# The Radio Neutrino Observatory in Greenland (RNO-G)



RNO-G
Radio Neutrino Observatory - Greenland


## Stephanie Wissel, Penn State


## 21 July 2021

## ICRC Theater of Dreams Highlight







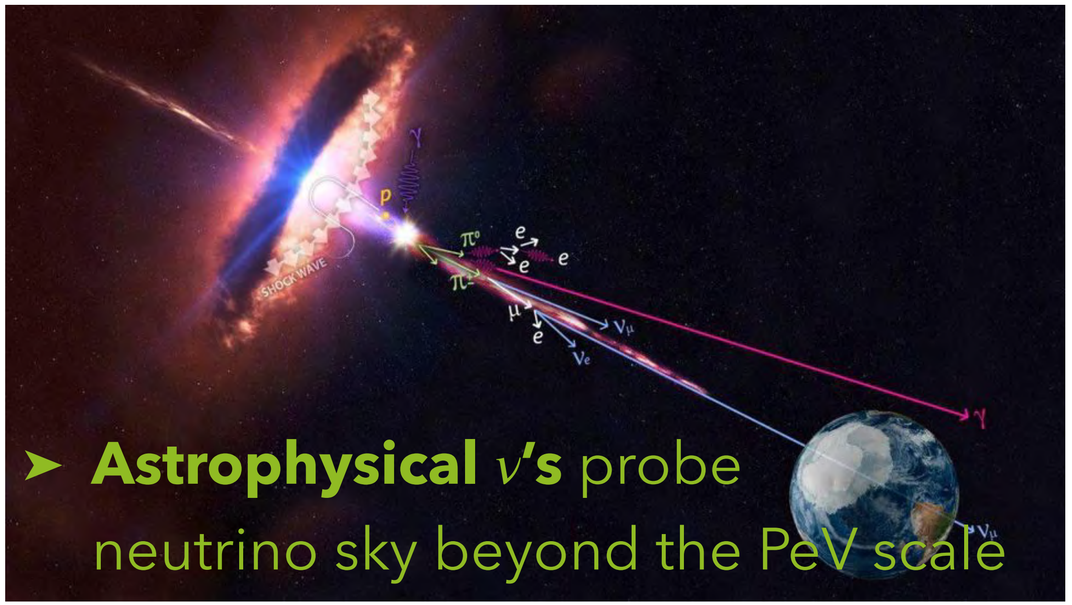




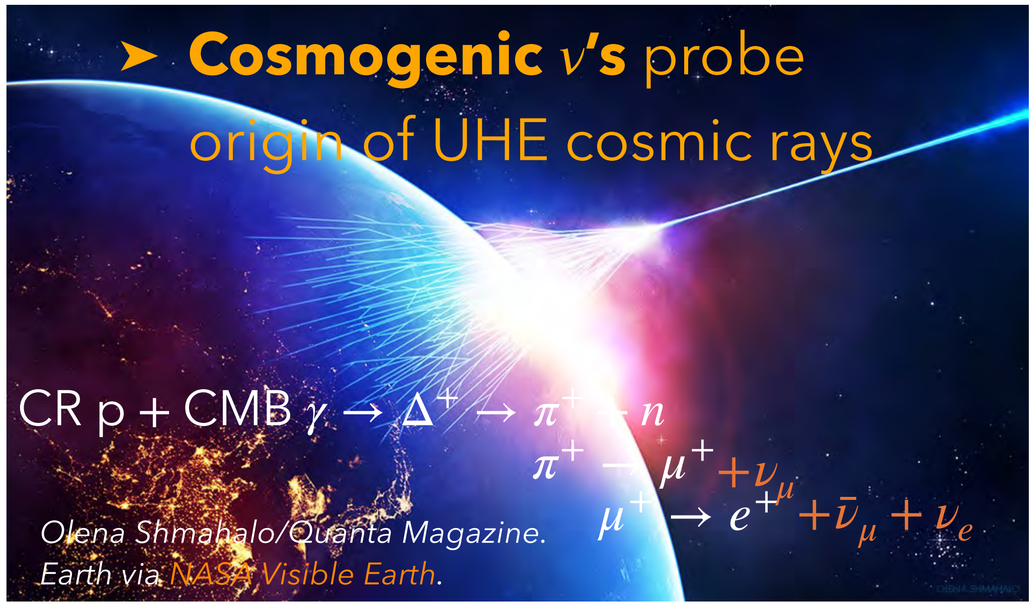




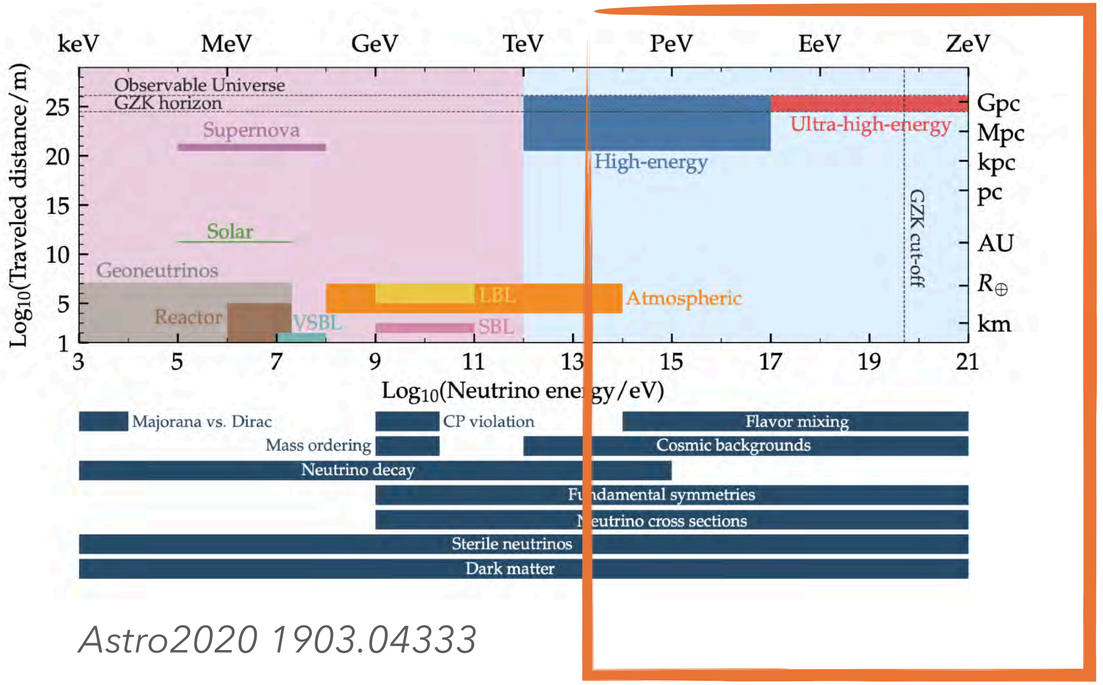

# Science with Neutrinos at Ultra-High Energies (UHE >10 PeV)




➤ **Astrophysical $\nu$'s** probe neutrino sky beyond the PeV scale




➤ **UHE $\nu$'s probe** fundamental physics in a new energy regime and the longest length scales



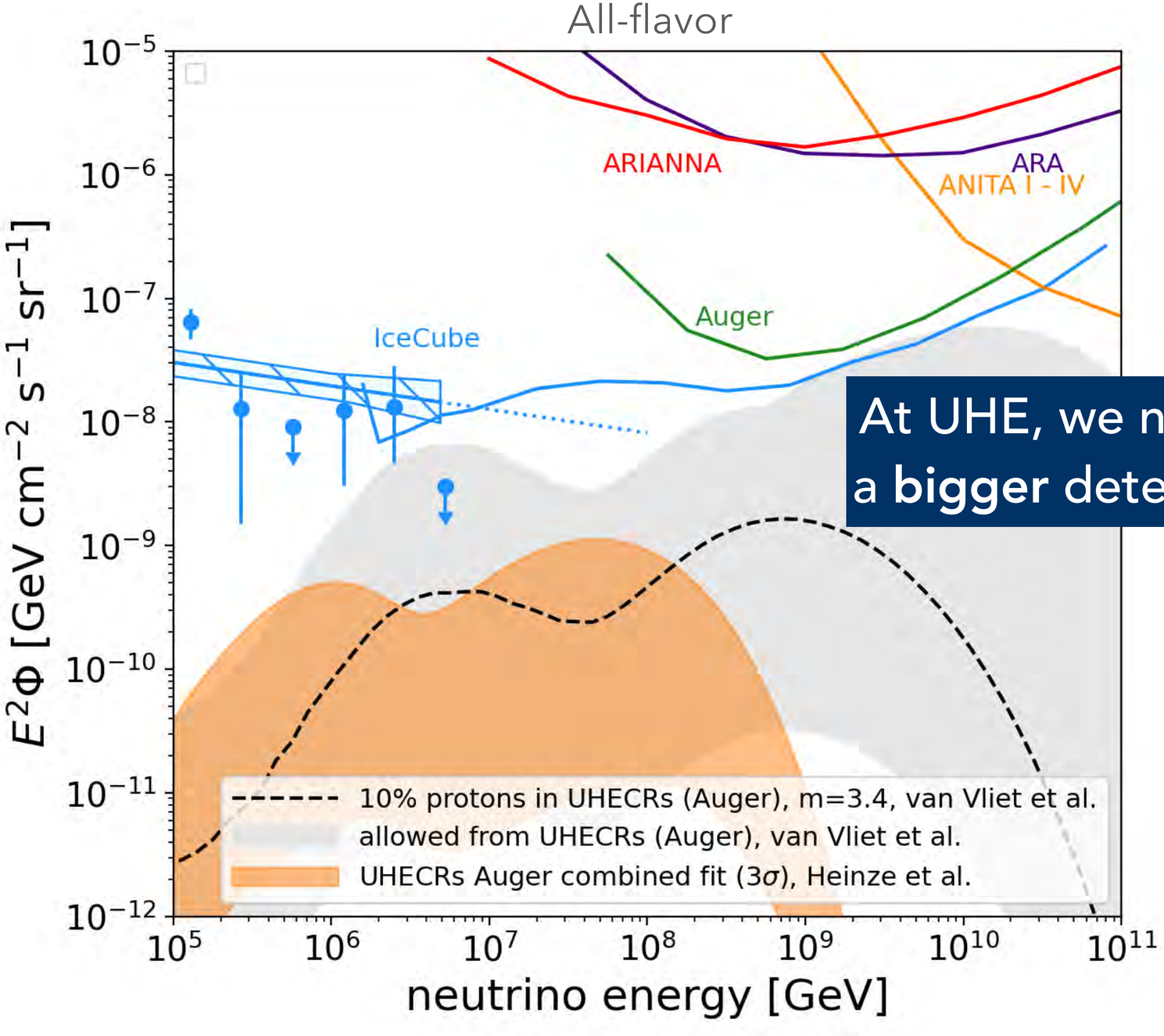

*Astro2020 1903.04333*

# The Diffuse Neutrino Flux at UHE Energies

- Flux is low and falls with energy as $E^{-2}$ (at best)

*See K. Hoffman talk PoS(014) from earlier today for excellent introduction to the field and ARA*

*See S. Barwick for ARIANNA PoS(1190)*




**At UHE, we need a bigger detector**

# RNO-G in a Nutshell

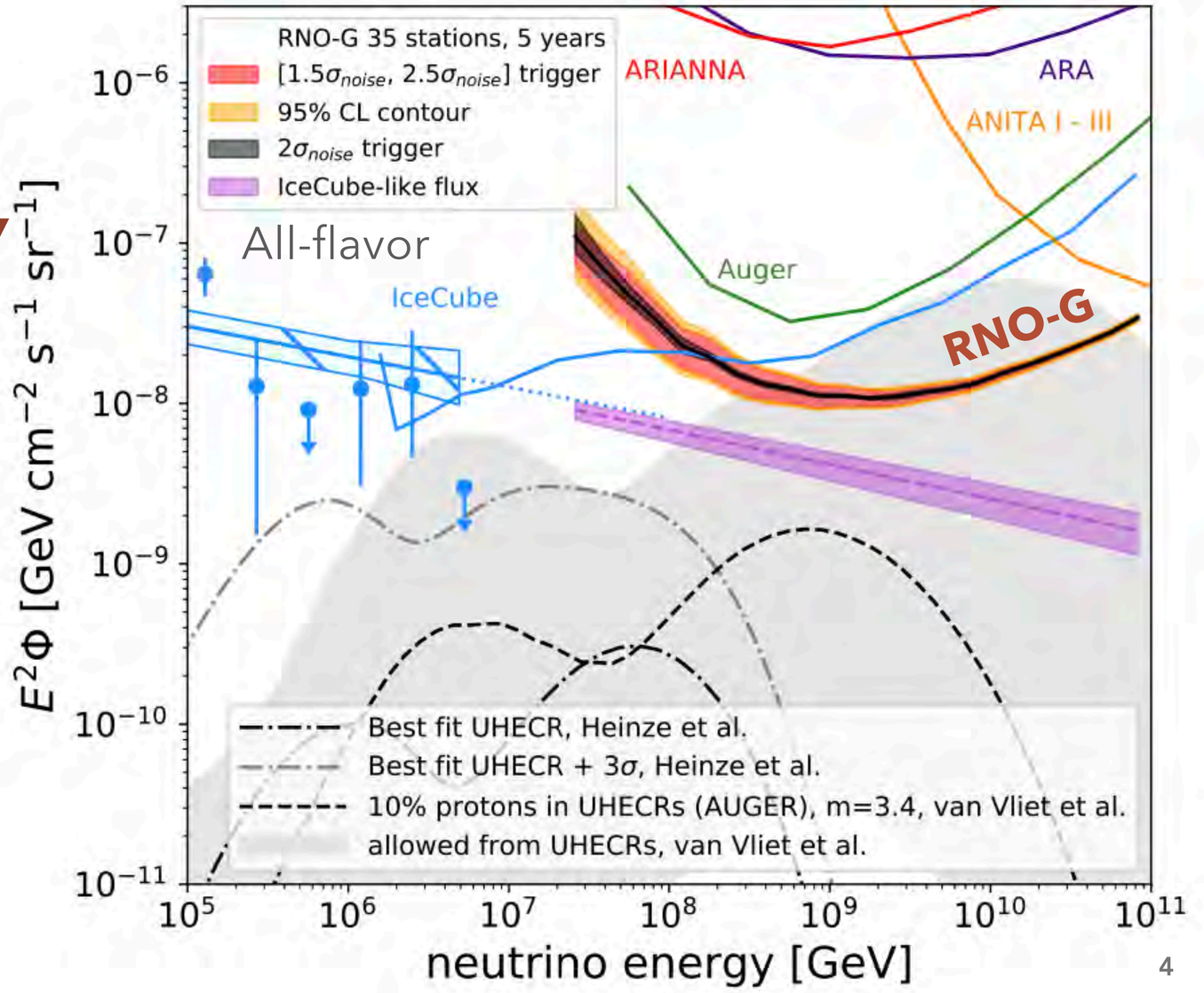
*See I. Plaiser PoS(1026), C. Welling PoS(1033) , and D. Smith PoS(1058) for more on RNO-G*

## Scale up from current arrays

- Hybrid design combines advantages of ARA (deep) & ARIANNA (shallow)
  - Large effective volume
  - Cosmic ray veto
- Highly scalable

*Projected limits assume 5 year livetime, trigger level sensitivities, 95% FC UL*

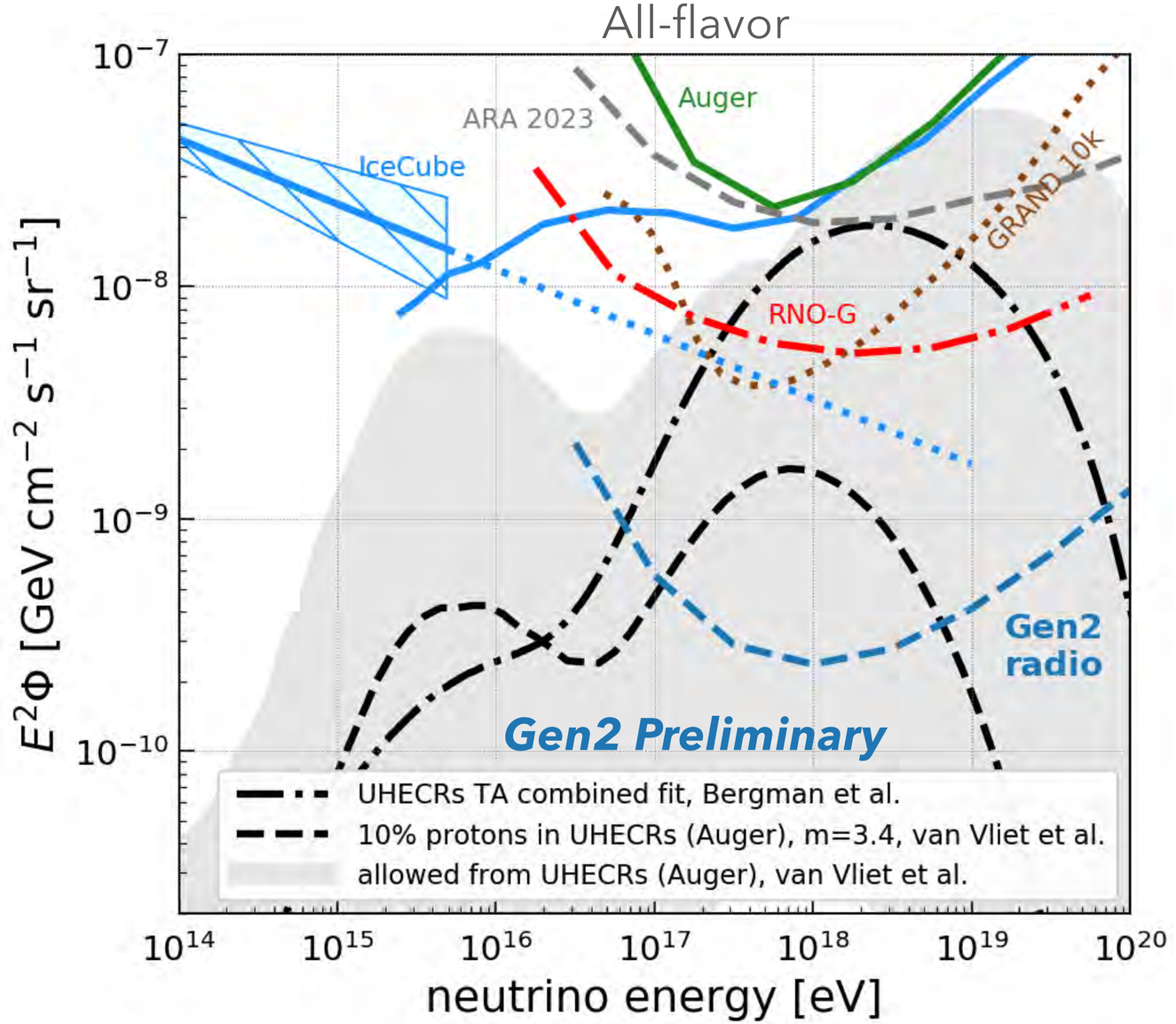
*RNO-G Whitepaper arXiv:2010.12279*



# RNO-G as a Midscale Detector

- Informs design for the hybrid stations of Gen2-radio

*See S. Hallman PoS(1185) & M. Kowalski PoS(022) for more on Gen2-radio*

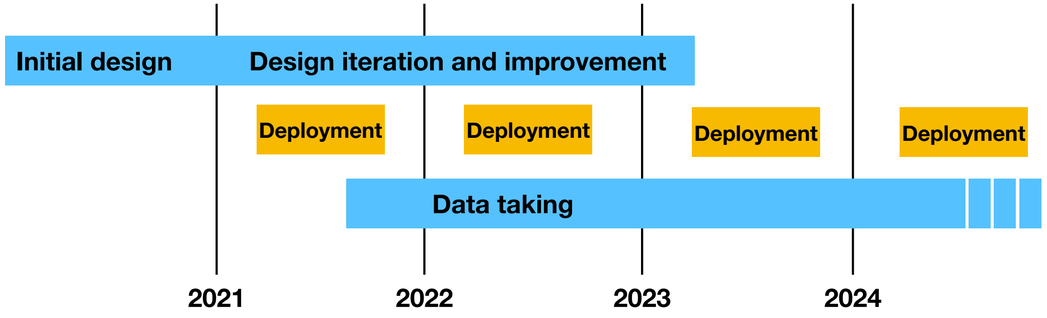


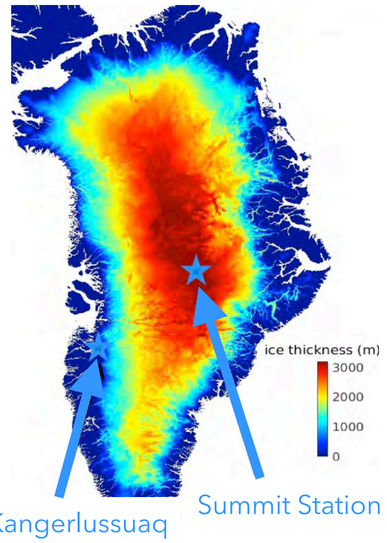

*Projected limits assume trigger level sensitivities, 90% FC UL and 10 year livetime unless otherwise stated*

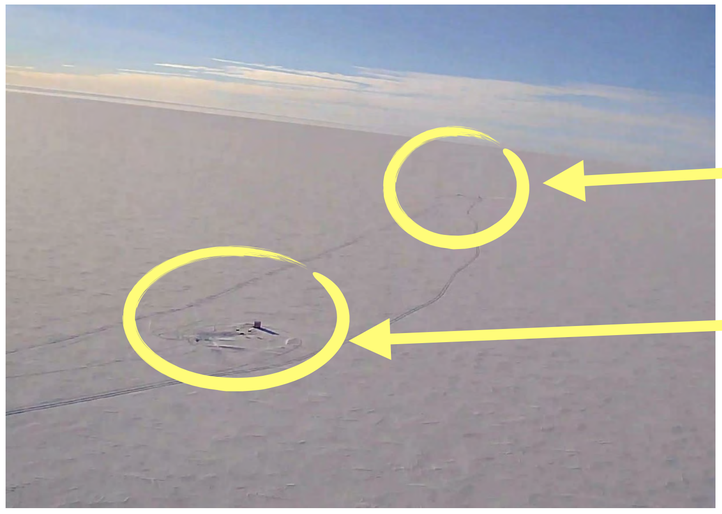
# RNO-G

See https://rno-g.github.io/station-map/

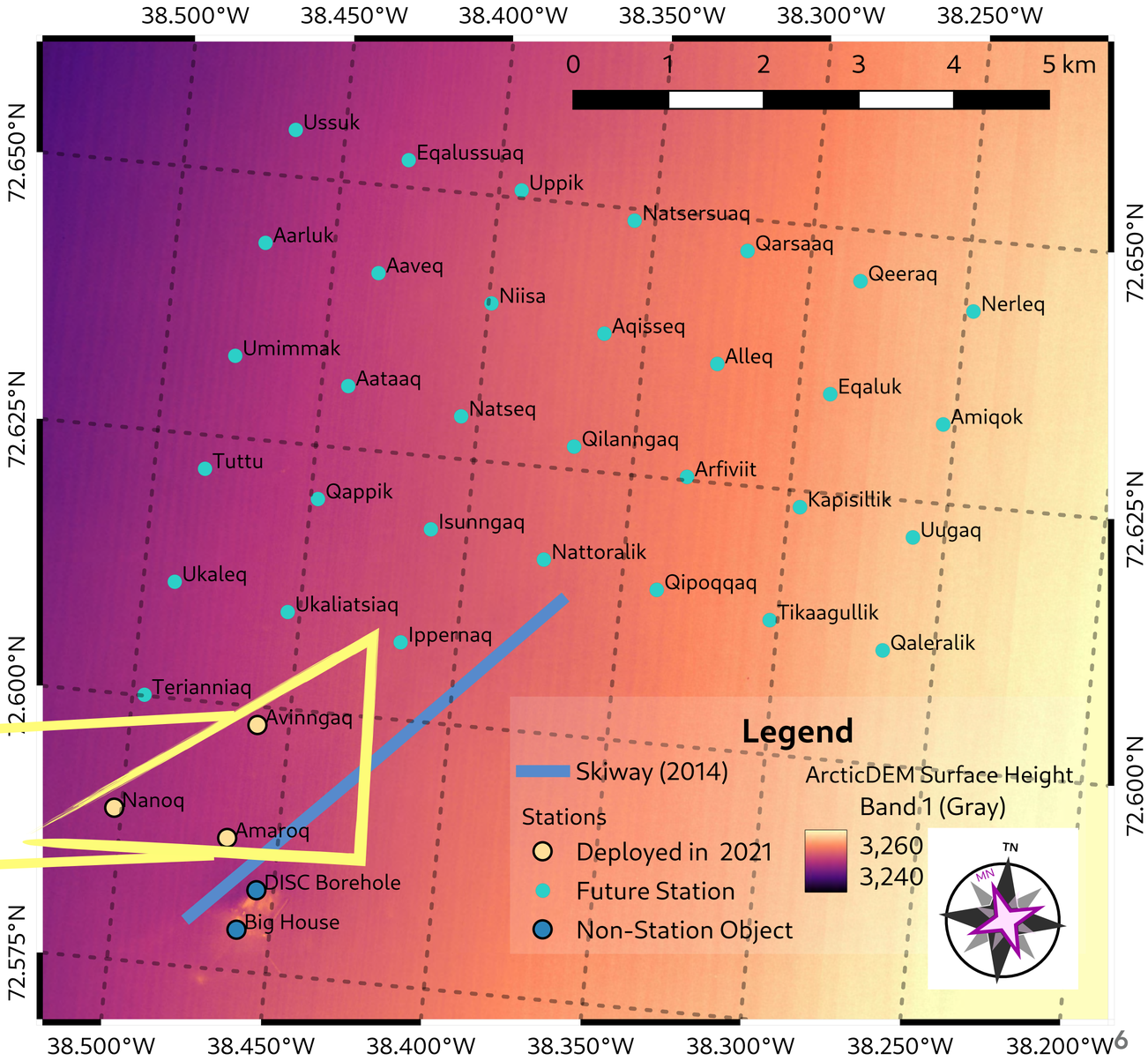
- 35 stations, 1.25 km spacing
- Summit Station, Greenland
- First deployment season happening **now**
- Expect 3 complete stations by end of season
- Deployment ends Summer 2024



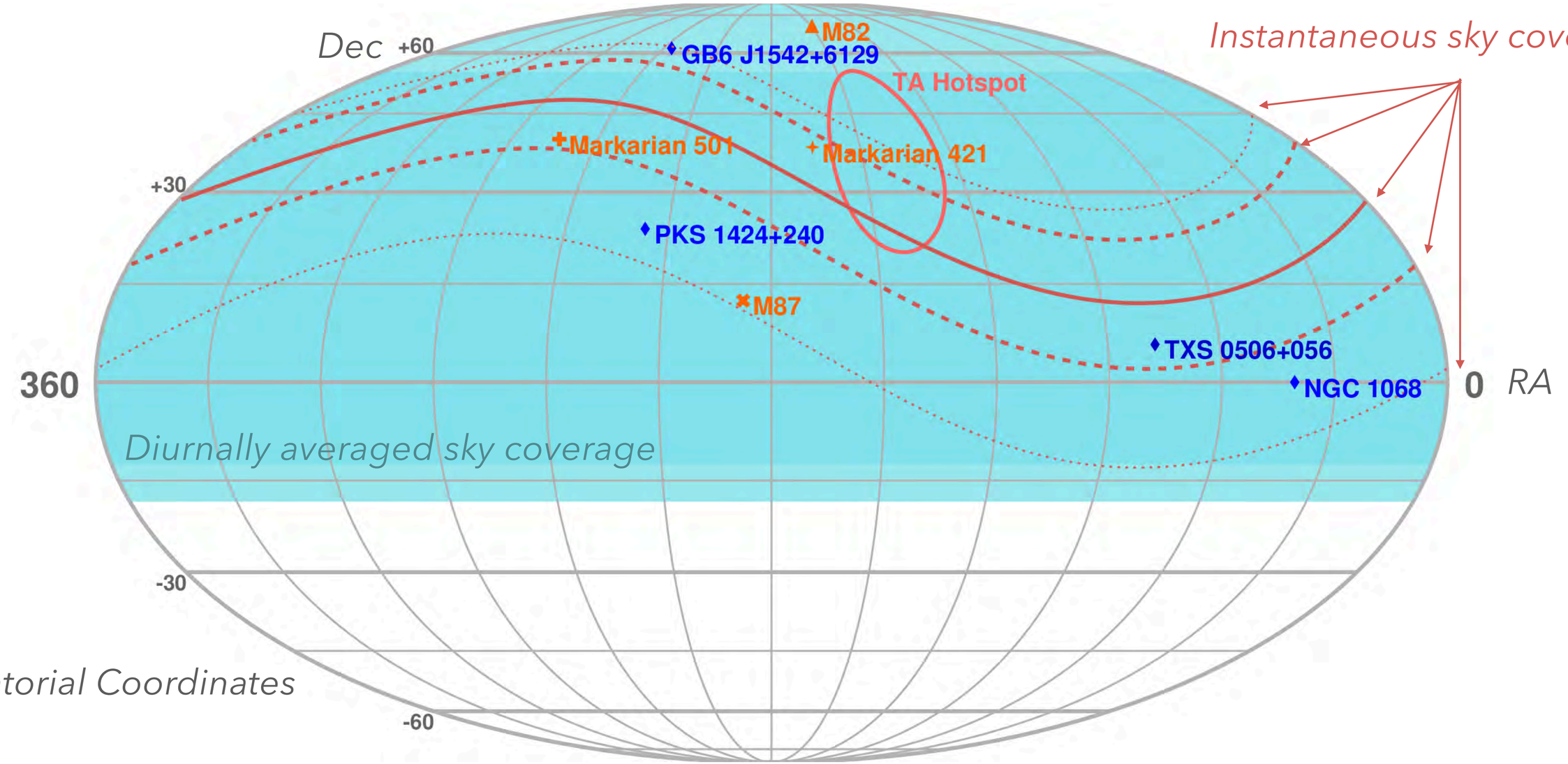
## RNO-G Planned Layout



# Northern Sky Coverage

*RNO-G Whitepaper arXiv:2010.12279*

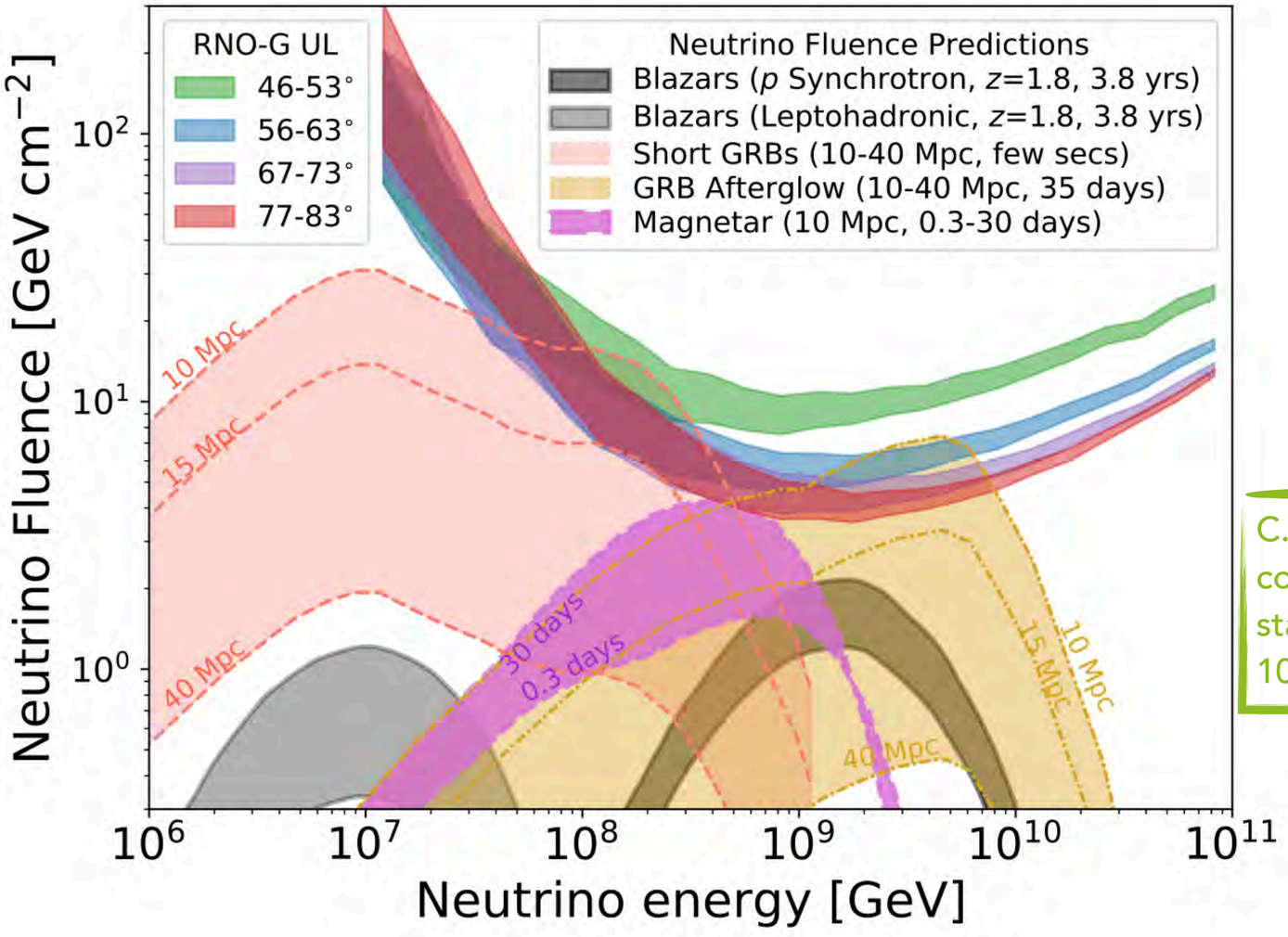
- At UHE energies, primarily sensitive to down-going or Earth-skimming neutrinos

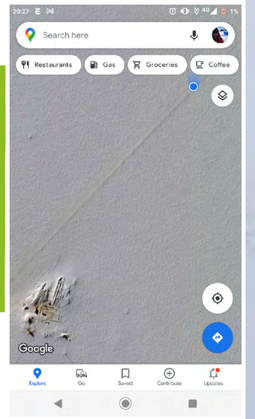


# Neutrino Fluence Sensitivity

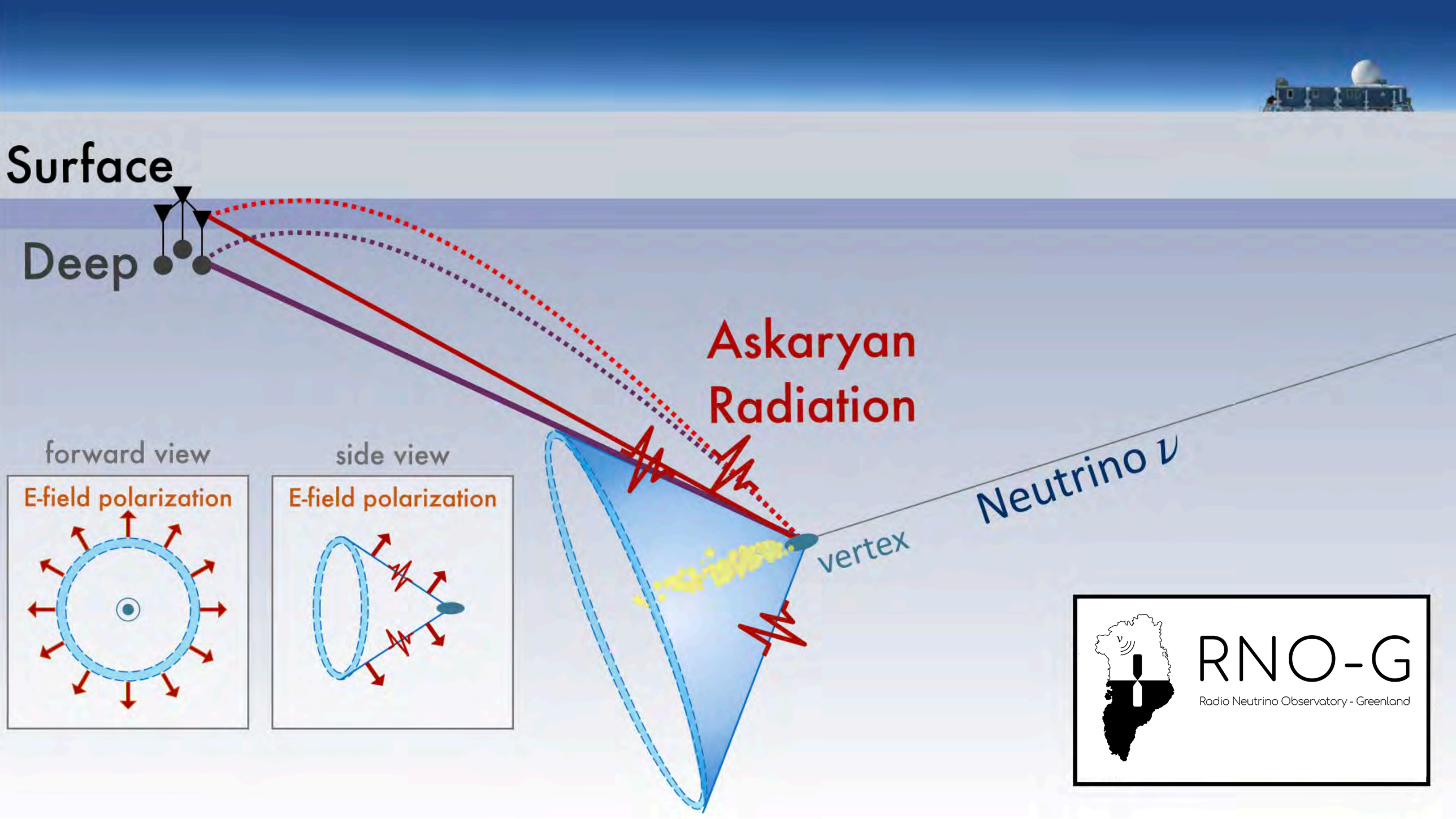
*RNO-G Whitepaper arXiv:2010.12279*

- Sensitive to nearby and/or bright transient events
- Multi-messenger follow-up enabled with continuous satellite coverage, beam-forming & LTE cellular comms networking




C. Deaconu with LTE coverage at furthest station site (Nerleq), 10 km away


Surface
Deep
Askaryan
Radiation
Neutrino ν
vertex
forward view
E-field polarization
side view
E-field polarization
RNO-G
Radio Neutrino Observatory - Greenland

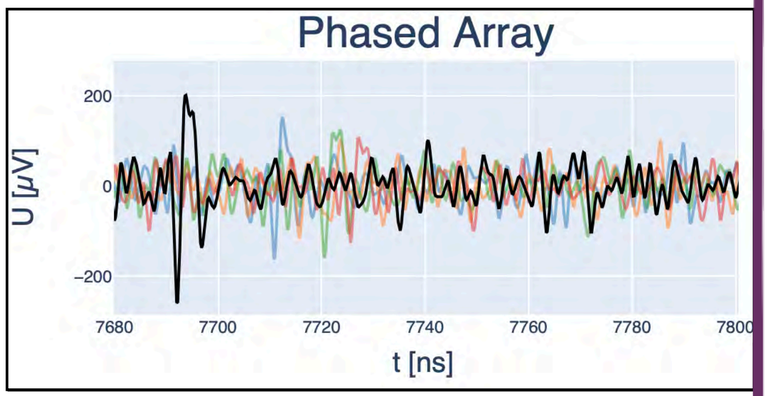
# RNO-G Station Concept

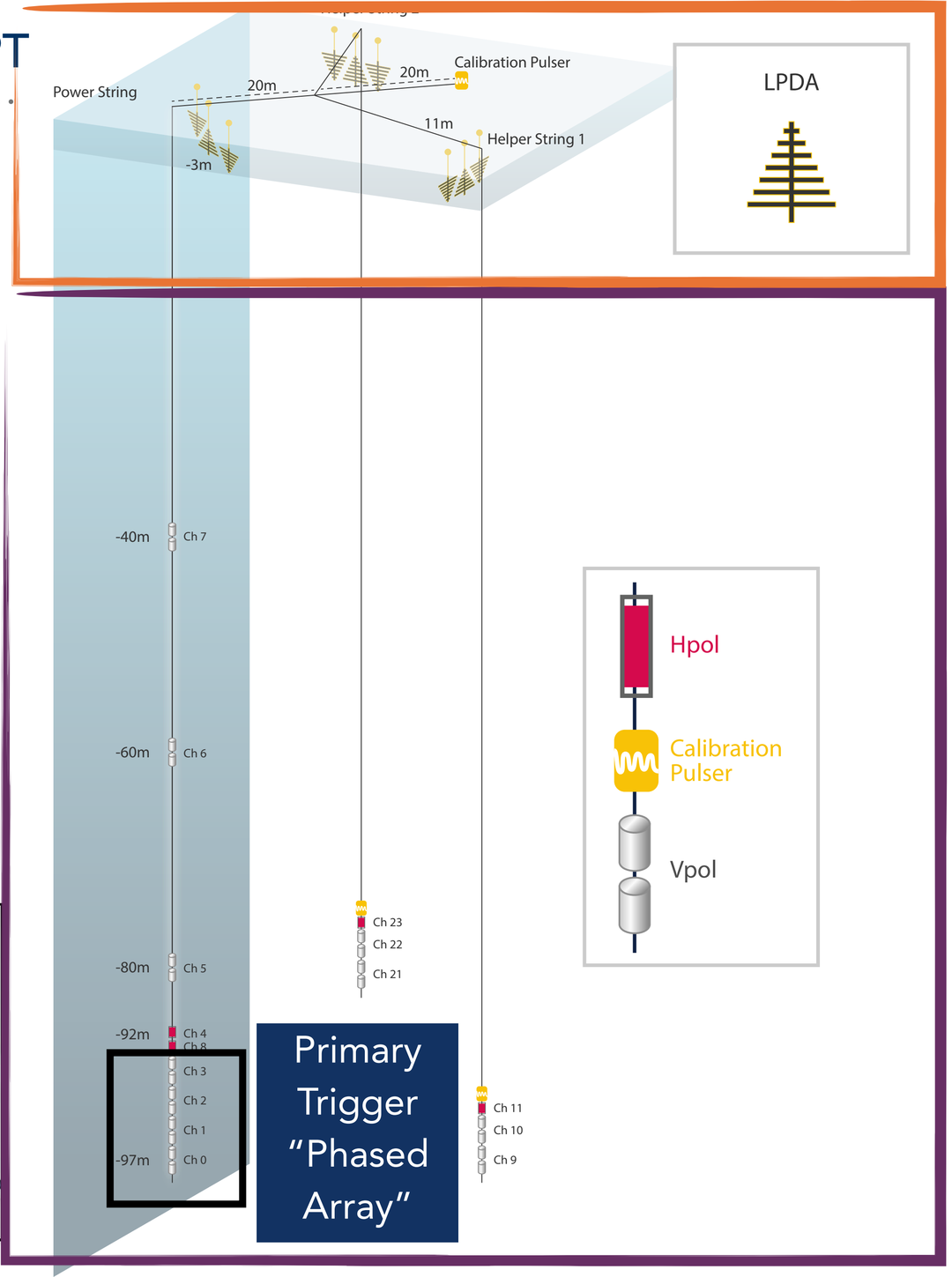
## Deep component:

Effective Volume

Low Threshold (2σ) trigger with compact phased array

Outrigger antennas enable reconstruction




## Shallow component:

Cosmic rays

Veto

Additional channels for reconstruction

Independent trigger

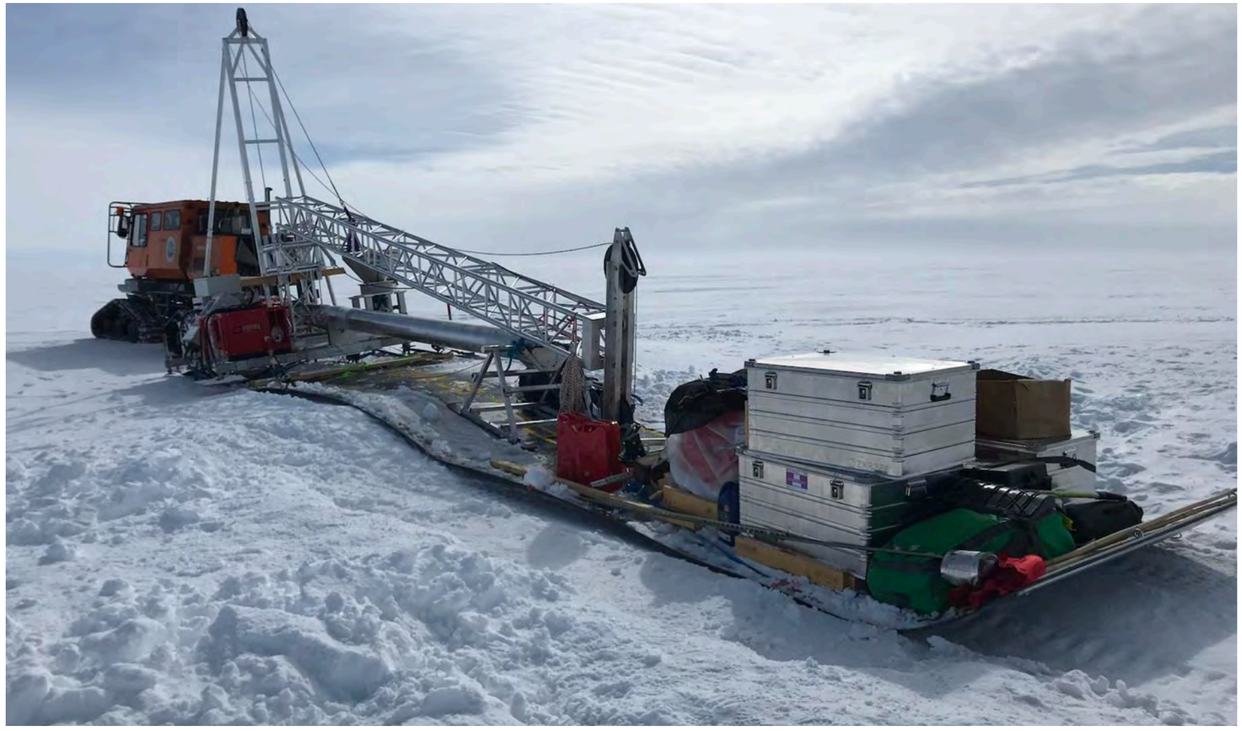
# First Station: Amaroq (Arctic Wolf)

Deployed June 2021

# RNO-G Drill

*See D. Smith PoS(1058) for more on the instrument hardware*

- **BAS BigRAID Drill**
  Custom auger drill developed for RNO-G by the British Antarctic Survey
- 11-inch diameter holes
- Capable of drilling 1 hole to 100 m in 1 shift (2 people)
  - Most holes drilled this season are 2 shifts / hole



# Station Deployment

*See D. Smith PoS(1058) for more on the instrument hardware*

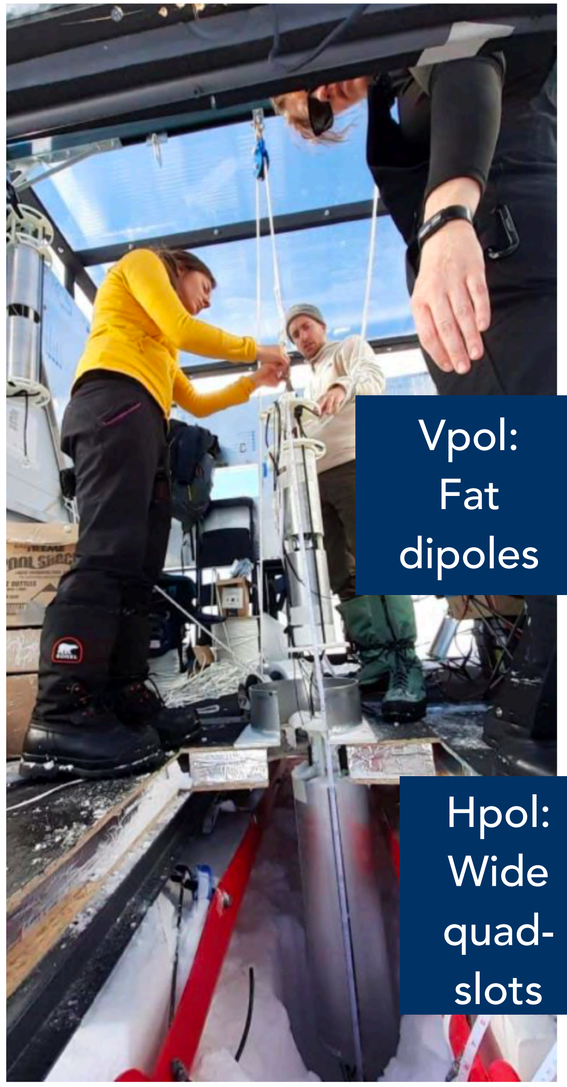
Warm deployment sled movable by snowmobile


…or people!

Shallow antennas deployed in trenches

Shallow: LPDAs


Deep channels lowered by hand

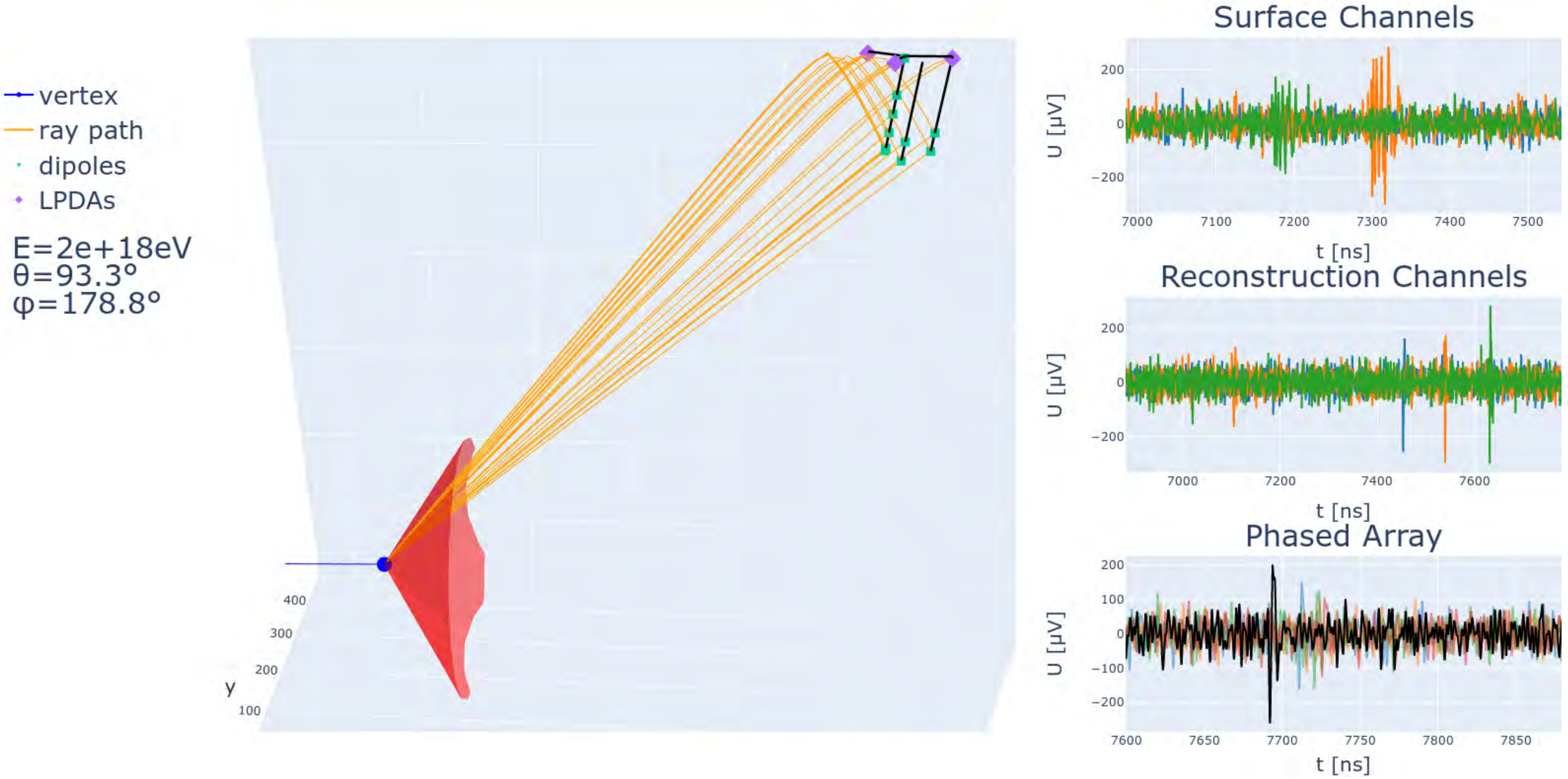


Vpol: Fat dipoles

Hpol: Wide quad-slots

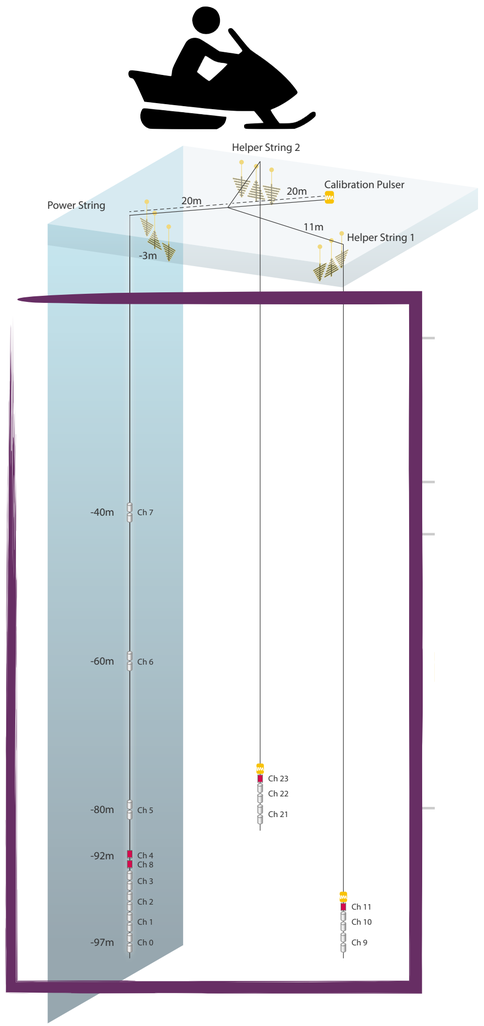
# RNO-G Events

*RNO-G Whitepaper arXiv:2010.12279*



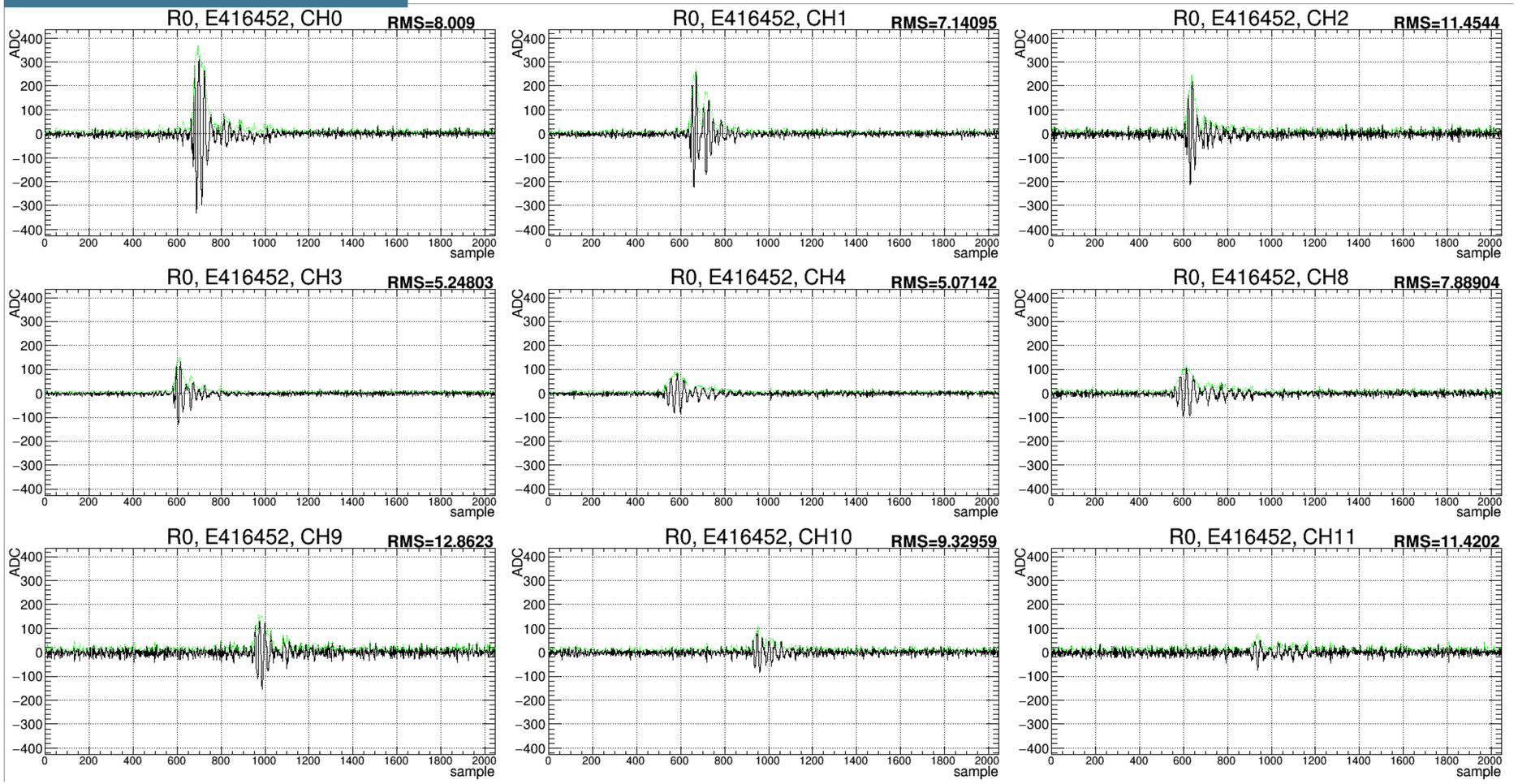

*See I. Plaiser PoS(1026), C. Welling PoS(1026) for more on event reconstruction*

# First Deep Events



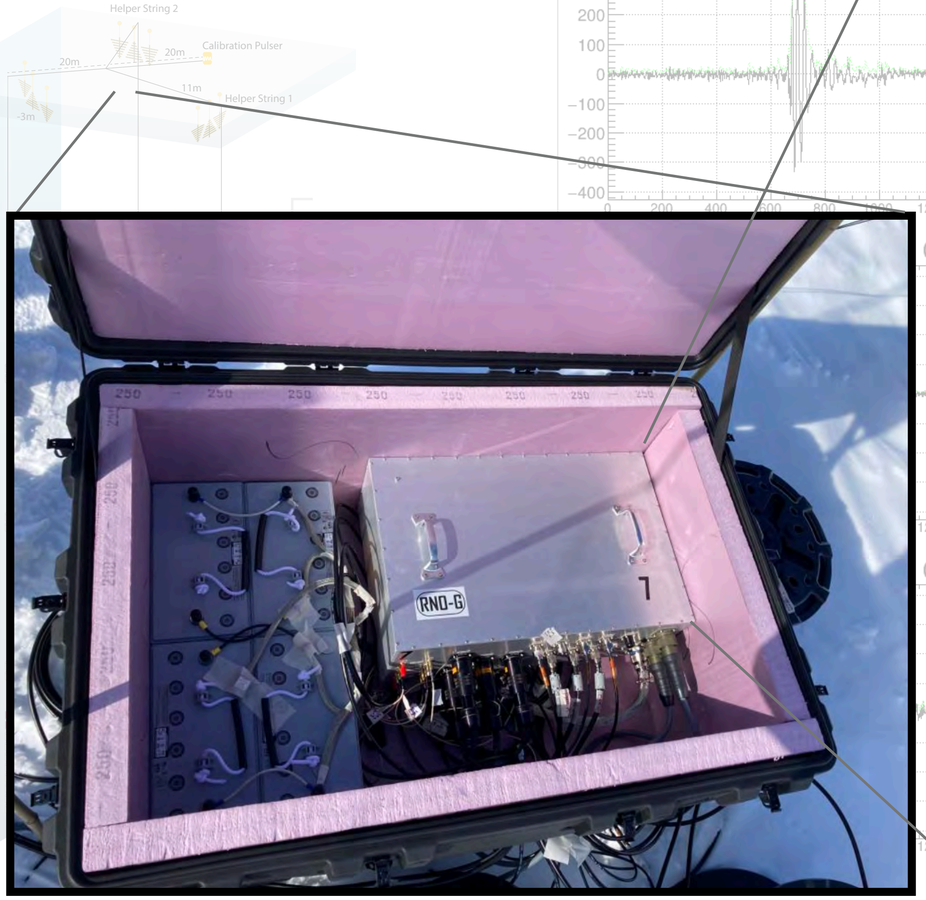

## Snowmobile lights up the deep channels

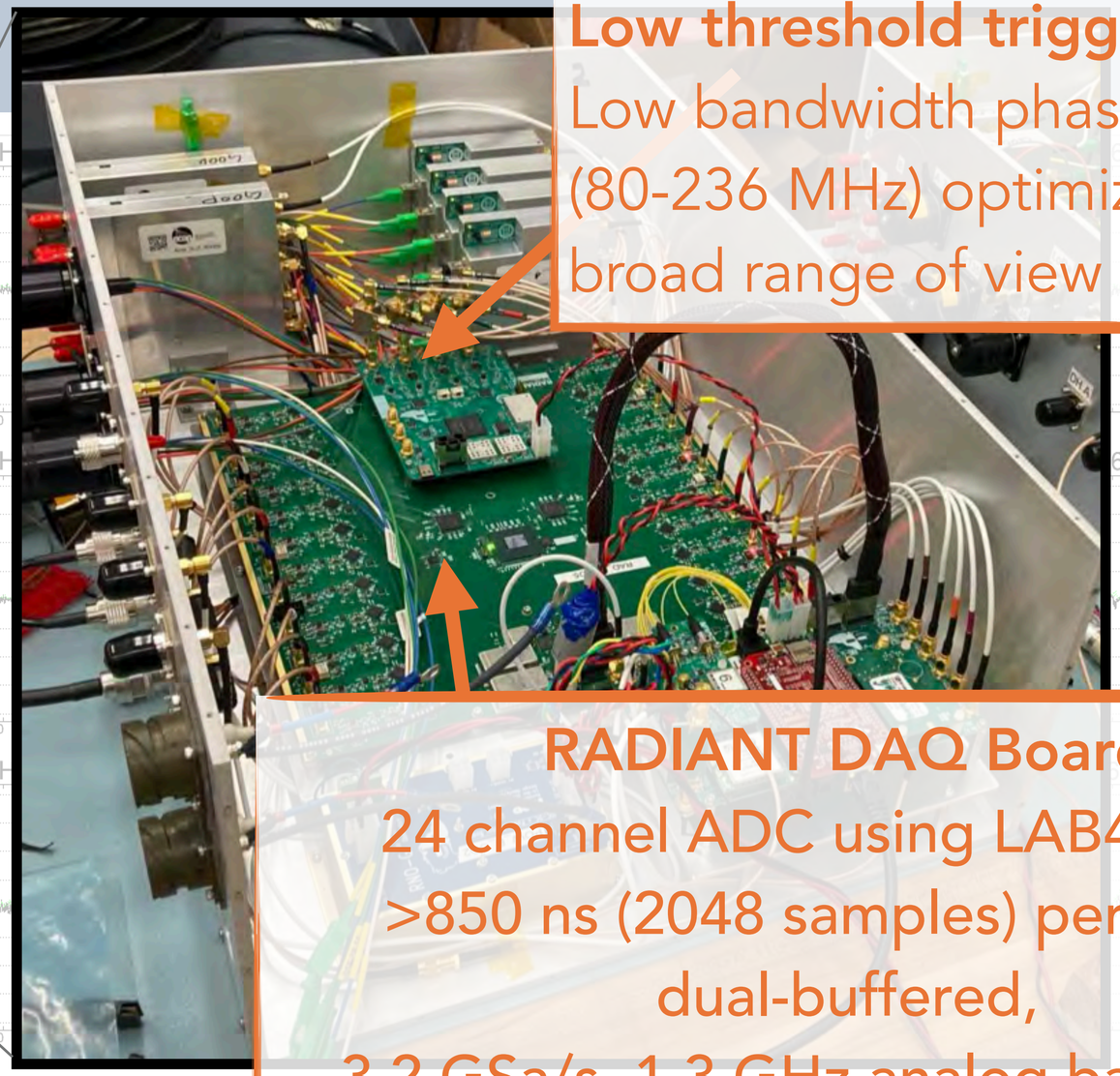
### Deep Vpol Channels



# First Deep Events - Hardware

*See D. Smith PoS(1058) for more on the instrument hardware*



**Low threshold trigger board**

Low bandwidth phased trigger (80-236 MHz) optimized for broad range of view angles

**RADIANT DAQ Board**

24 channel ADC using LAB4D SCA

>850 ns (2048 samples) per event, dual-buffered,

3.2 GSa/s, 1.3 GHz analog bandwidth

Low power envelope trigger

# Stations are designed for **scalability**

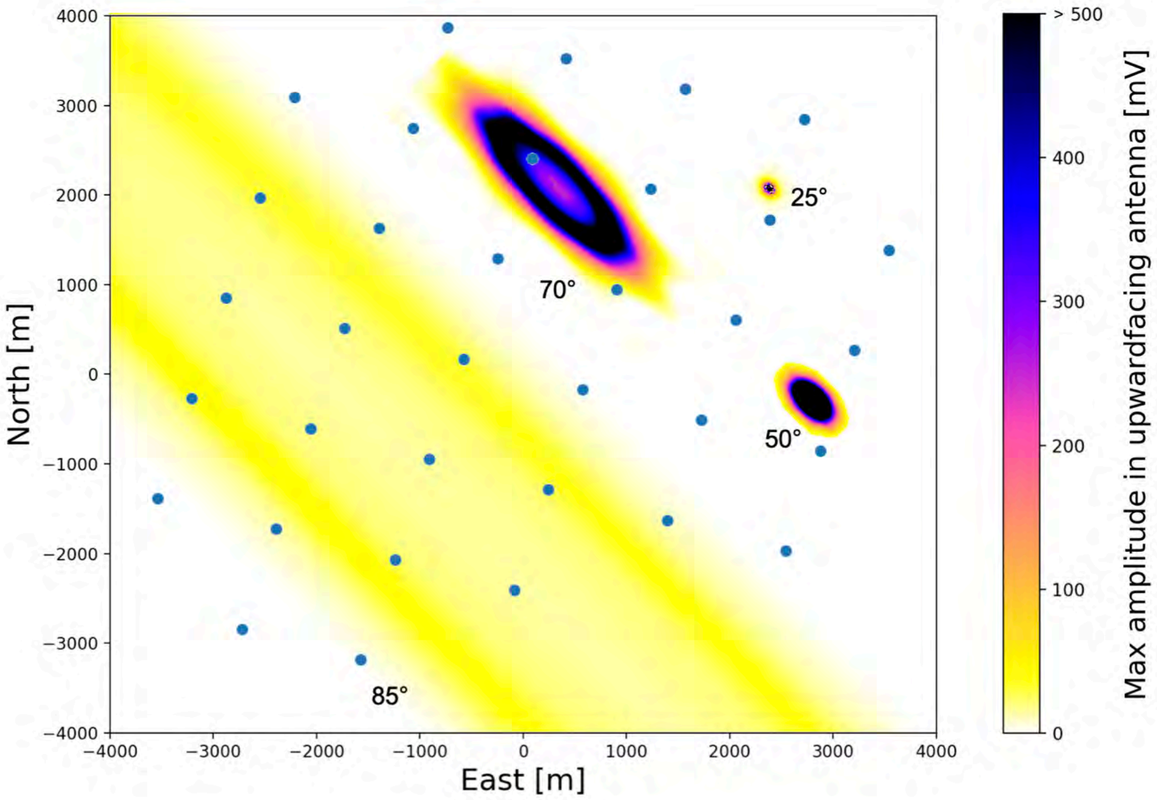
- Low Power ~ 25 W / station
- Autonomous:
  - Solar power ~ expect 60-70% uptime
  - LTE / LoRaWAN communications
- Plan to use wind turbines in later seasons to extend livetime

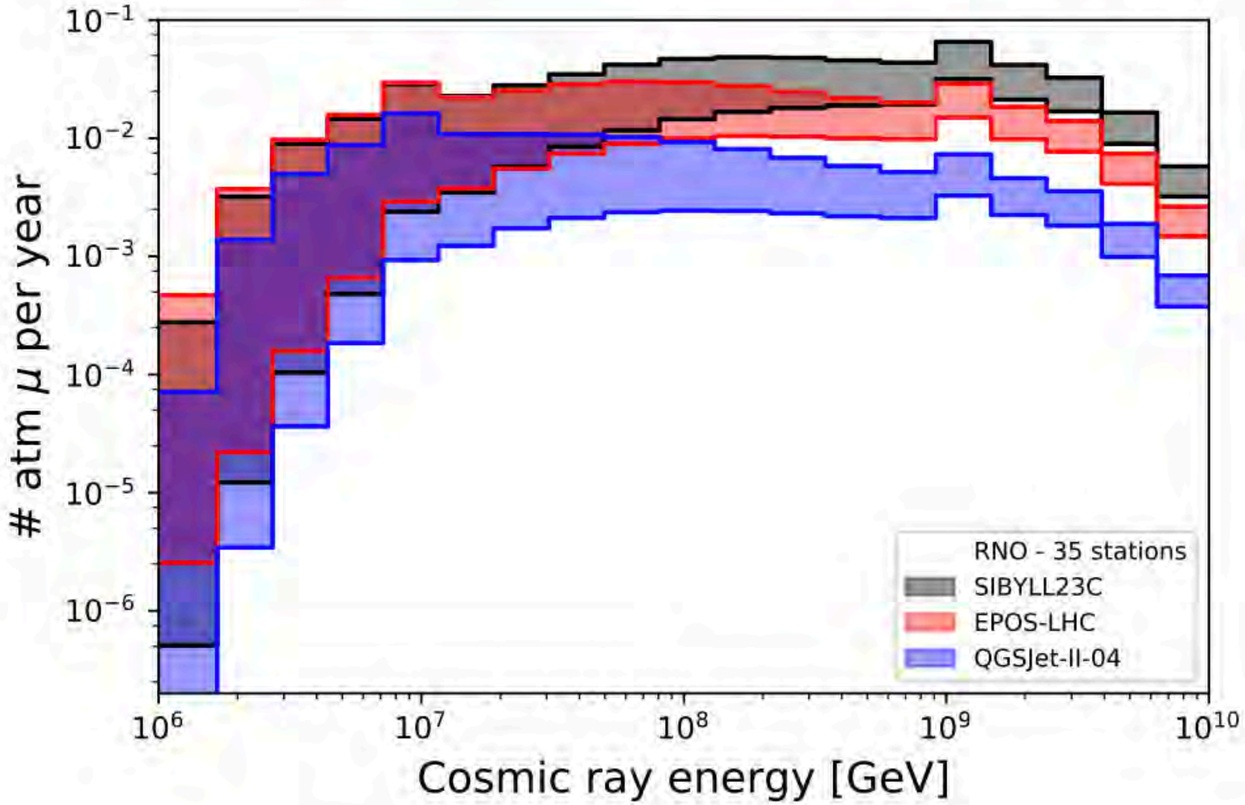
*See D. Smith PoS(1058) for more on the instrument hardware*

# Cosmic Ray Backgrounds

*RNO-G Whitepaper arXiv:2010.12279*

- Shallow component vetoes both kinds
  - Cosmic ray air showers
  - Penetrating muons from cosmic ray air showers
    - Would otherwise be $\mathcal{O}(0.1-1)$ per year for the array, comparable to possible neutrino event rates



# Summary

- RNO-G is the first science-level instrument to target the **UHE cosmic neutrino sky** in the **North**
  - **New** hybrid design combines ***deep component*** for high effective volume from deep, low threshold trigger with ***shallow component*** for redundancy & vetos
  - Designed for **scalability** – large scale deployment, low power
  - Planned **35 stations** are currently under construction
  - **First** stations are taking **data…**

RNO-G
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