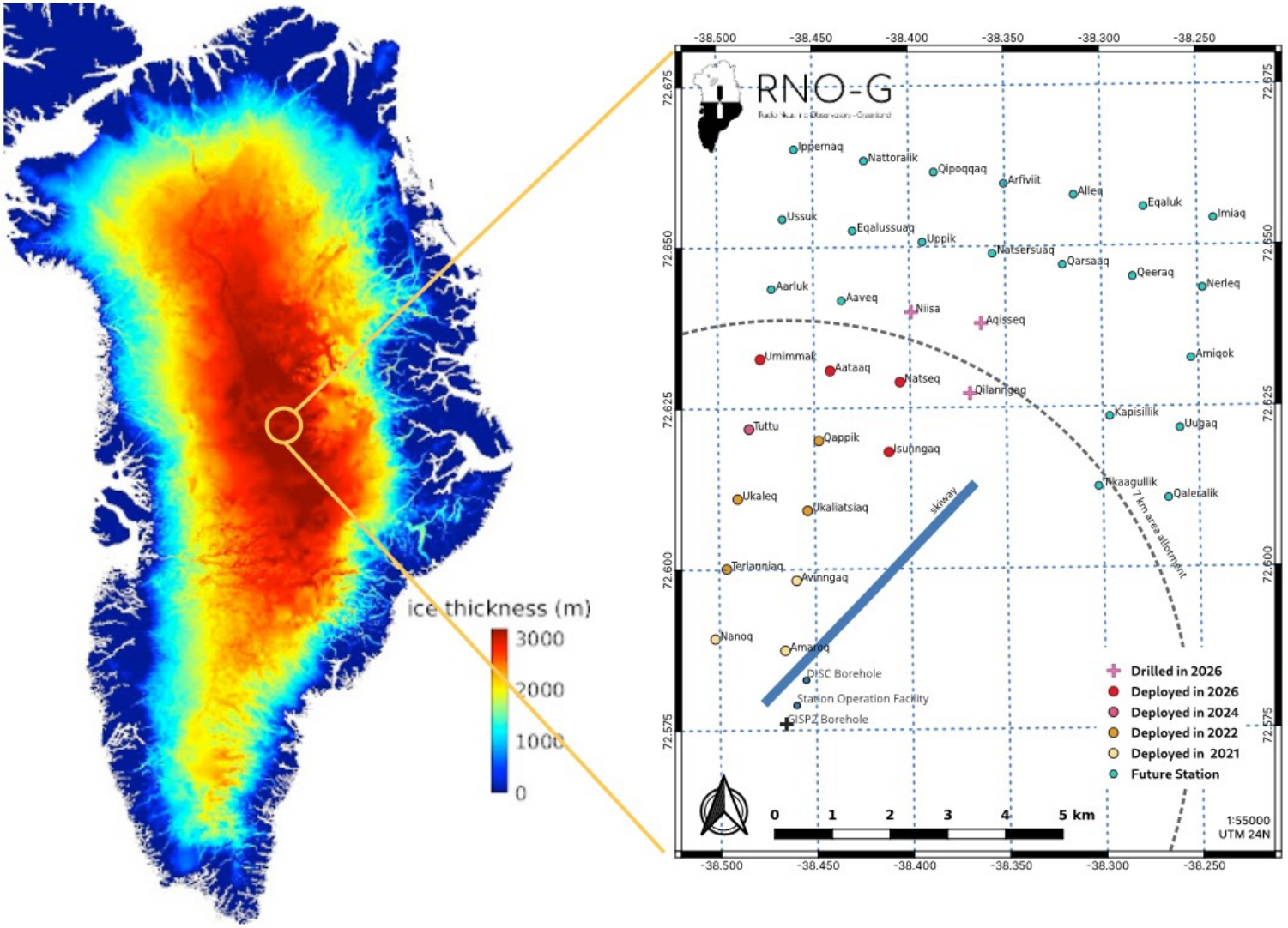
In-ice Askaryan (RNO-G, ARA)



In-ice Radar (RET)



Radio Neutrino Observatory Greenland (RNO-G)



35 stations on 1.25 km grid

- **12** stations already in operation
- Fully funded (23 more to go)
- Stations are all solar powered and send data over LTE
- Each station acts as independent detector

S. Toscano

Radio Neutrino Observatory Greenland (RNO-G)

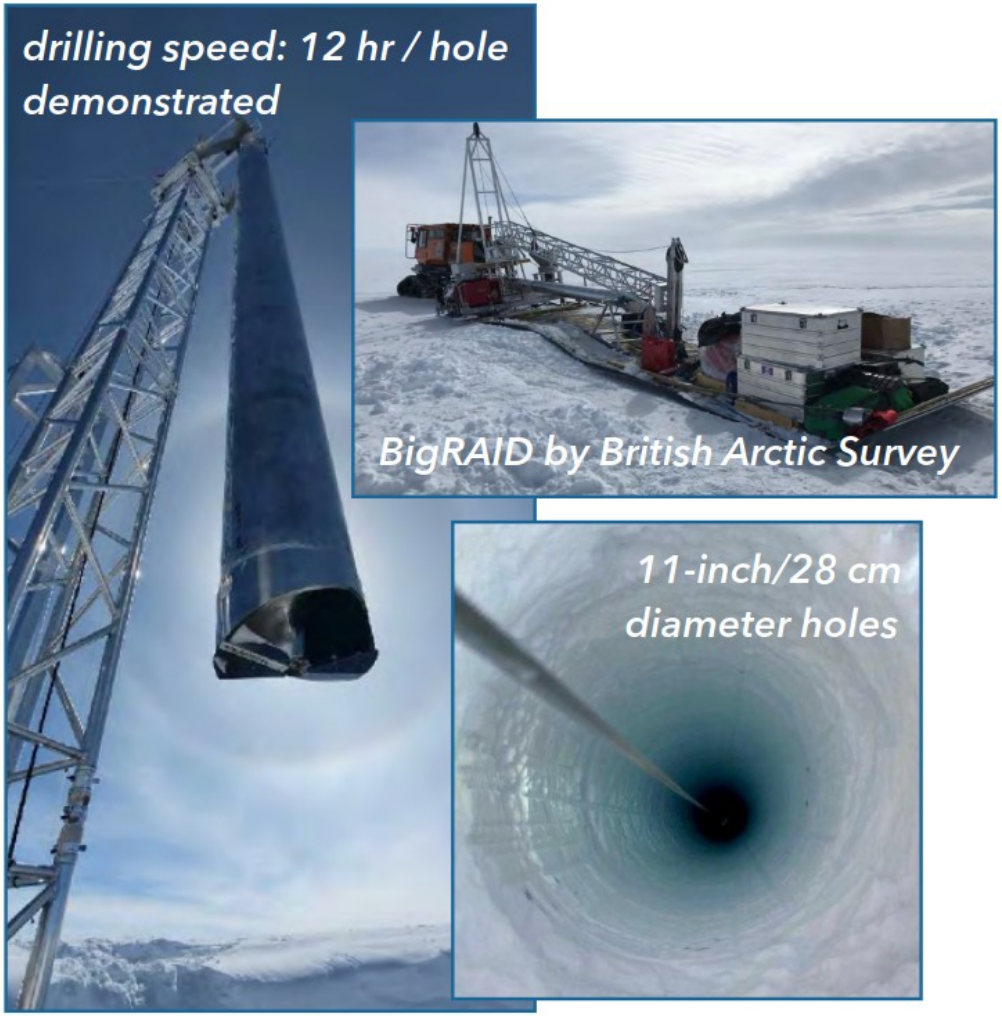
- Deployed 4 new stations and drilled an additional 3
- Deployed new DAQ
- Alex is taking over the RNO-G monitoring coordinator role
- Absolute gain calibration (Ruben,Felix,Gursharan)
- Cosmic ray analysis underway



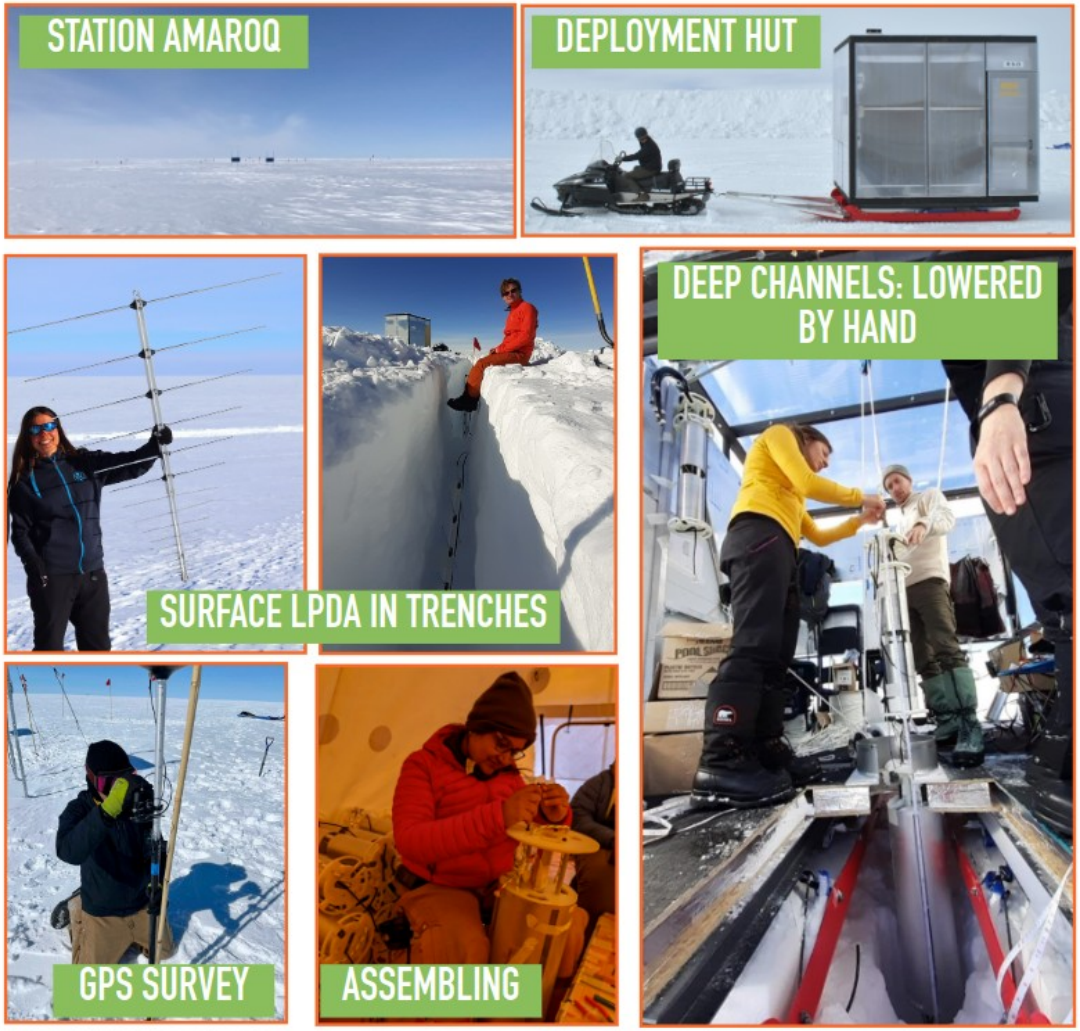


RNO-G Deployment 2026

3 stations drilled, to be installed in 2027



4 new stations installed



RNO-G Monitoring System

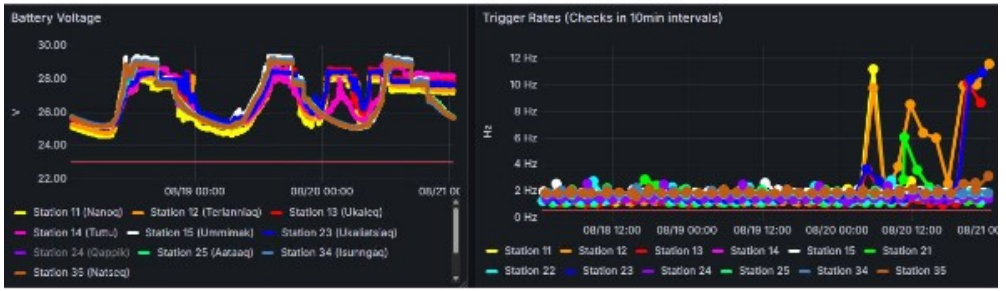
- **Knowing the real-time status of stations is crucial to:**
  - Quickly identify & address problems
  - Maximize duty cycle & physics data

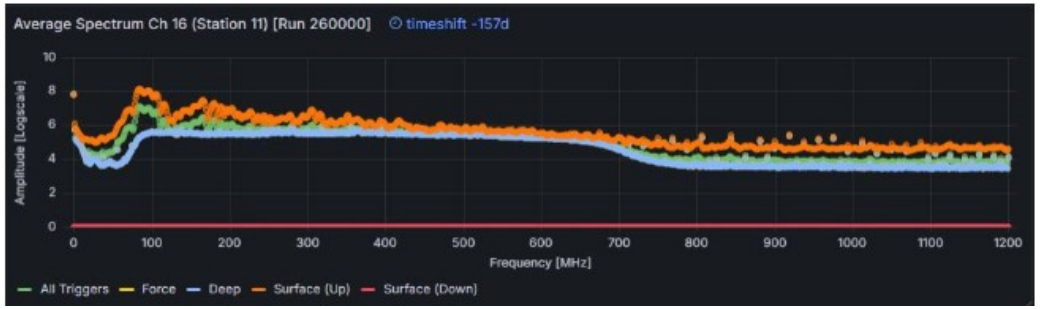
- **Live data visualization & alerts with Grafana:**
- Station electronics, wind turbines, battery voltage, LTE, trigger rates, weather data, flights and more

- **Monitoring lead now at IIHE:**
  - New winter monitoring dashboard
  - Integration of physics metadata: RMS, spectra





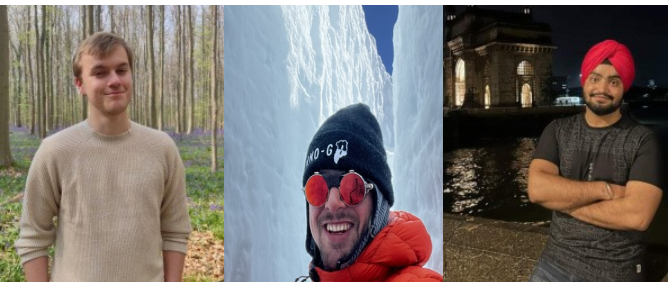






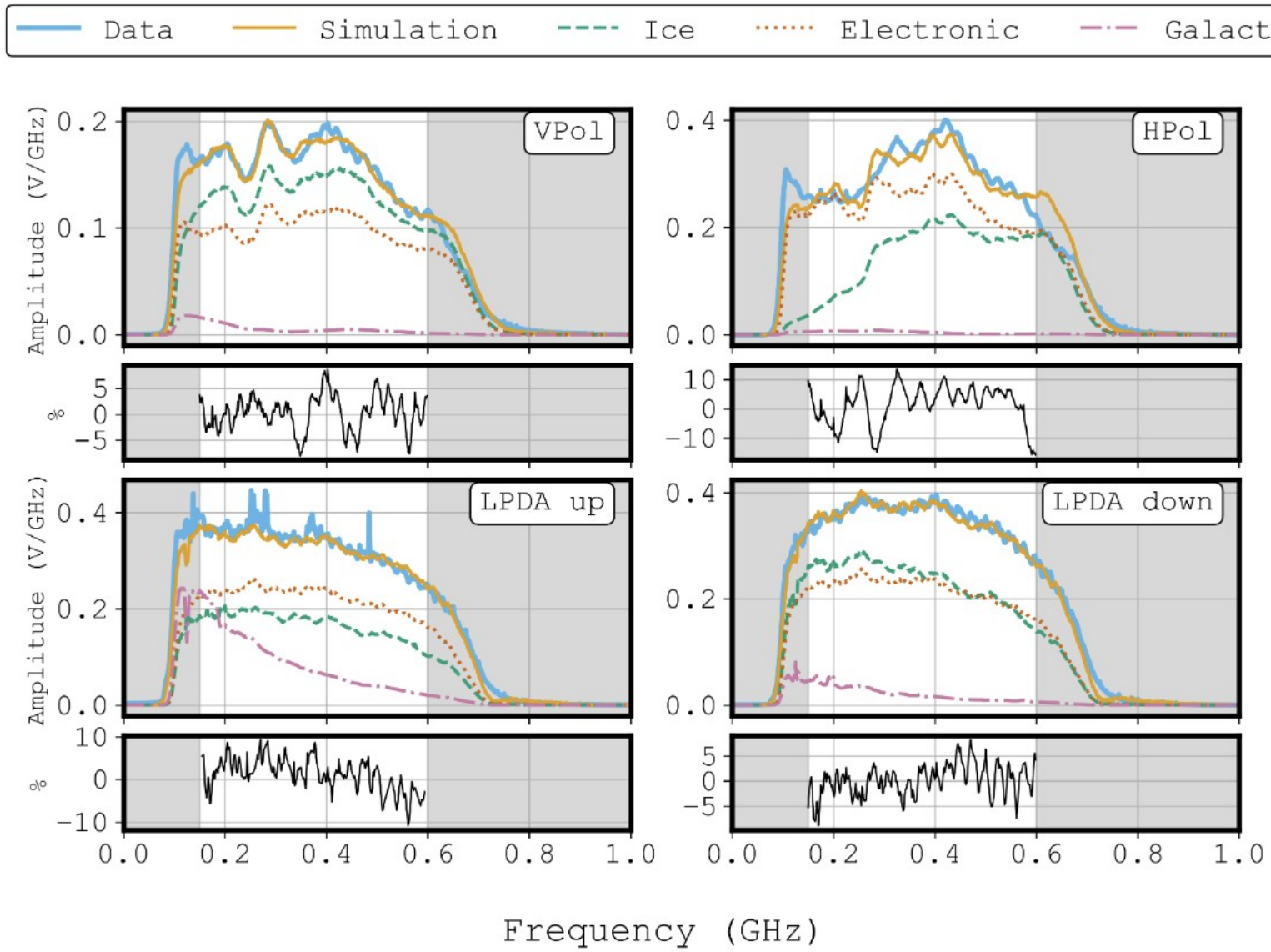
RNO-G Absolute Gain Calibration

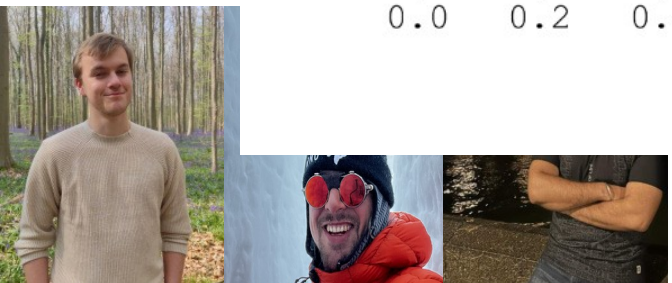
- A full chain simulation of all noise sources in RNO-G has been built here at IIHE, including galactic, thermal ice, and electronic noise.
- After folding the expected noise with the measured detector response and antenna patterns, we compare with forced triggered events from the deployed detector.
- We can then determine the absolute gain for each antenna in each station
- Publication is under internal review



RNO-G Absolute Gain Calibration

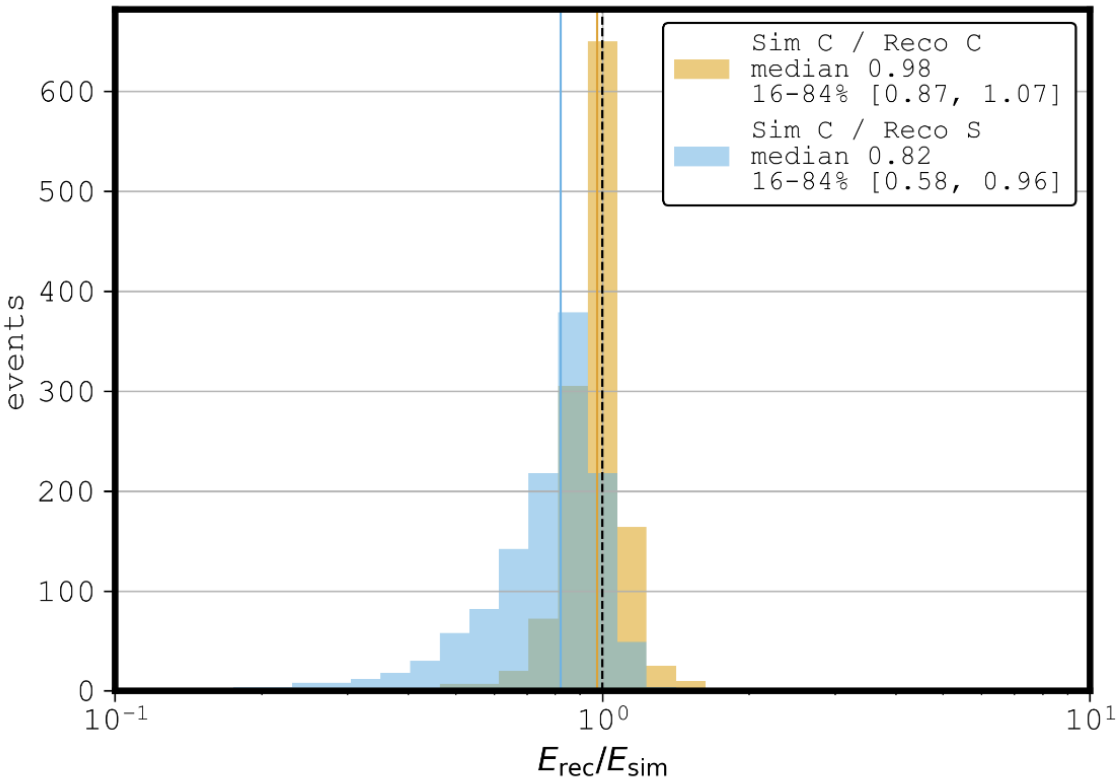
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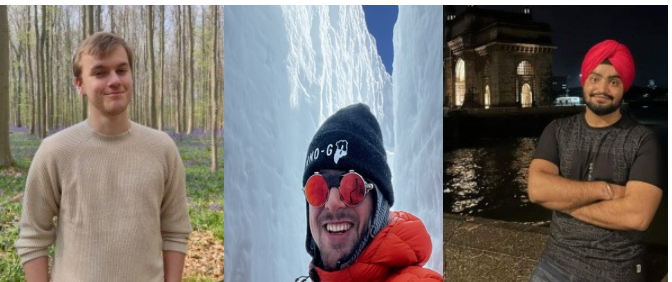




RNO-G Absolute Gain Calibration

- This gain calibration will ultimately improve the RNO-G reconstruction
- Here we show simulation results comparing the old calibration and the new IIHE led calibration

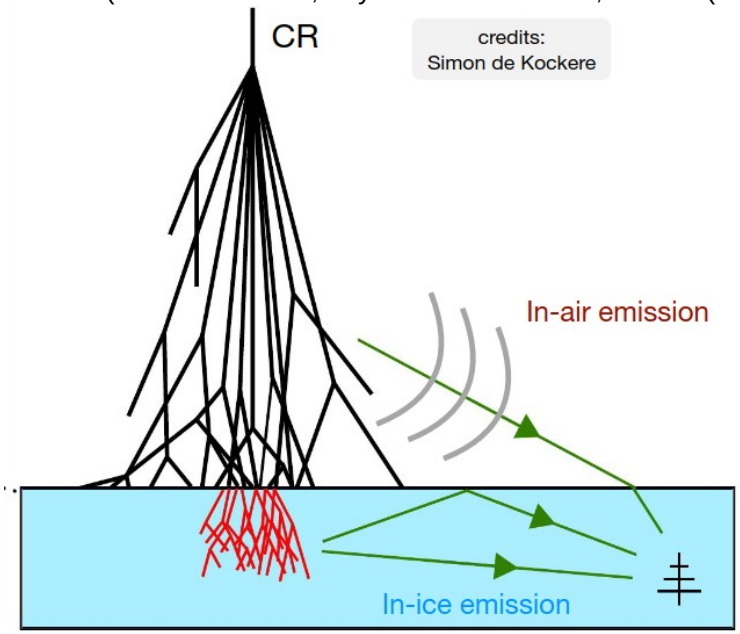




In-Ice Askaryan from Cosmic Rays

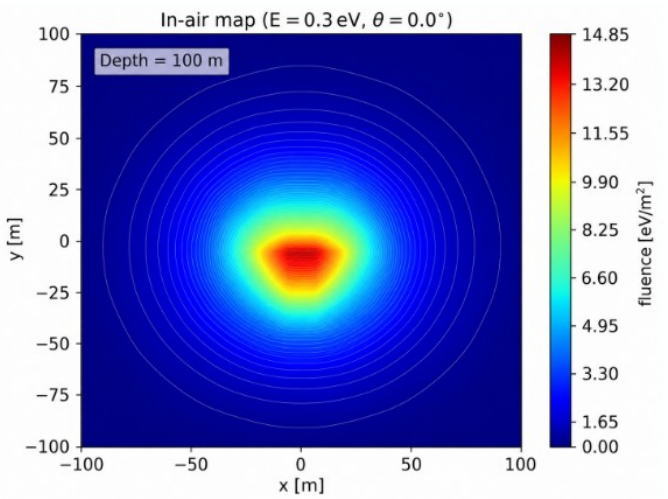
- **The main science background for in-ice radio neutrino detectors is the in-ice Askaryan signal created by UHE CR showers**
- **This signal is now well understood due to IIHE work on FAERIE**
- **UHE CR flux is much higher than UHE neutrino, so we aim to use this channel as an in-nature test beam of our experiment**

S. De Kockere (.D. Kockere et al, Physical Review D 110, 023010 (2024))

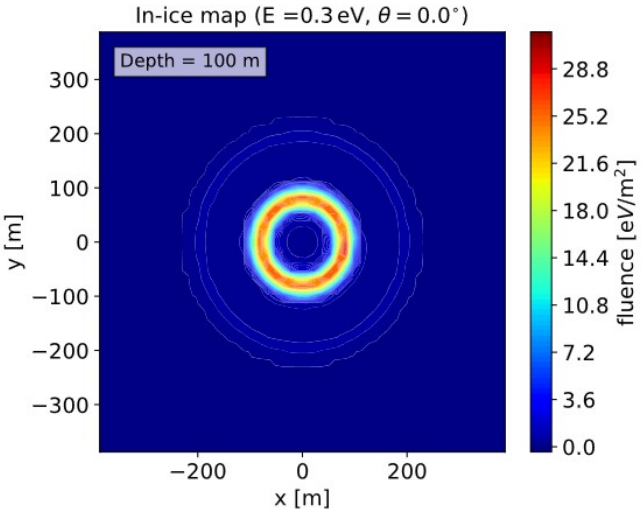




In-air



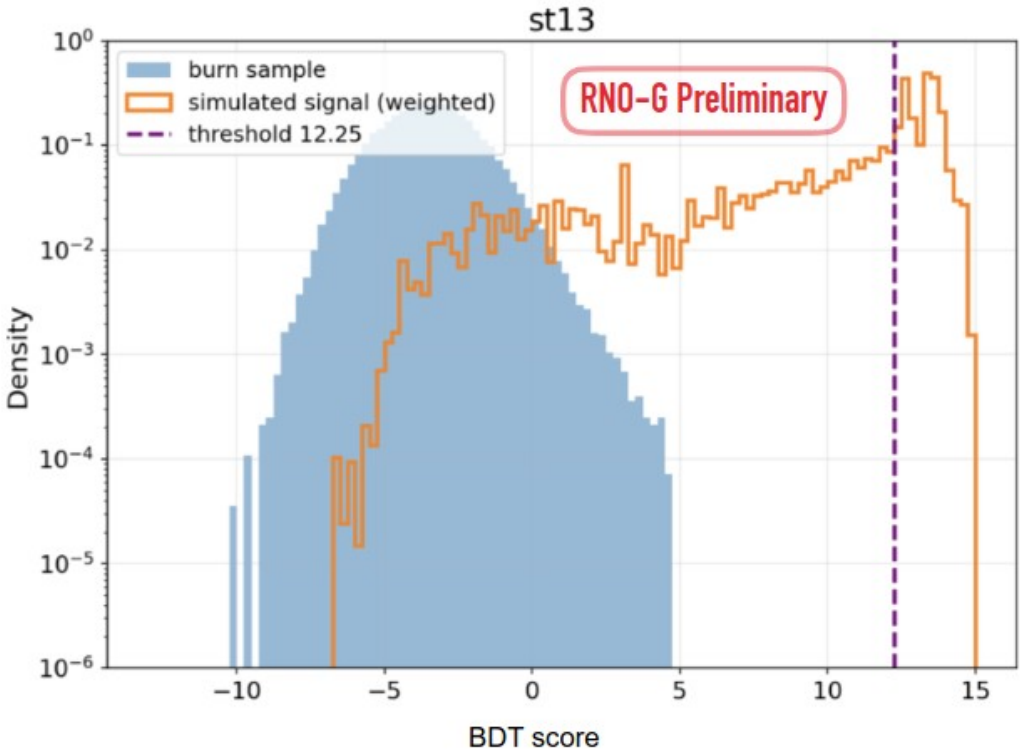
In-ice

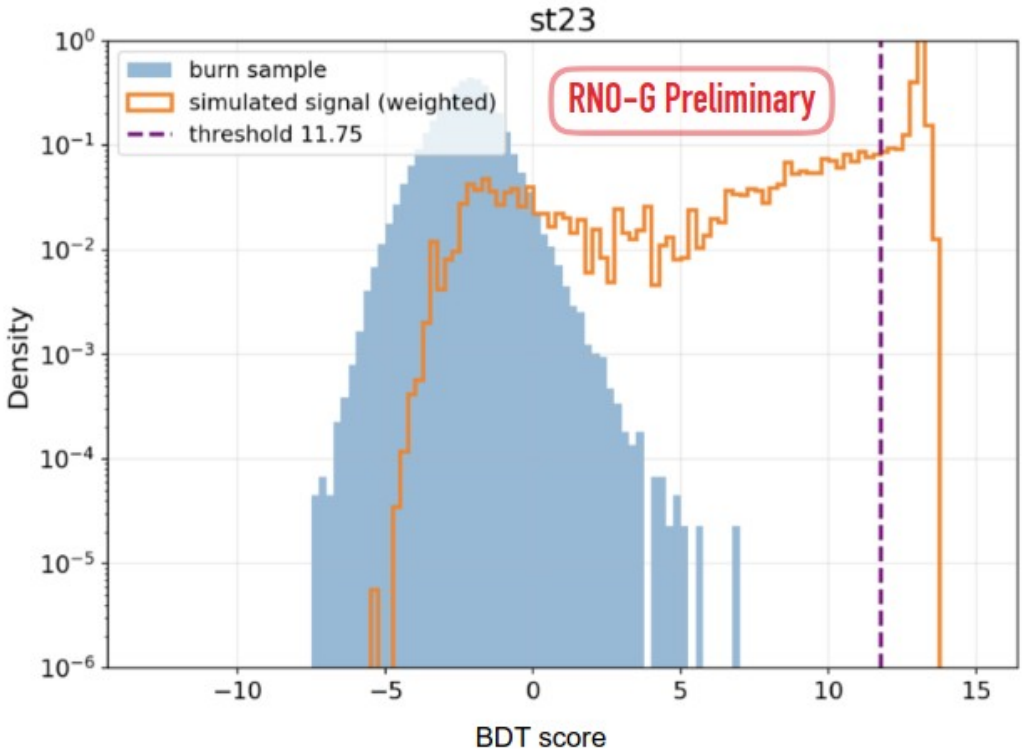


Simon Chiche (S. Chiche, S. Toscano, K. D. de Vries, Astroparticle Physics, 182, 103276 (2026)

RNO-G Cosmic Ray Analysis

- **A deep cosmic ray analysis is currently ongoing using a blinded approach.**



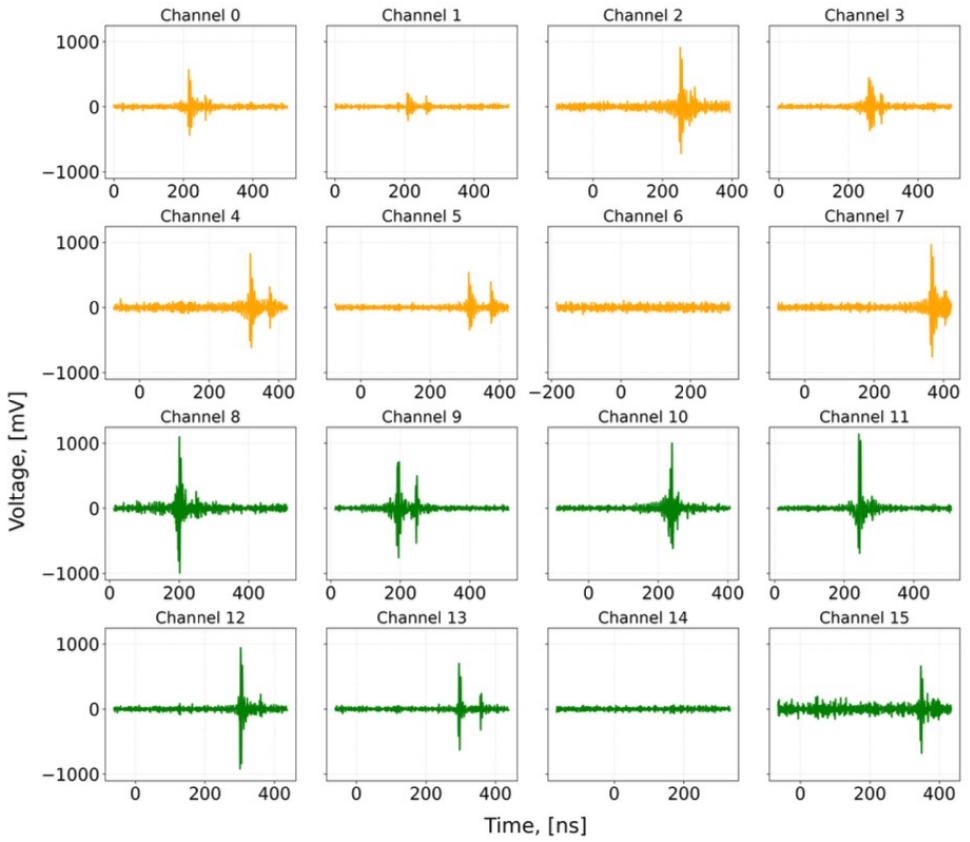




+ RNO-G deep cosmic ray working group (co-led by Simona)

Askaryan Radio Array (ARA)

- **Published the first ever in-ice Askaryan measurement**
- **This analysis was enabled in-part by FAERIE, developed here at IIHE**
- **We are working with collaborators on a “double pulse” analysis looking for coincident geomagnetic and in-ice Askaryan emission in a single station**



PHYSICAL REVIEW LETTERS **136,** 151003 (2026)

Editors' Suggestion | Featured in Physics

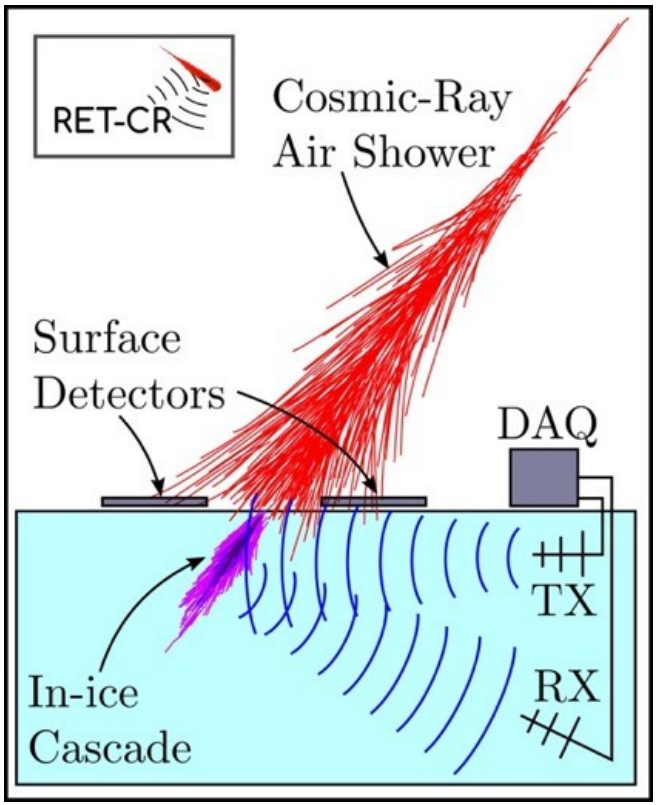
Observation of In-Ice Askaryan Radiation from High-Energy Cosmic Rays



ASKARYAN RADIO ARRAY

Radar Echo Telescope (RET)

- **Cosmic ray analysis for 2024 season is ongoing (Dylan)**
- **Radar echo signal properties (Isha, Jannes)**
- **Combined Radio and Radar signal simulation for RET-CR**

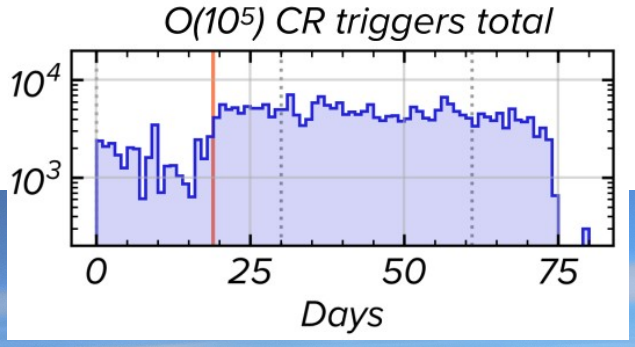


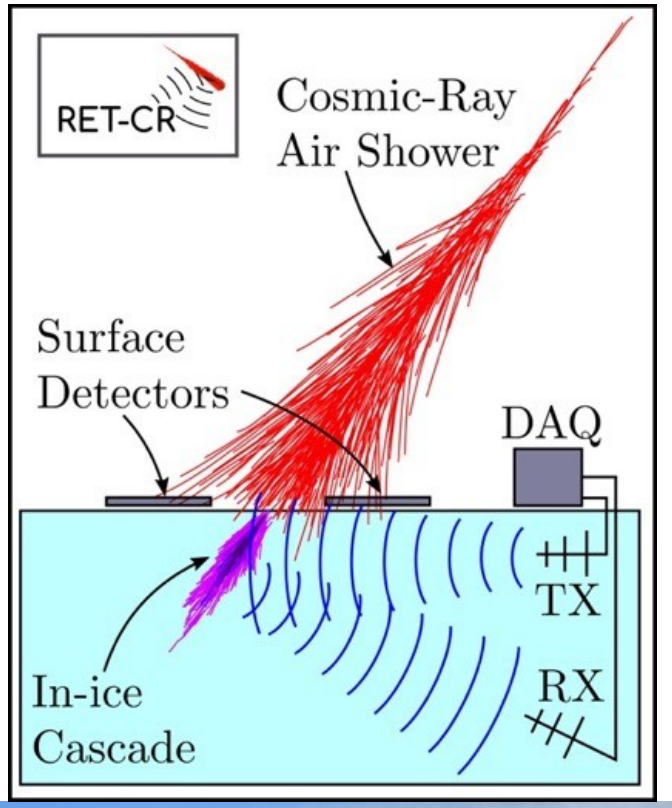


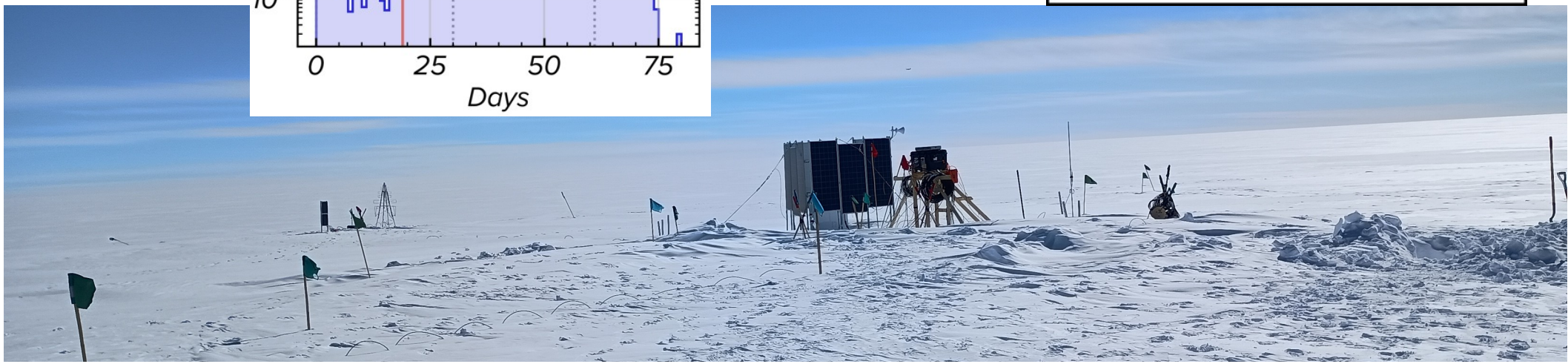
RADAR ECHO TELESCOPE

RET-CR

- **RET-CR was deployed to Summit Station Greenland in 2024, operating from May to August**
- **In-ice radar array triggered by a surface array of scintillator panels**

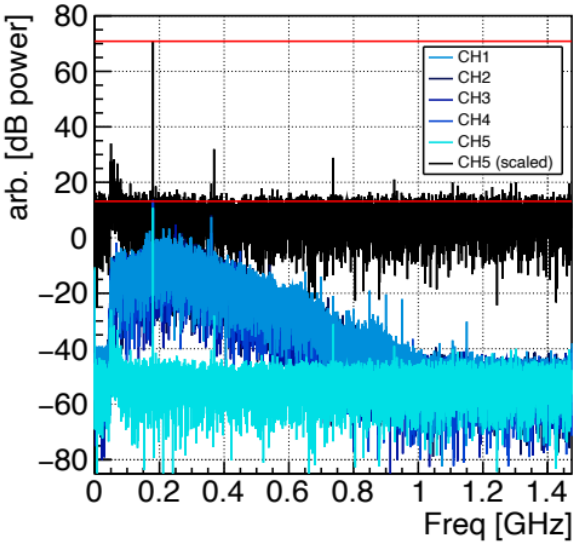


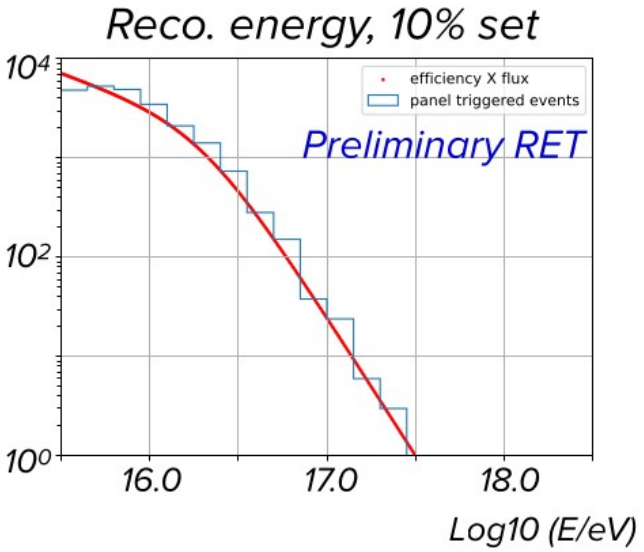




RET-CR Analysis Progress

- We have been able to characterize the detector and its backgrounds to the level of thermal noise
- We are currently finalizing the analysis on a 10% burn sample, and aiming for a box opening in the near future

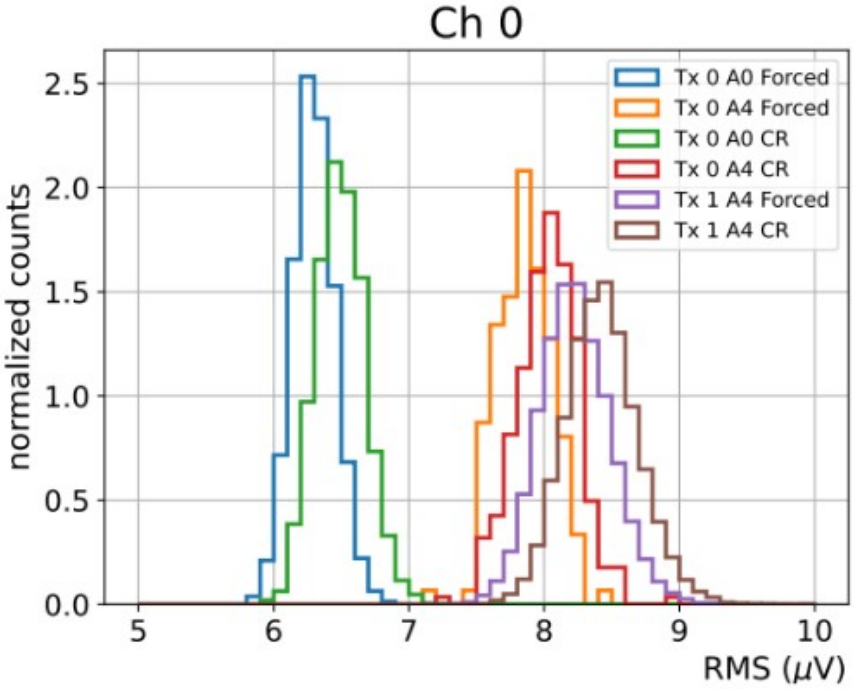






RET-CR Analysis Progress

- Here we show the event RMS broken down by detector configuration after excess Tx and background CW removal
- We show an RMS in our channels near thermal noise for our band
- We see a ~2μV increase from Tx Power amps (A4)

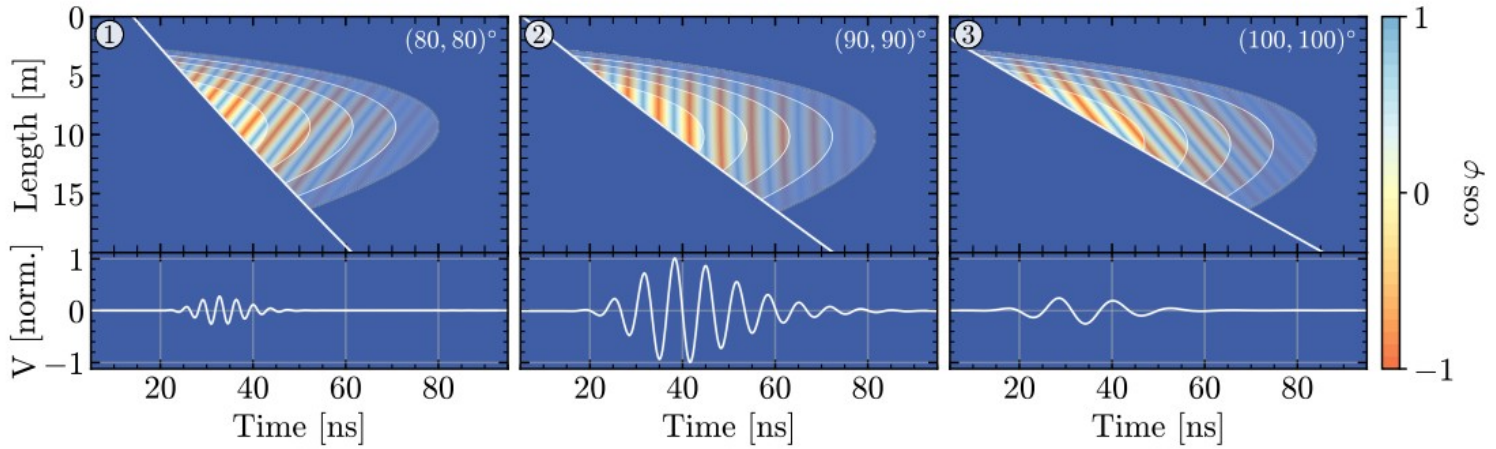


Legend Key:
Tx (on/off) Tx amps on(N) Trigger Type



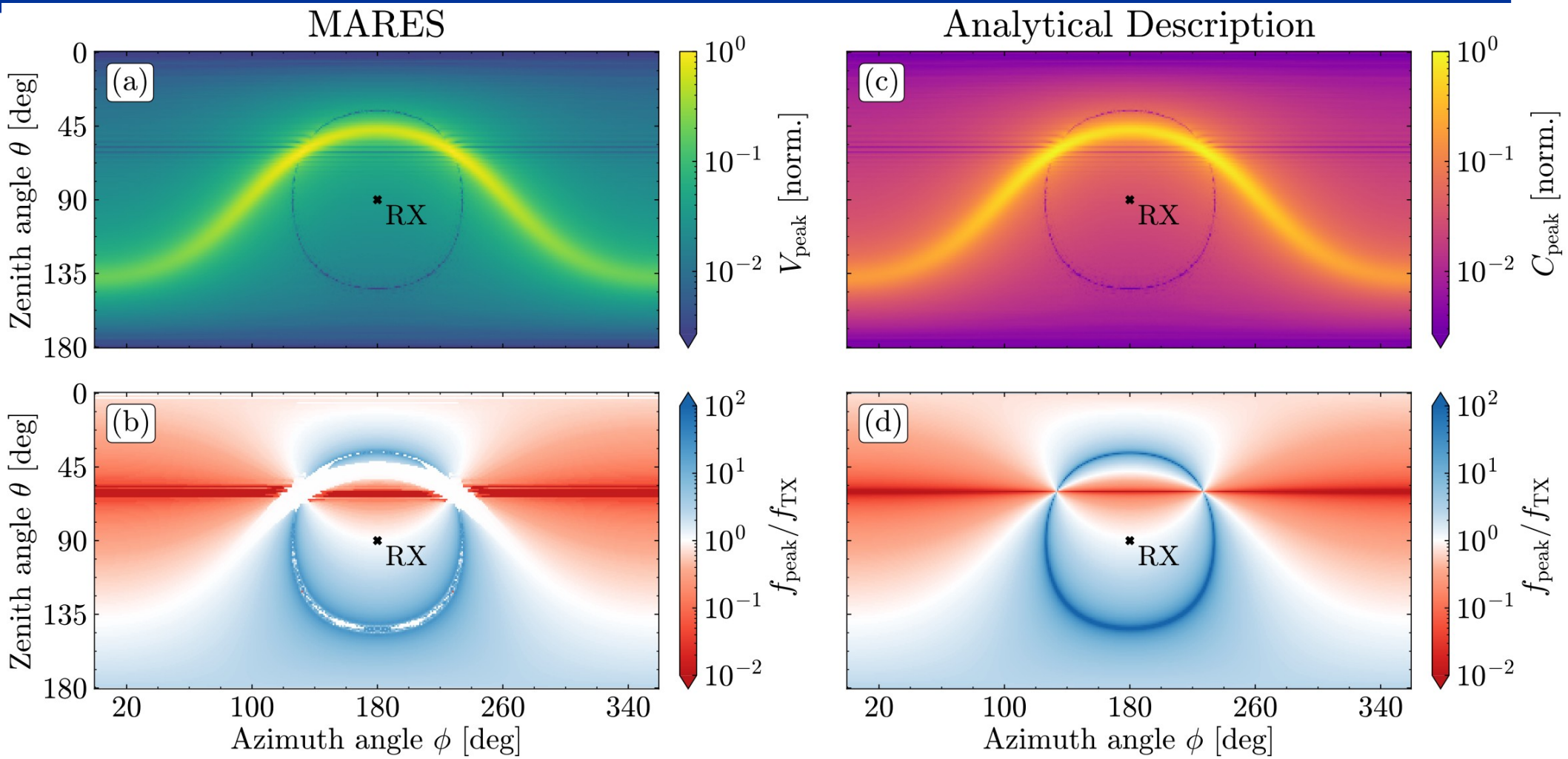
Radar Echo Signal Properties

- using an analytical description we call the phase coherence, we can fully reproduce the signal properties of the radar signal demonstrated in the MARES simulation showing that we now understand the expected signal
- Submitted as joint PRL PRD papers (in review)





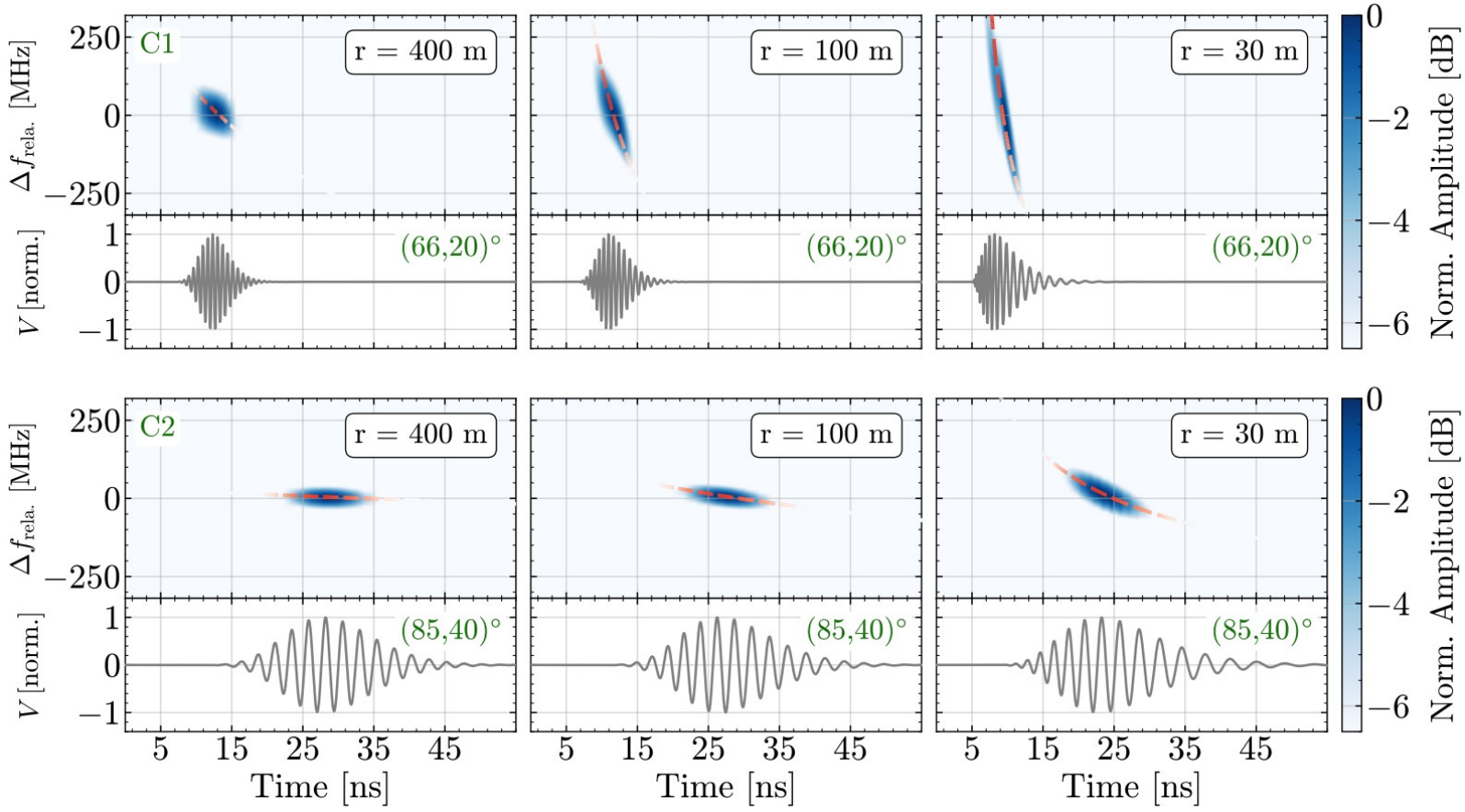
Radar Echo Signal Properties





Radar Echo Signal Properties

- **We have developed an understanding of the geometry-dependent relativistic Doppler shift expected in the radar echo signal**
- **Submitted as joint PRL PRD papers (in review)**



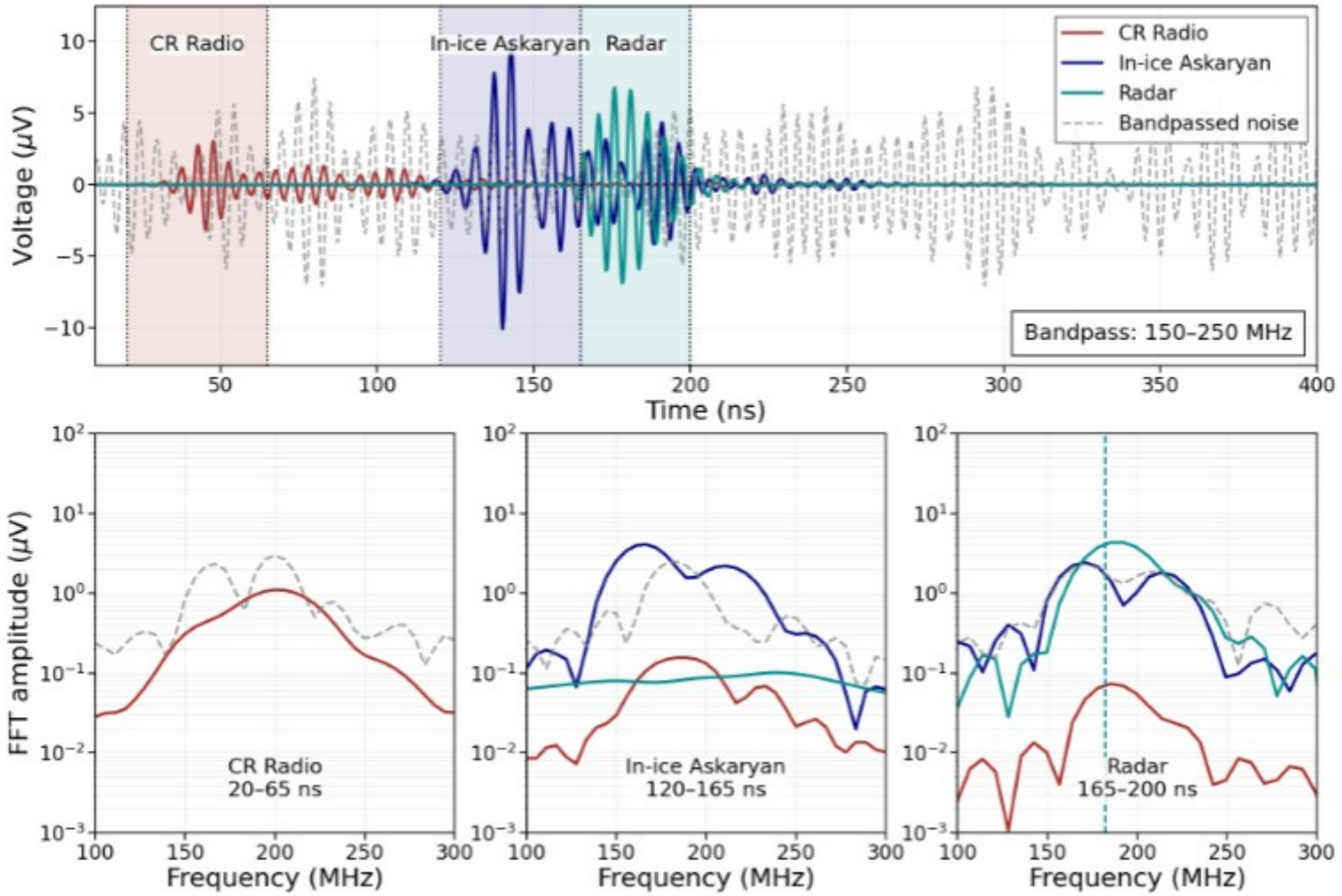


RET-CR Full Chain Simulation

- **Using tools developed at IIHE, our colleague (Dr. Krishna Nivedita – Radboud University) simulated the full radio footprint to RET-CR**
- **We consider geomagnetic, in-ice Askaryan, and in-ice radar signals to determine the associated amplitudes and signal properties**
- **Paper submitted, in review process**

RET-CR Full Chain Simulation

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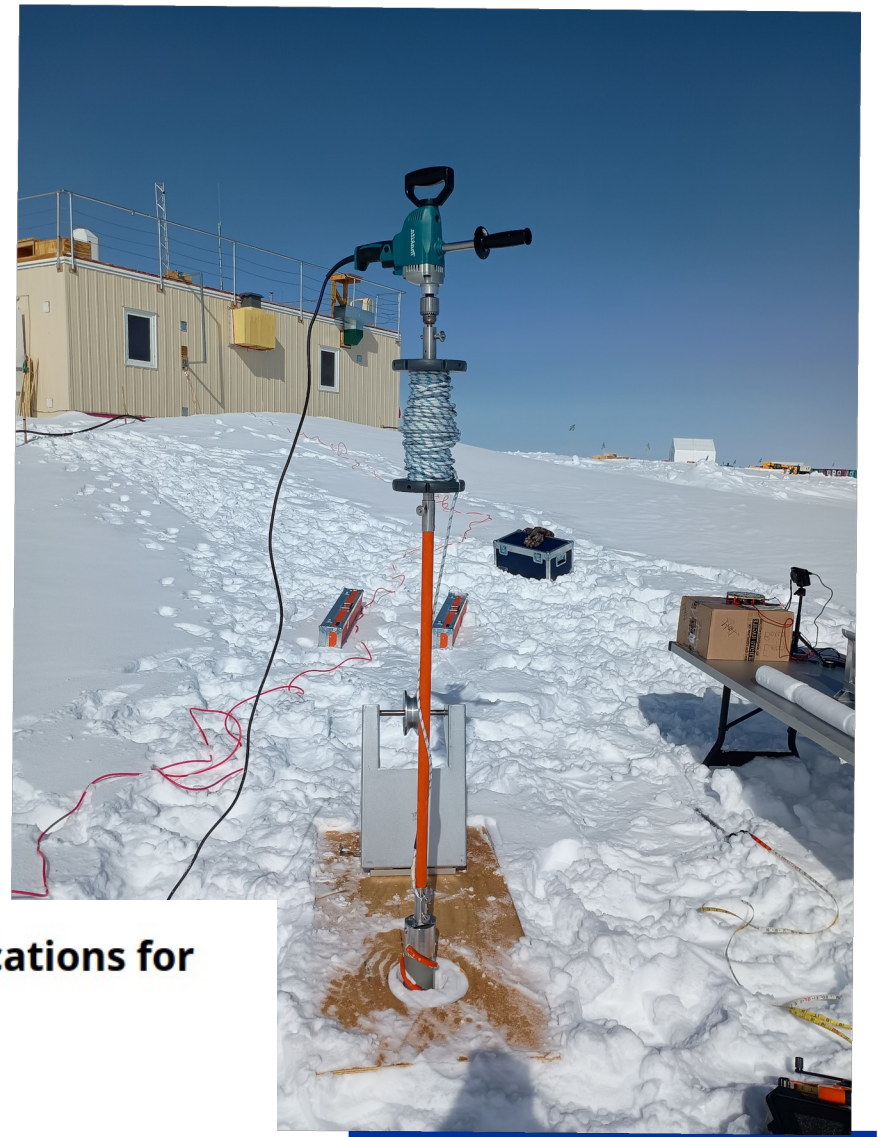
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Ice Properties

- **Seasonal variation of polar ice: Implications for ultrahigh energy neutrino detectors (Alex)**
- **Deployed to Summit Station, Greenland to perform ice property measurements (Dylan)**





Seasonal variation of polar ice: Implications for ultrahigh energy neutrino detectors

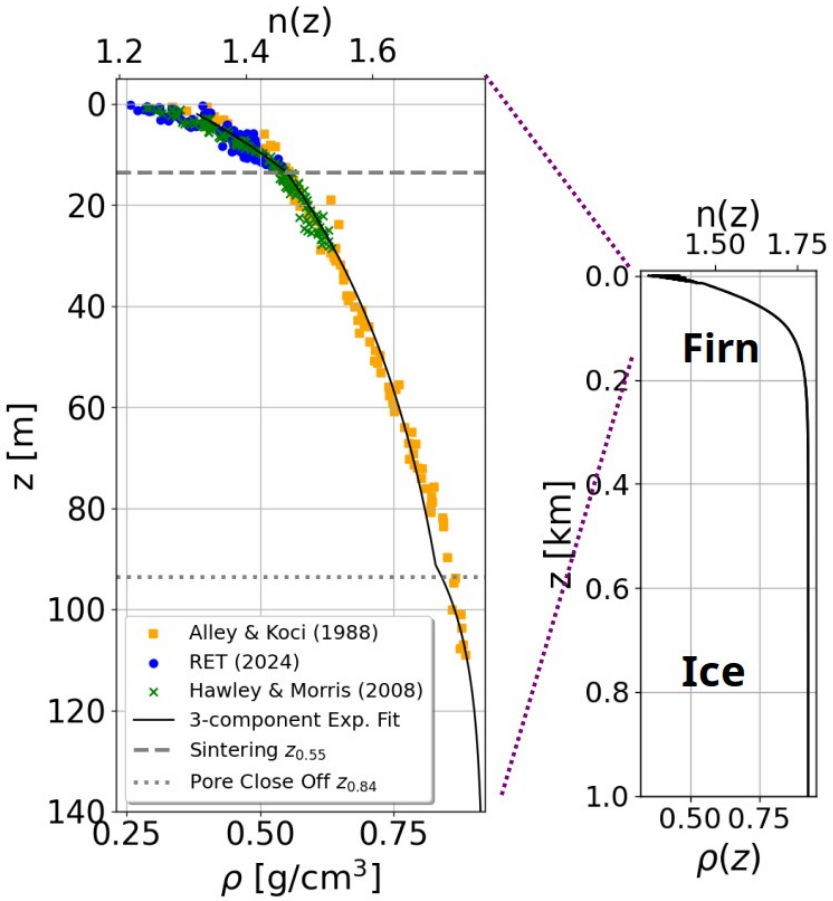
A. Kyriacou[*,†], S. Prohira, and D. Besson

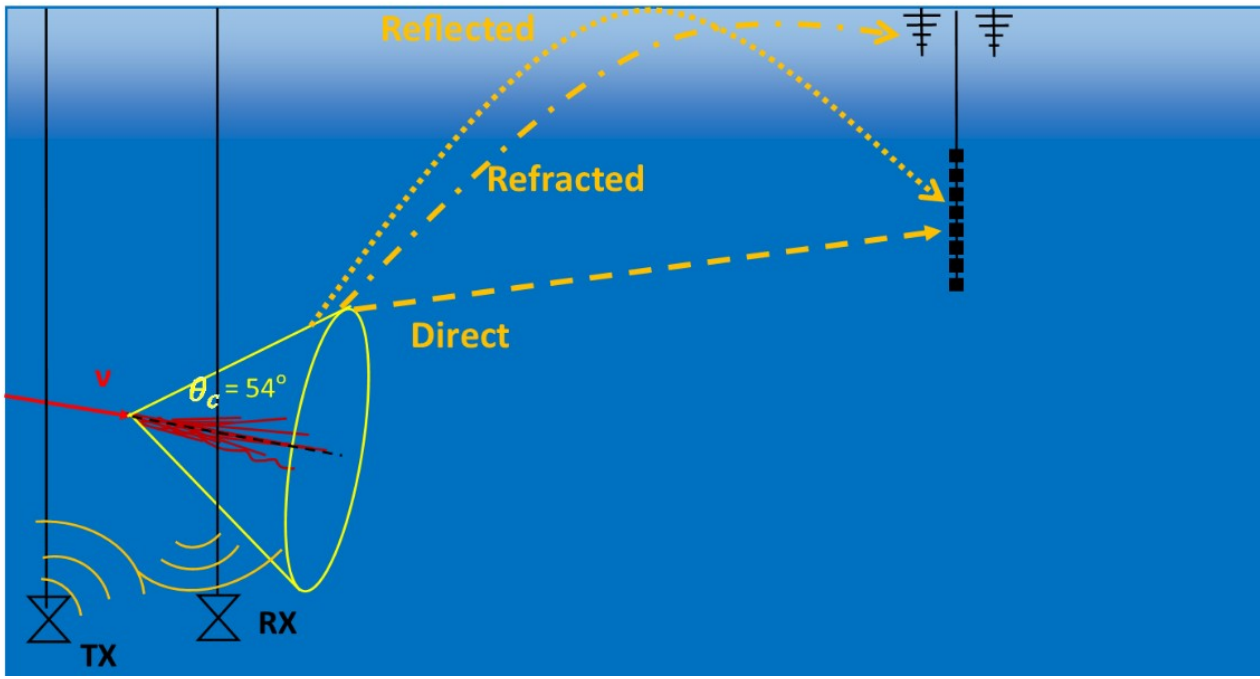
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Phys. Rev. D **114**, 103005 – **Published 3 November, 2026**

DOI: https://doi.org/10.1103/xw6h-qx5c

Seasonal Variation in the Firn

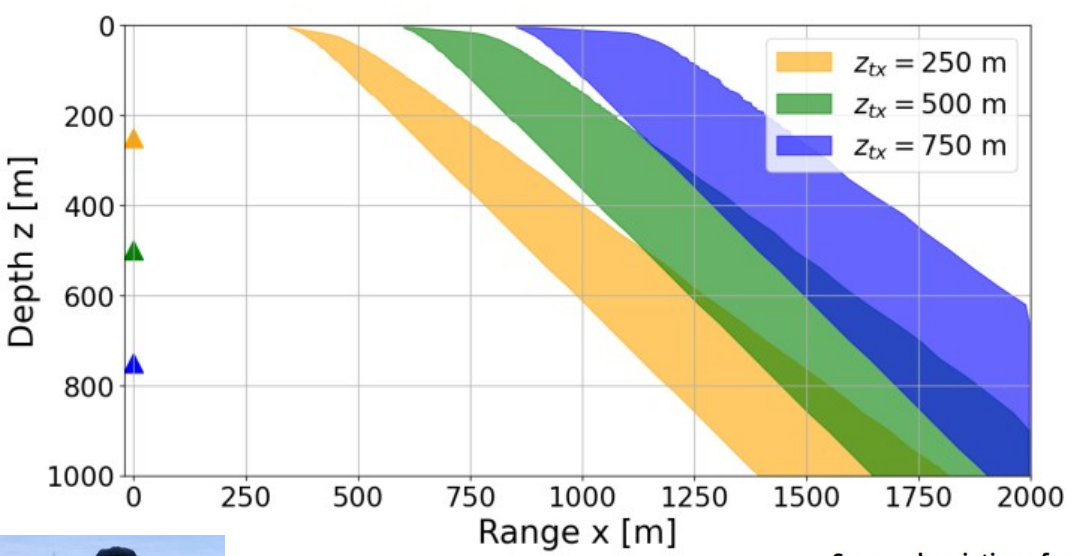


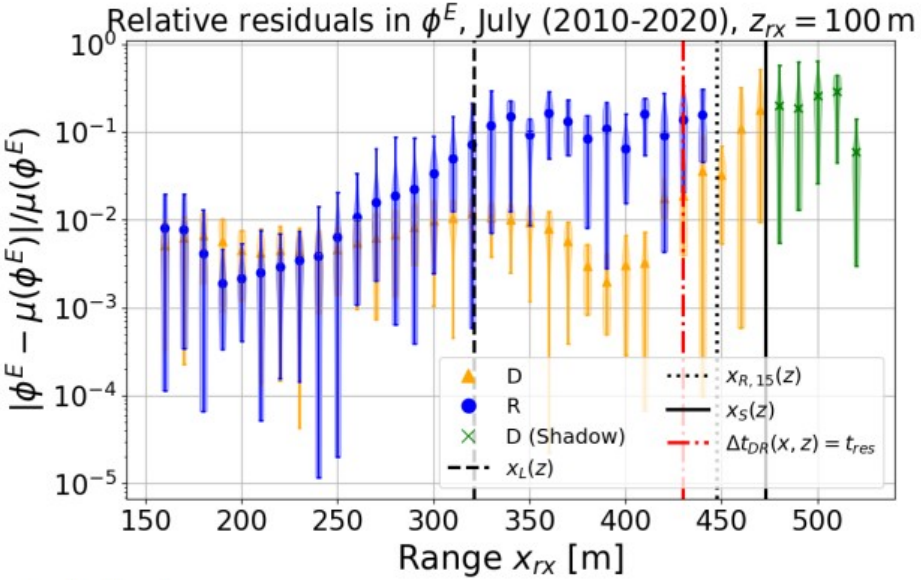




Seasonal Variation in the Firn

- Density of upper 15 m of the firn fluctuates over time
- 10% fluctuation of signal power for rays refracting through this domain
- Results in background uncertainty for energy and arrival direction
- Paper published this week!







Seasonal variation of polar ice: Implications for ultrahigh energy neutrino detectors

A. Kyriacou, S. Prohira, and D. Besson

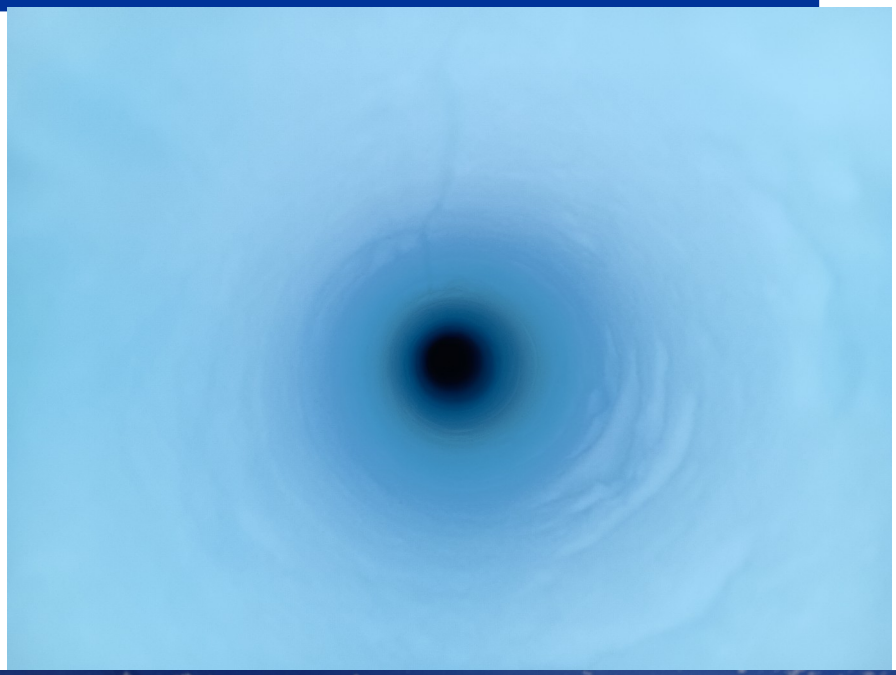
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Phys. Rev. D **114**, 103005 – **Published 3 November, 2026**

DOI: https://doi.org/10.1103/xw6h-qx5c

Ice Property measurements

- **Drilled 8 ice cores to ~15m in order to measure the density of the firn, which is used to derive the index of refraction as a function of depth(n(z)) and location**
- **Open questions in the field:** how long the coherence length of n(z). What scale are local fluctuations occurring and how should we model that?
- **Initial hints from data suggest the coherence length is much smaller than previously thought (~100m or less)**
- **Data analysis underway, and a 2027 trip is planned to take more samples**







RNO-G

Radio Neutrino Observatory - Greenland

RADAR ECHO TELESCOPE

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ASKARYAN RADIO ARRAY

Thank you

