

The Radio Neutrino Observatory in Greenland

Status and Perspectives

42nd International Conference on High Energy Physics, Prague, 2024

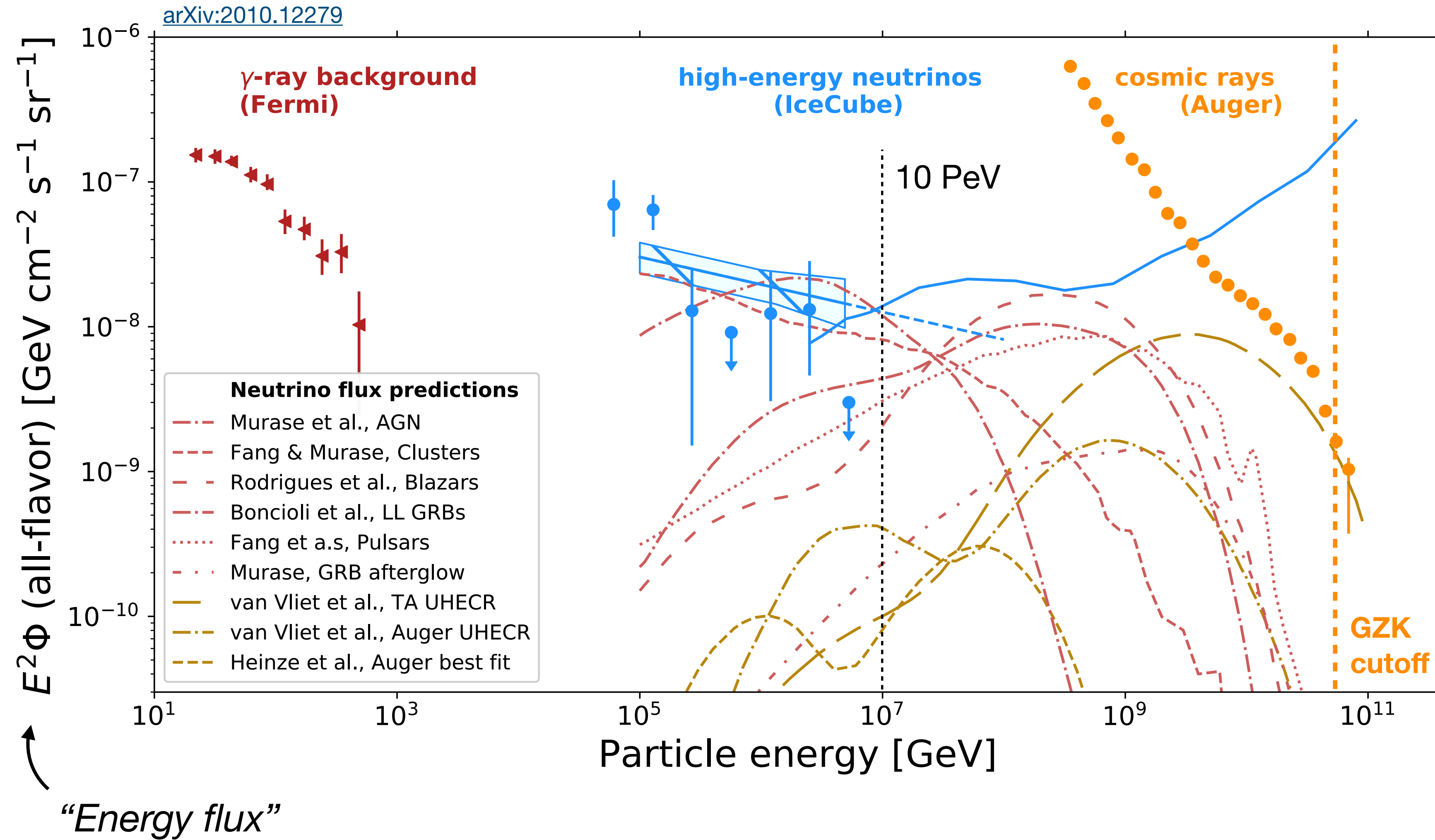
July 18, 2024

Philipp Windischhofer on behalf of the RNO-G Collaboration

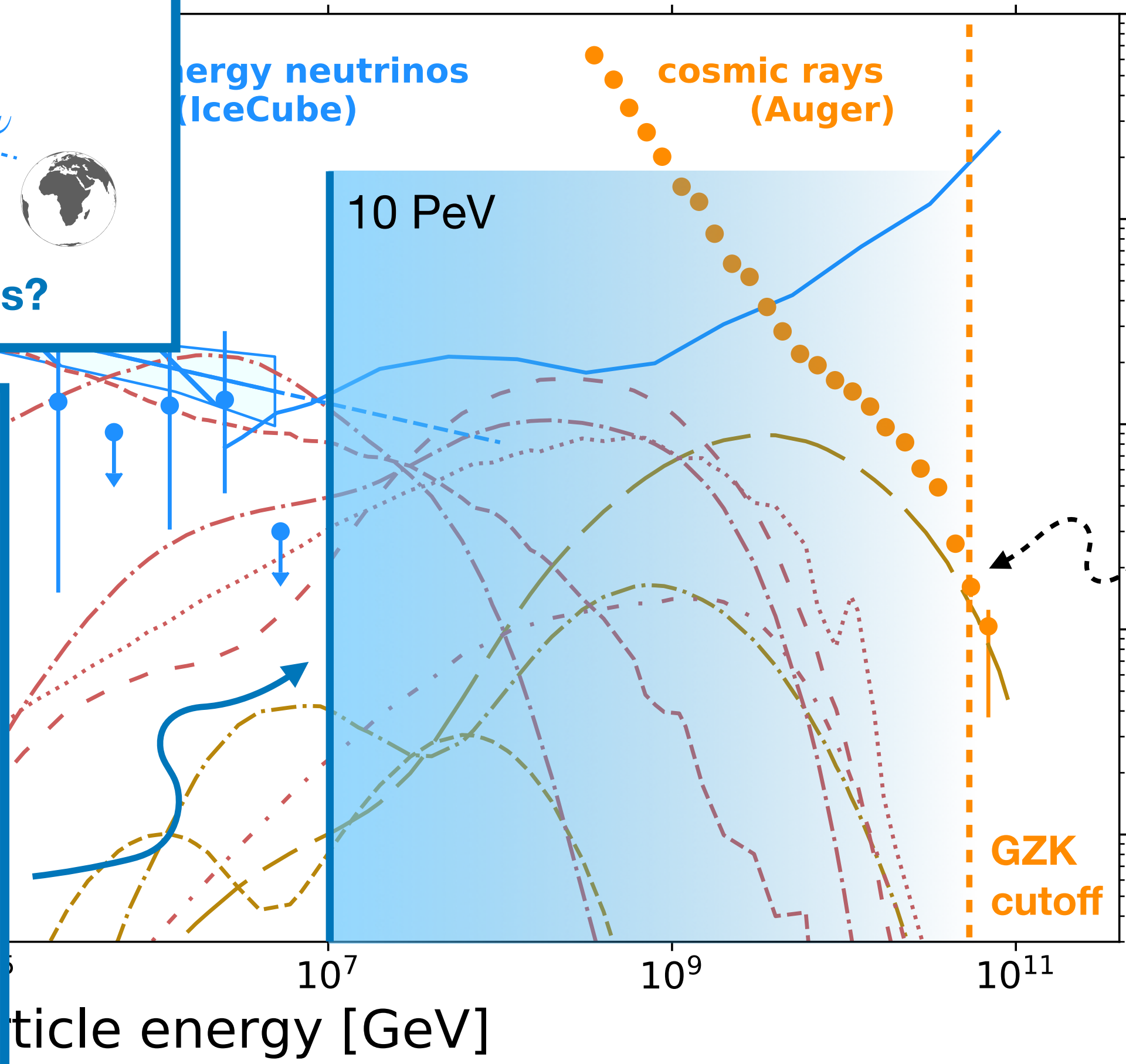
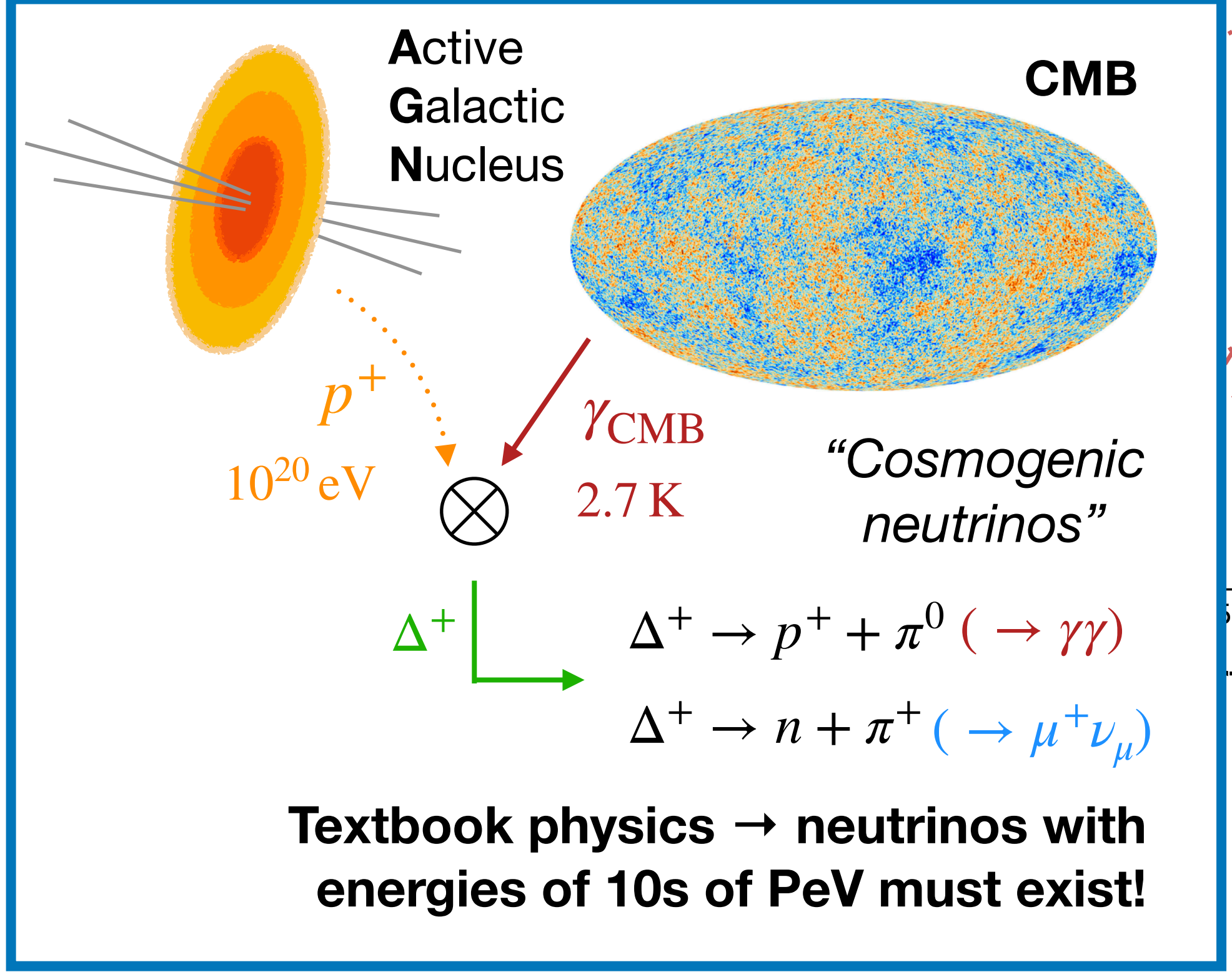
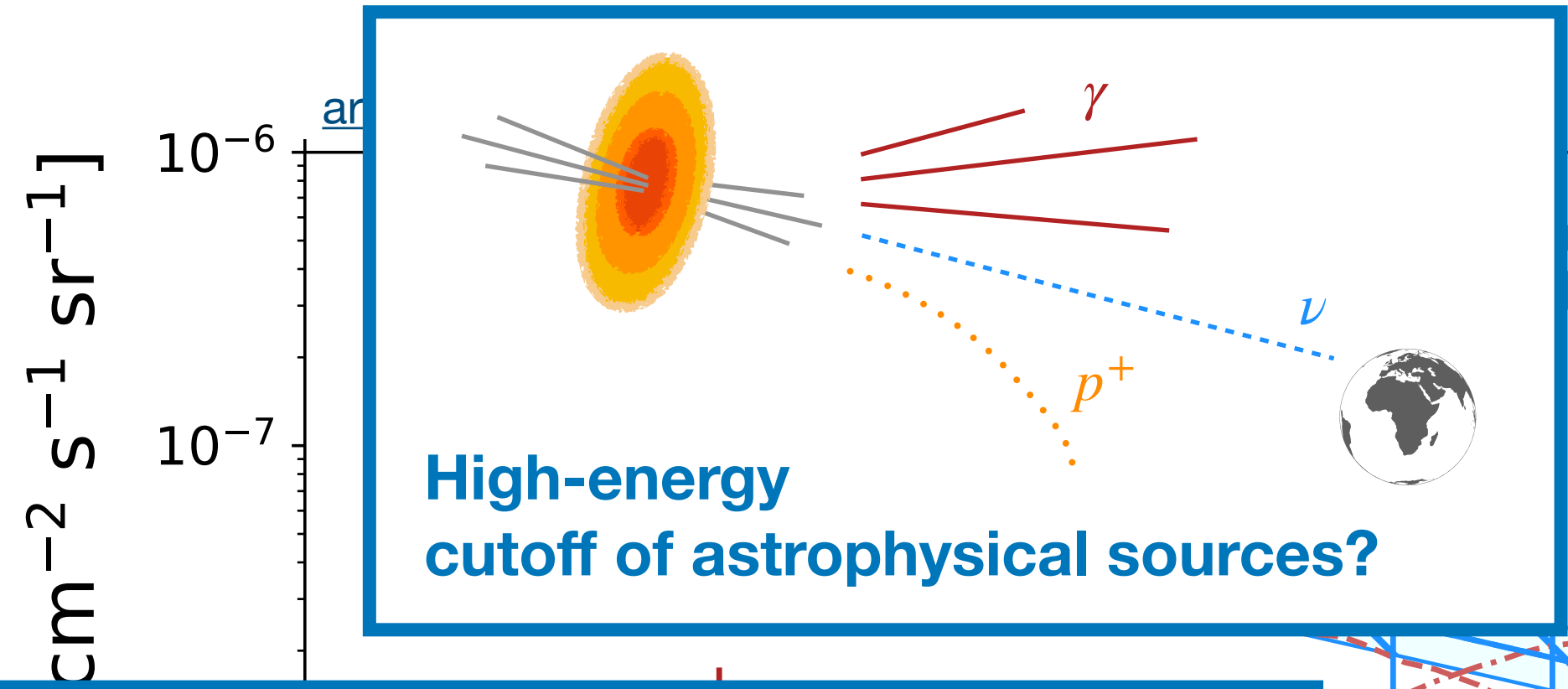
University of Chicago



The high-energy landscape of our universe



The high-energy landscape of our universe



Expect **0.01** interactions / km³ / year of GZK-scale neutrinos

Requires instrumented volume of **O(100) km³!**

Radio Neutrino Observatory in Greenland (RNO-G)
 First science-scale radio array targeting $\geq 10 \text{ PeV}$ neutrinos in the northern hemisphere

Radio neutrino detection

Use Greenlandic ice as detector medium

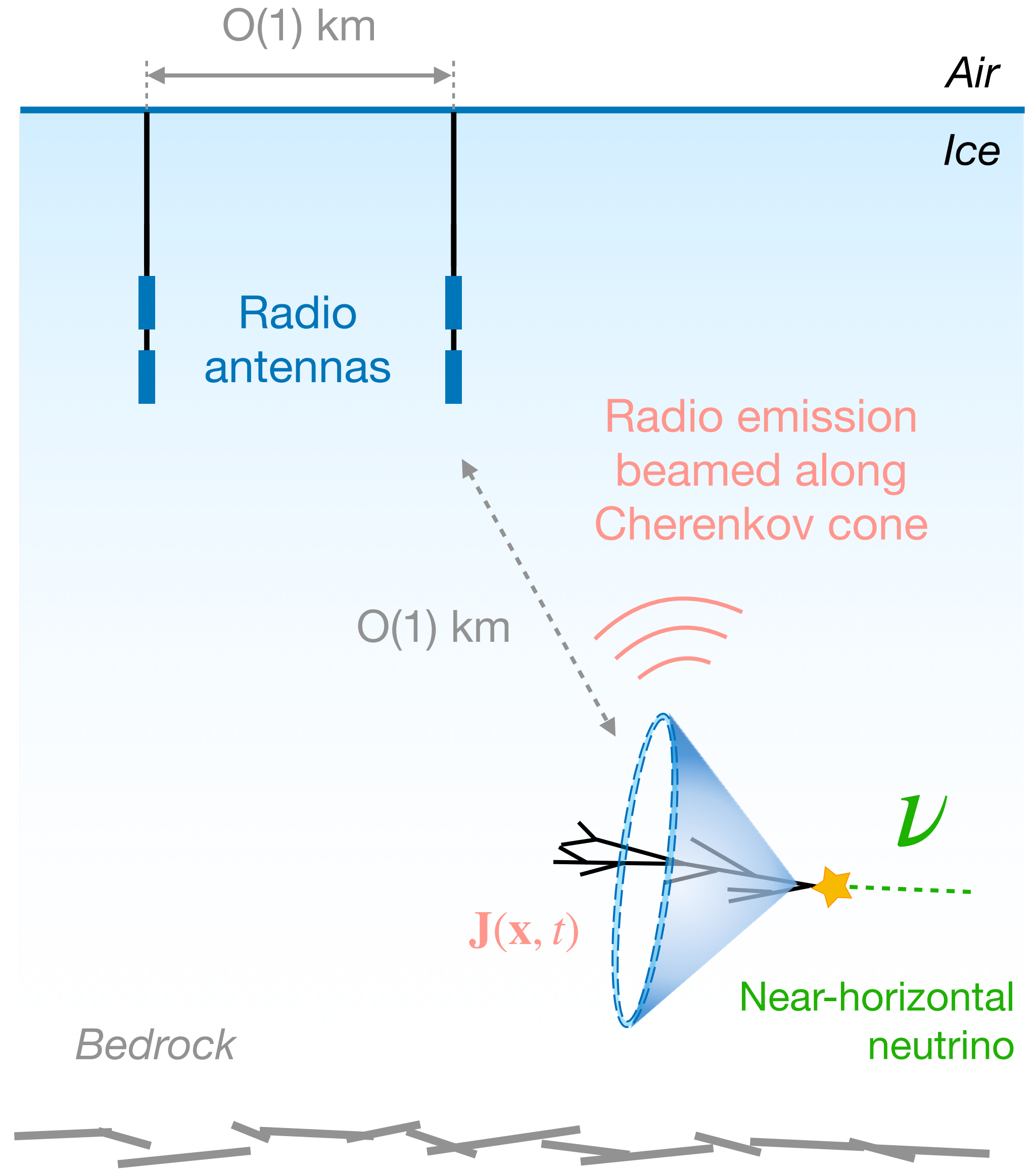
Ice is dense!

Good target material for weakly-interacting particles
Charged particles in shower → **electric current**
Shower front smaller than wavelength
→ **Coherent emission**

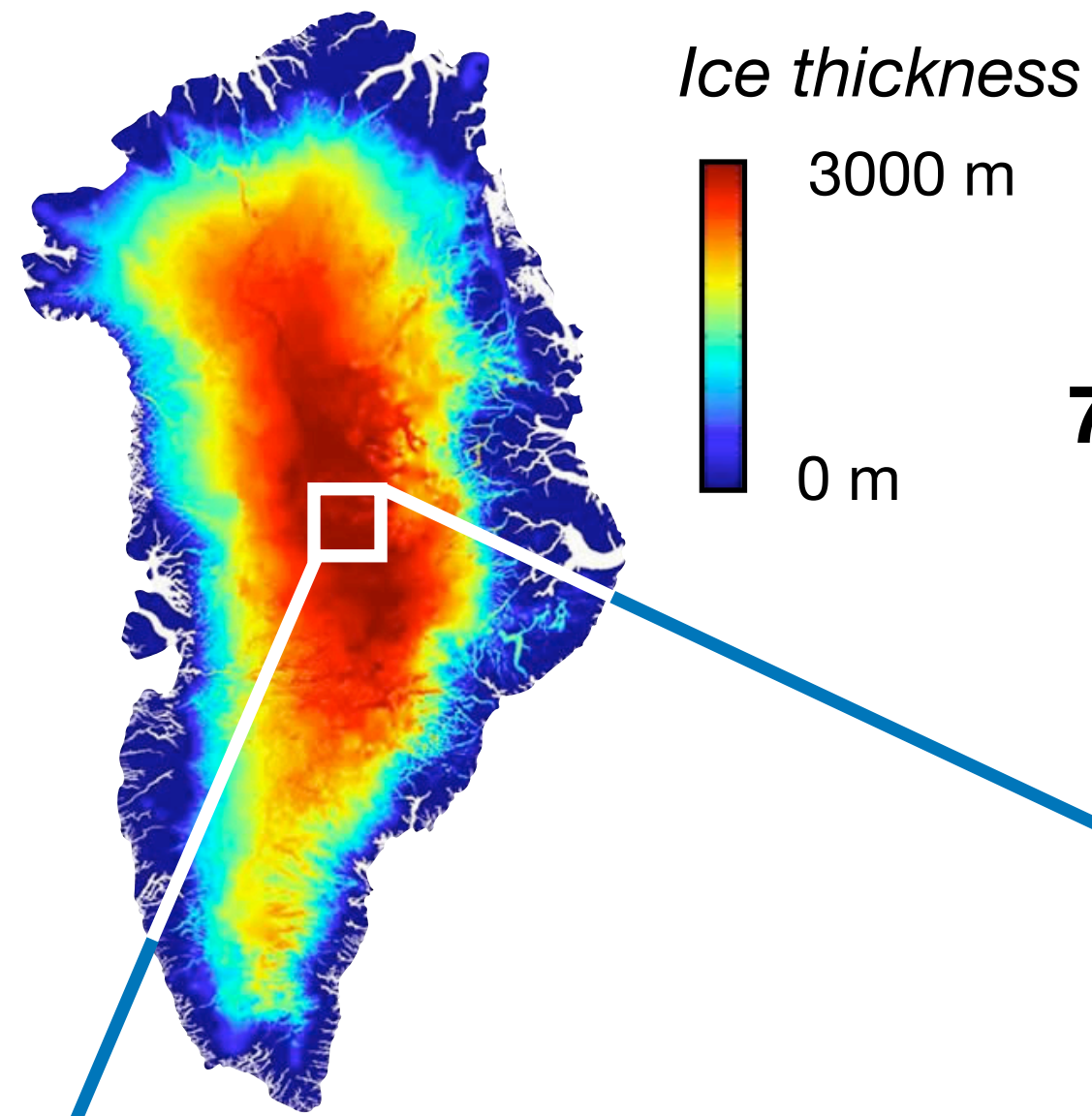
Ice is clean and cold!

Very transparent to electromagnetic radiation
in the MHz - GHz band!
→ **Attenuation length $O(1 \text{ km})$**
 $f \sim 500 \text{ MHz} \leftrightarrow \lambda \sim 0.4 \text{ m}$

**Expect strong signals at high energies,
detectable over long distances**

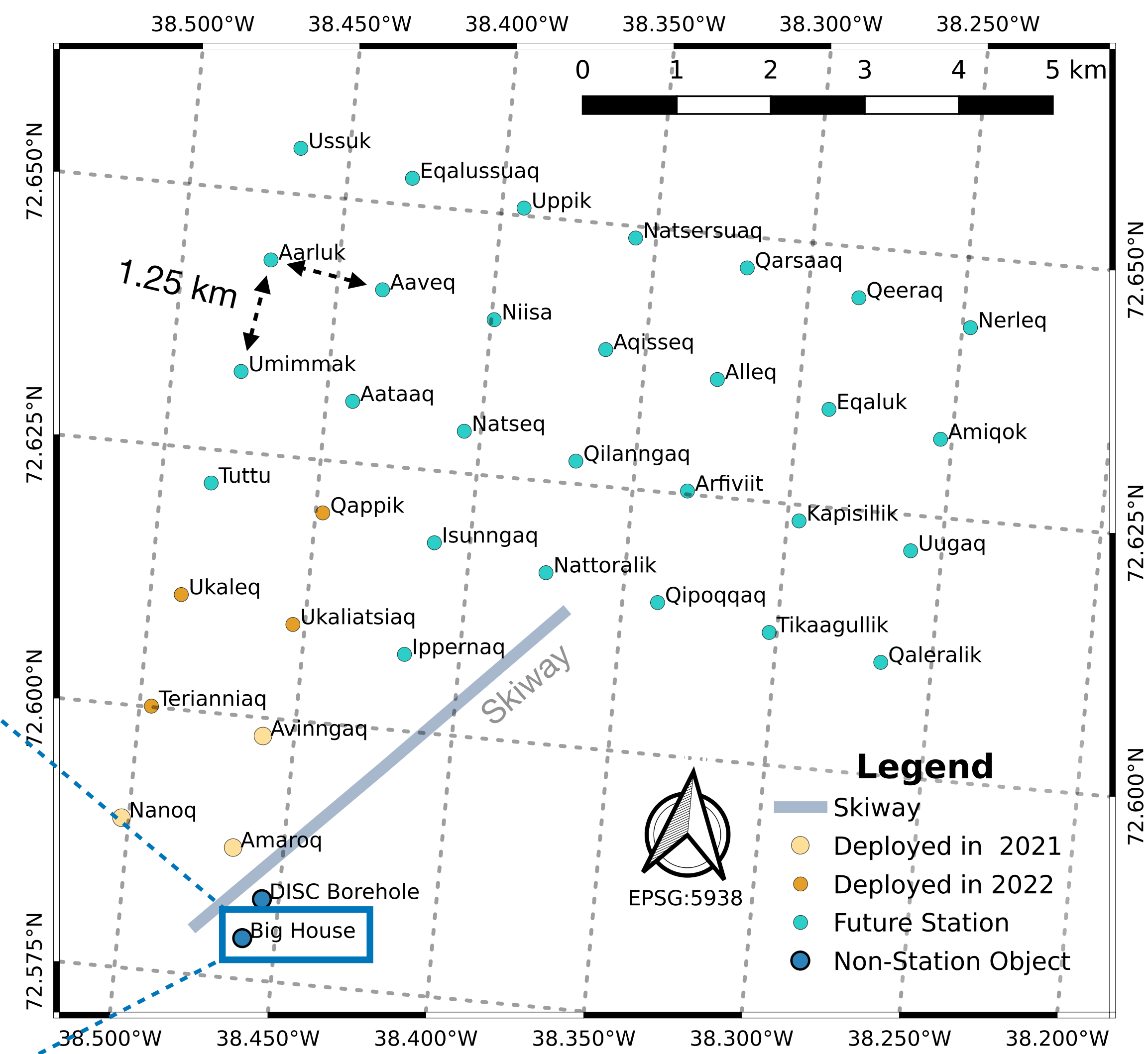


RNO-G: array design



7 stations already deployed and taking data;
35-station array fully funded!

Summit station, Greenland (NSF-operated) ↓



RNO-G: station design



Triangular station layout with downhole and surface antennas

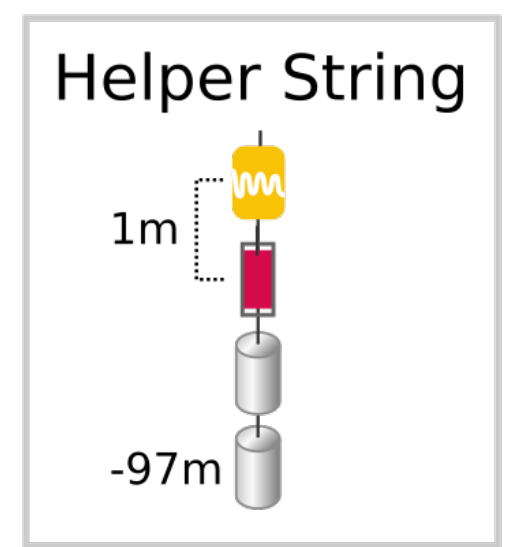
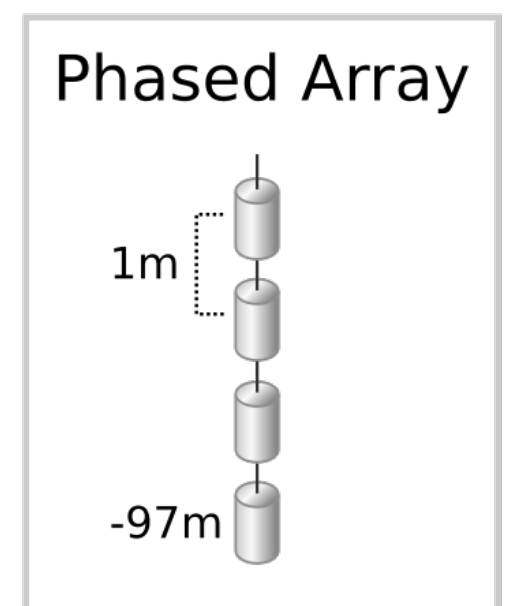
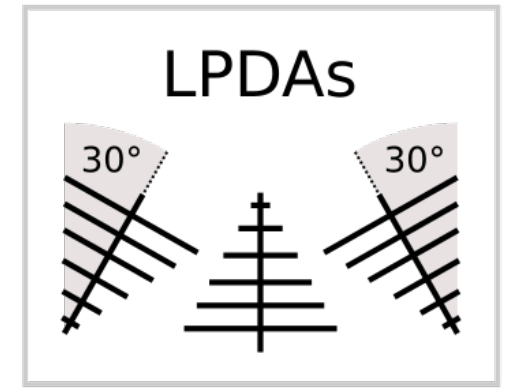
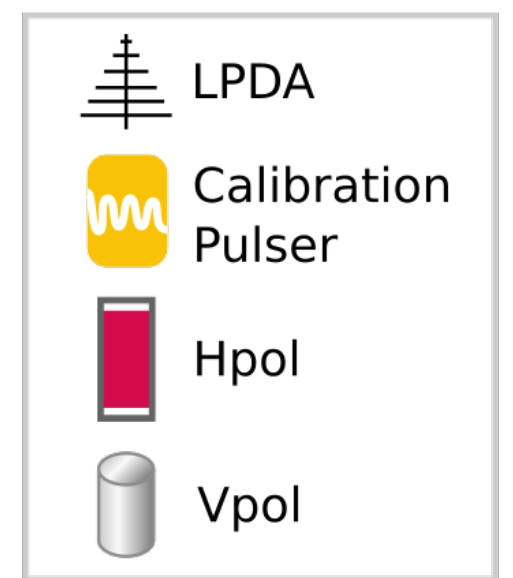
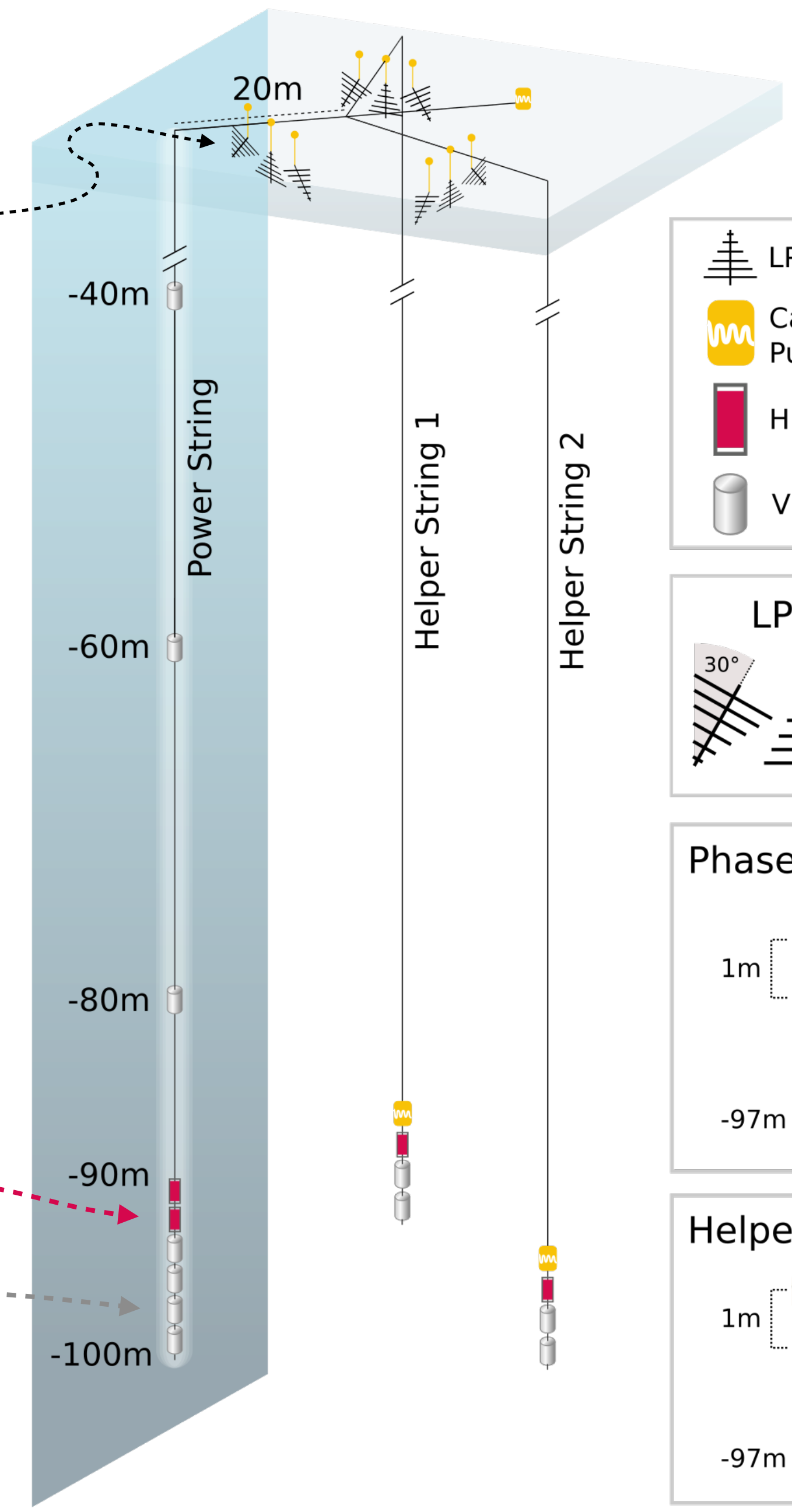
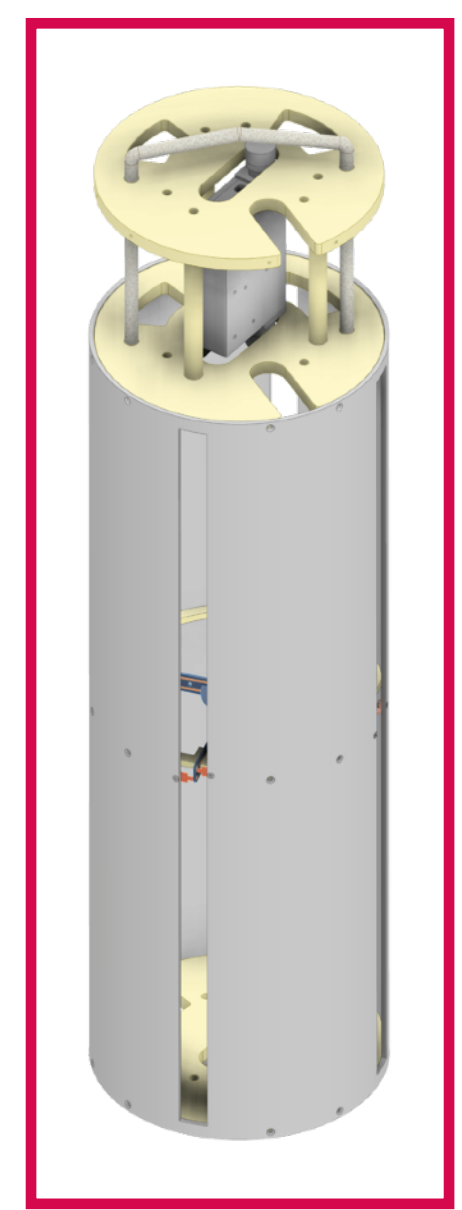
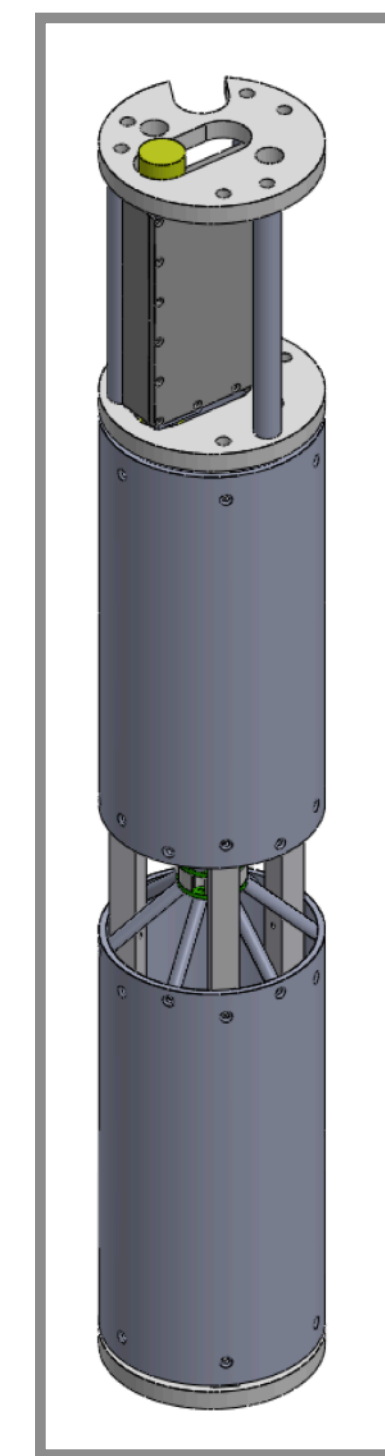
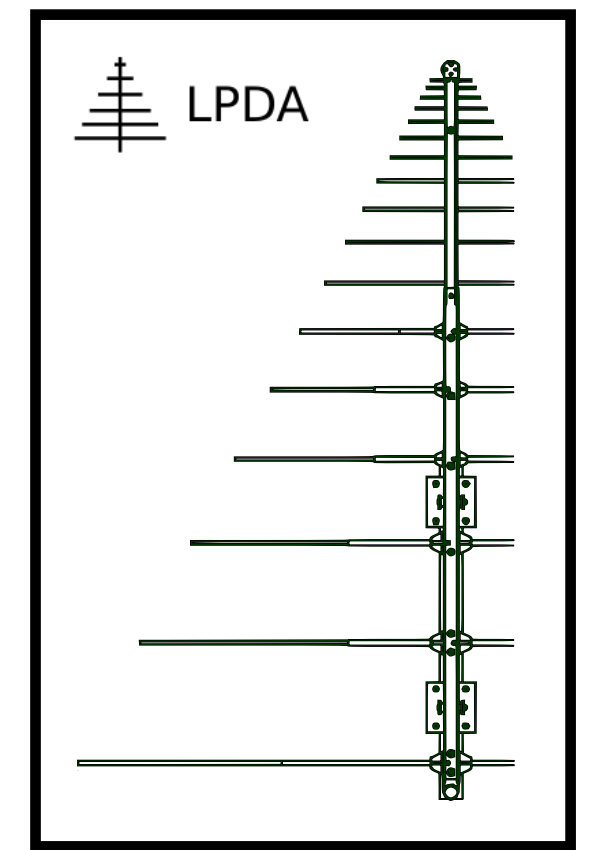
Downhole: Horizontally- (*Hpol*) and vertically-polarized (*Vpol*) dipole antennas

Hole \approx 100m deep in more-homogeneous and radio-quiet ice

Polarization-sensitivity improves direction-finding

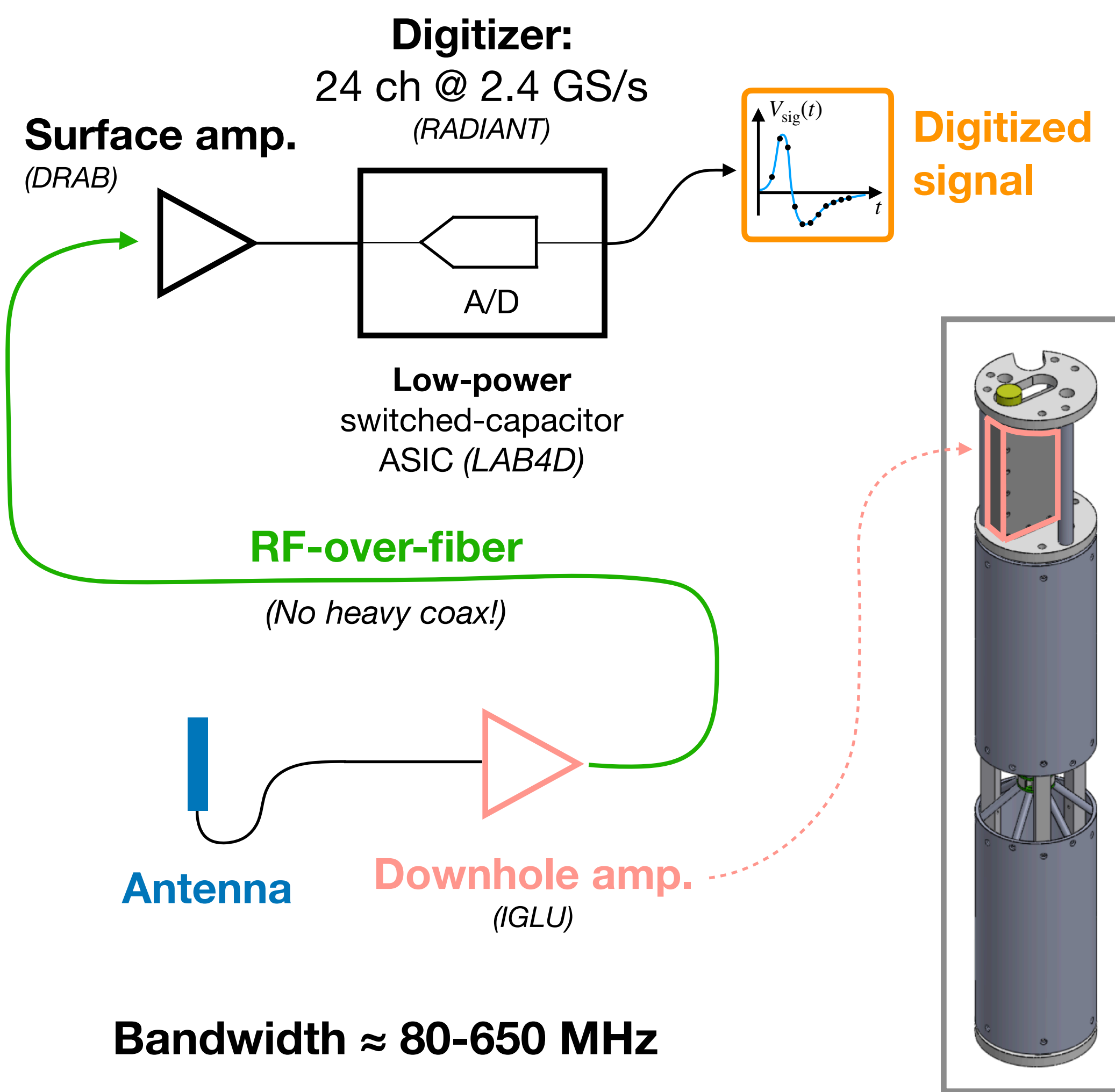
Surface: Upward- and downward-looking (*directional!*) log-periodic dipole antennas (*LPDAs*)

Sensitivity to (down-going) cosmic rays \rightarrow veto

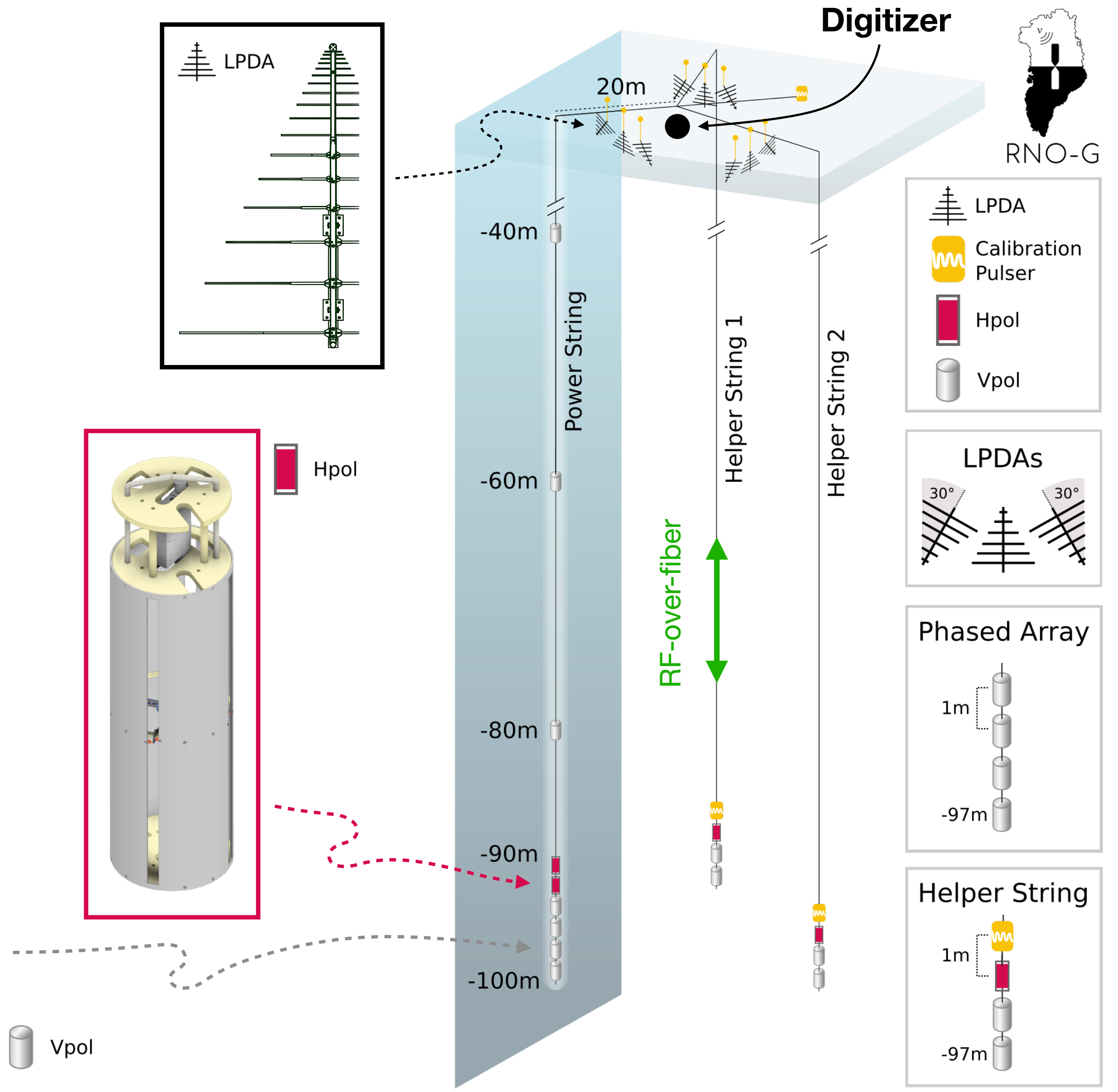


RNO-G: station design

Fully-analog downhole signal chain



Bandwidth \approx 80-650 MHz



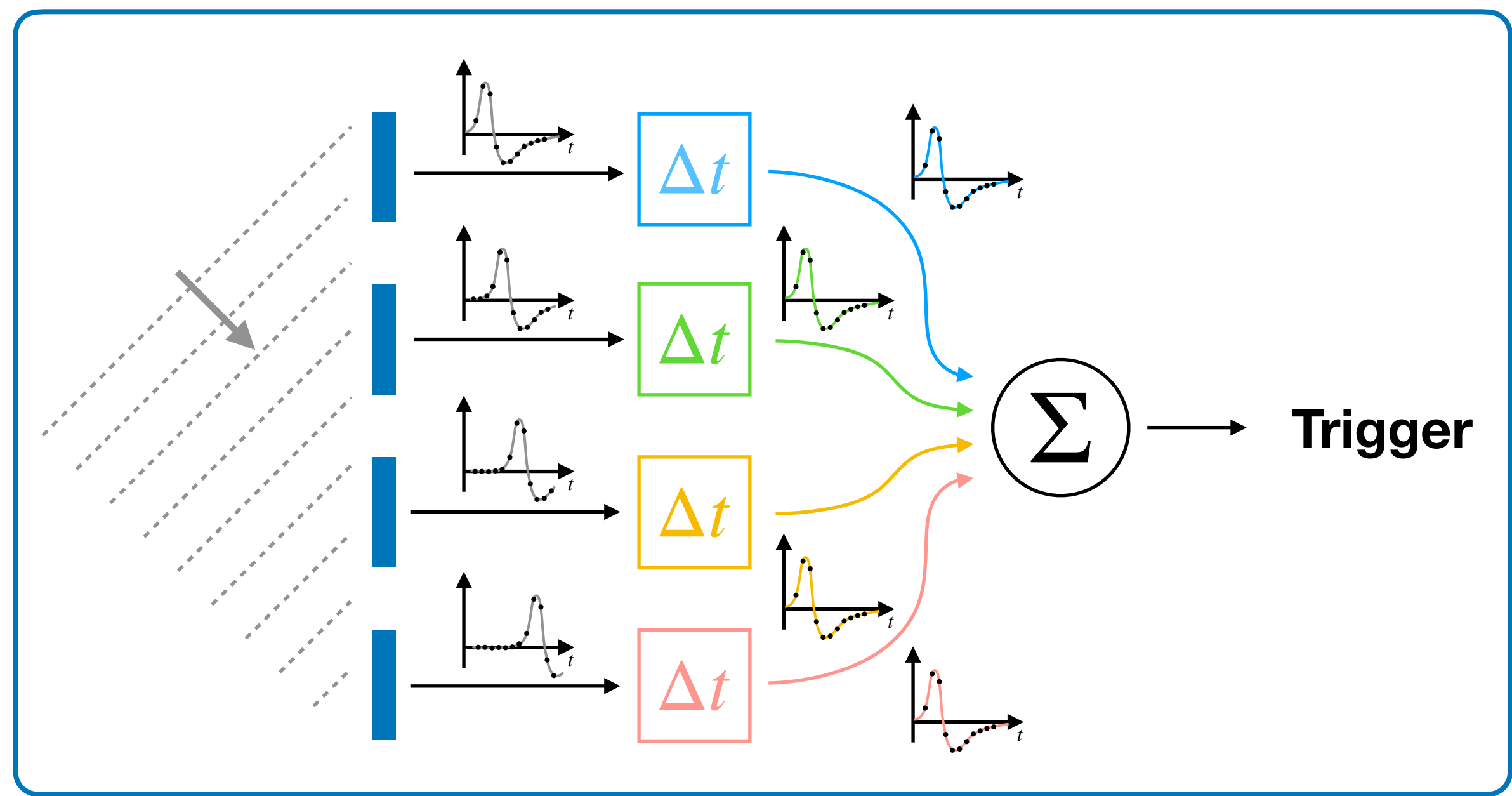
RNO-G: station design



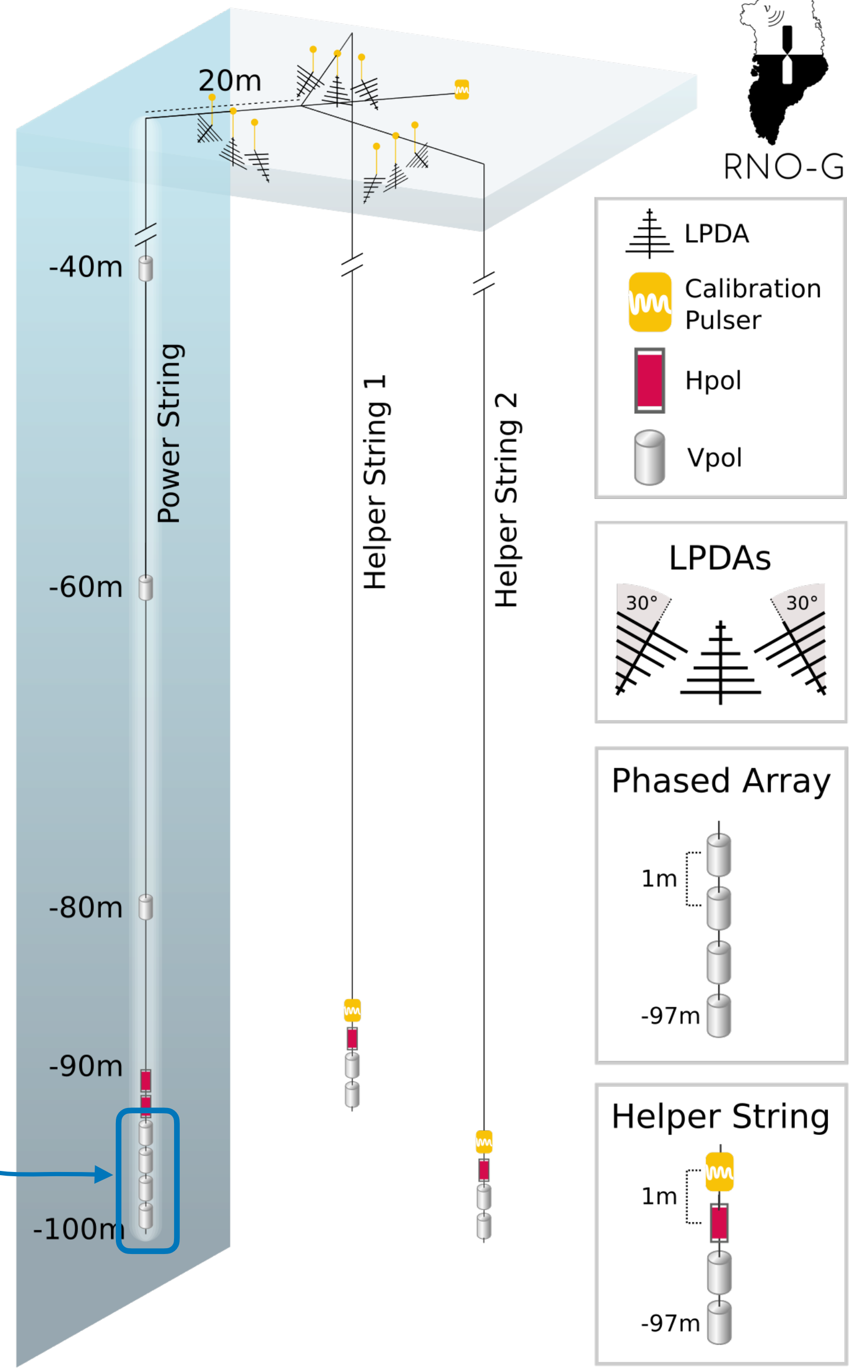
Beam-forming for radio trigger

Downhole-dipoles have low antenna gain
(\varnothing 28cm hole)

→ Synthesize higher-gain directional beams through digital phasing of narrowly-spaced downhole antennas (*“phased array”*)

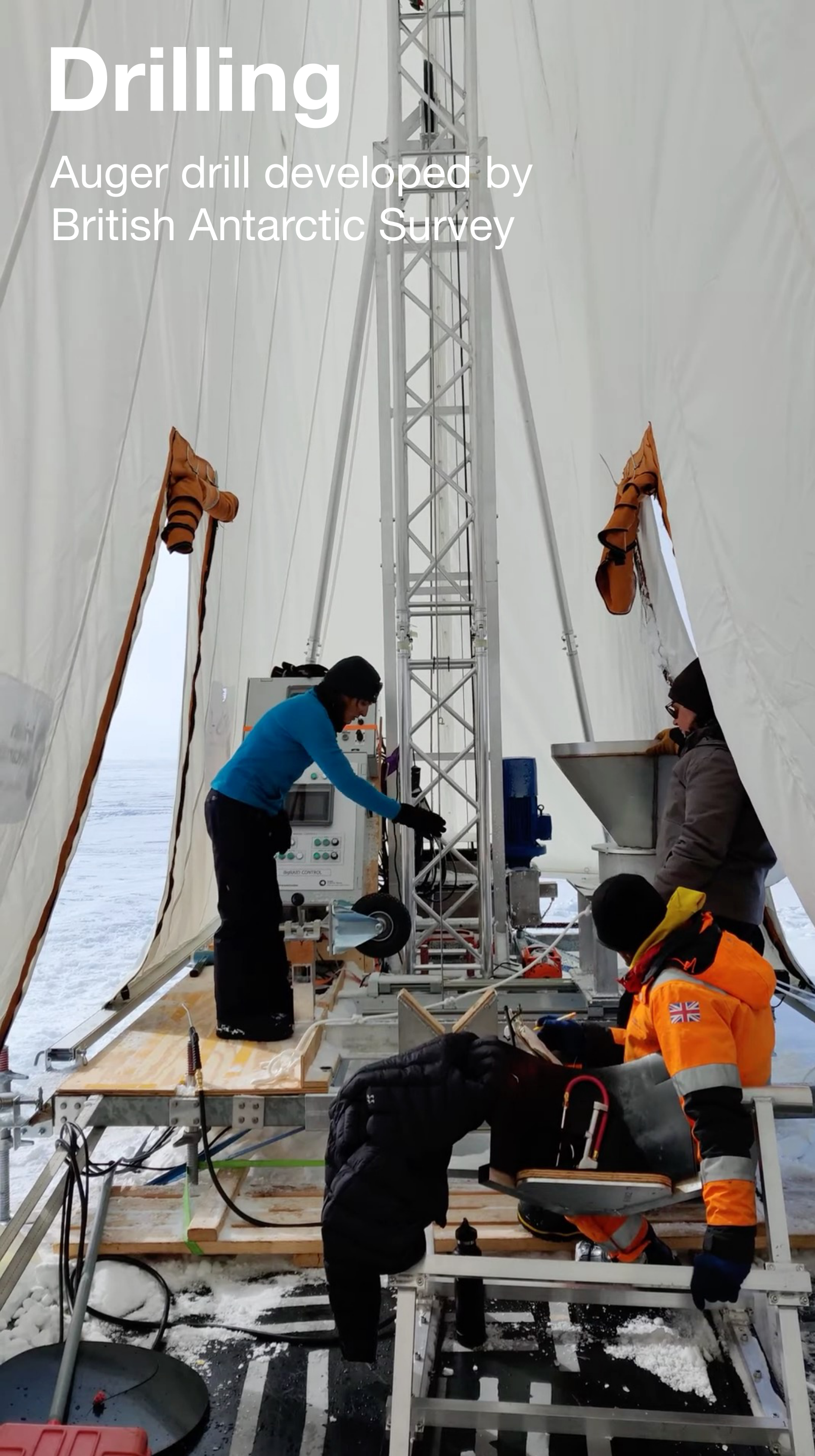


Significantly lower trigger thresholds (relative to single-antenna trigger)
→ To be activated in deployed stations soon!



Drilling

Auger drill developed by
British Antarctic Survey



Antenna
deployment



DAQ installation



Wind turbine
installation

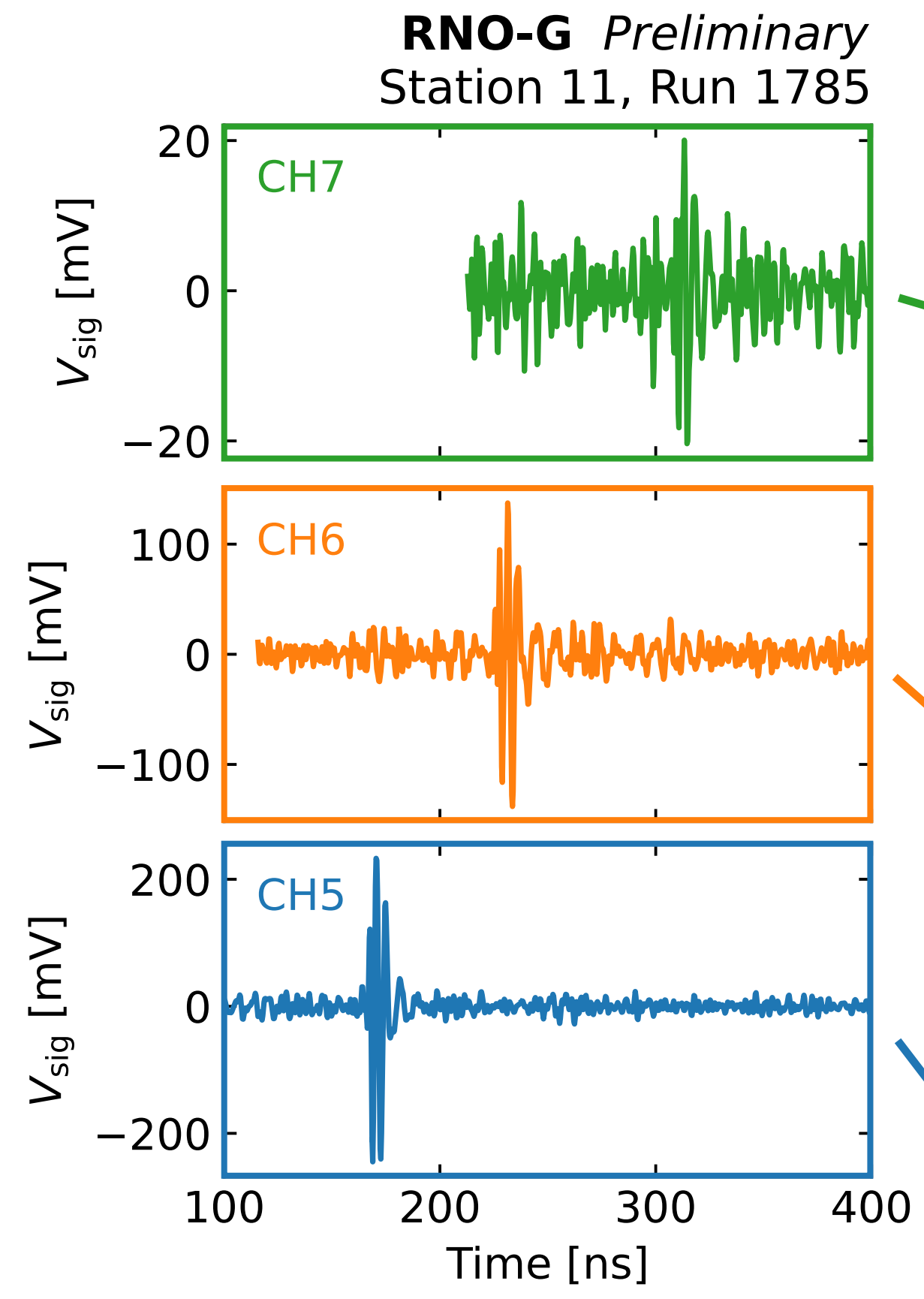
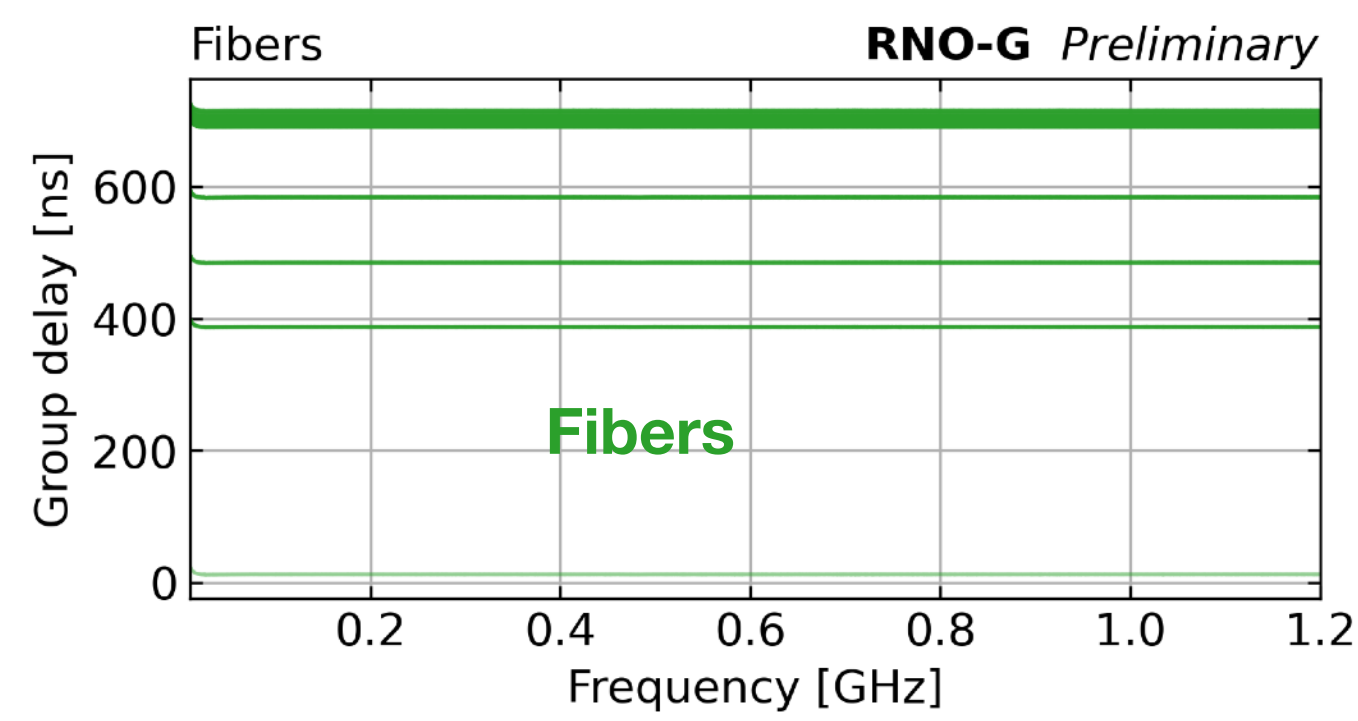
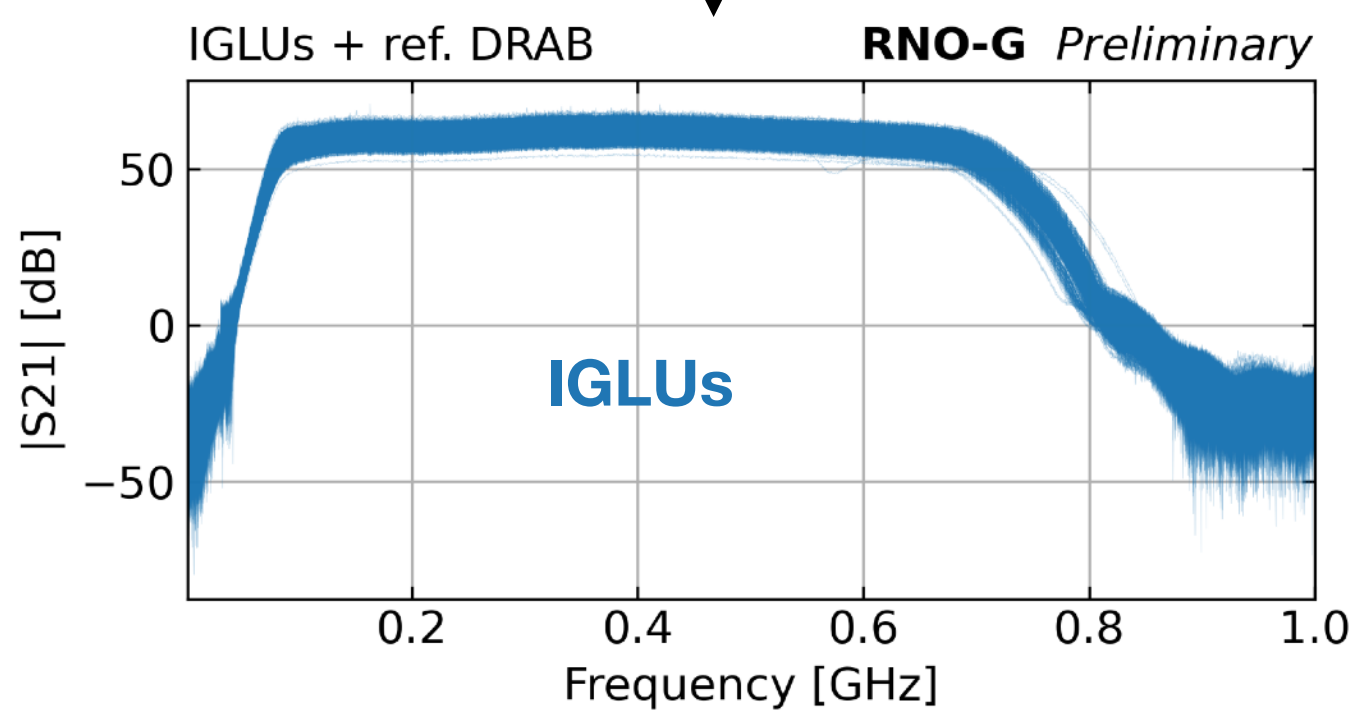
Calibration



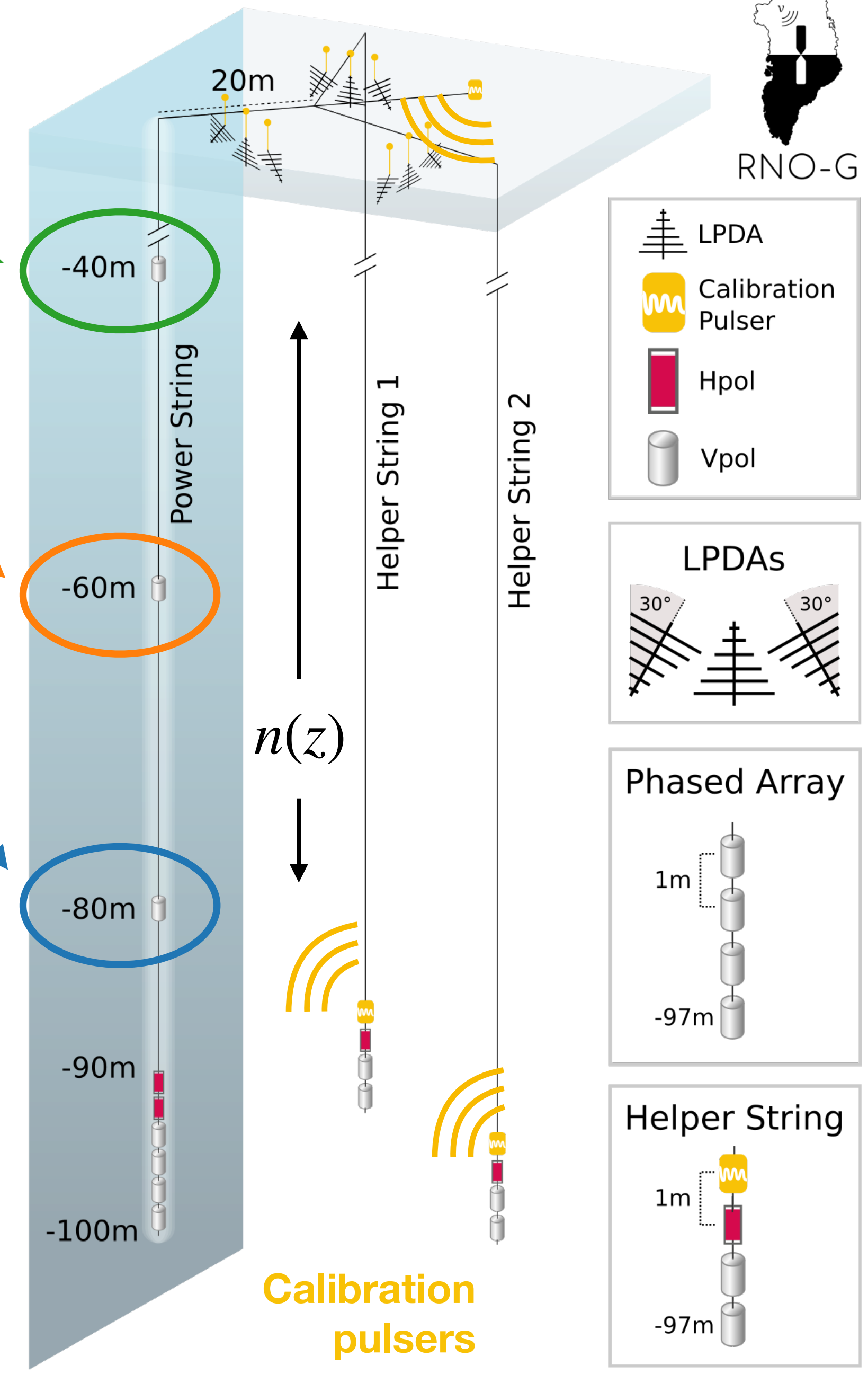
RNO-G

Multi-component signal path:
Forward gain ↔ event energy scale
Group delay ↔ event localization

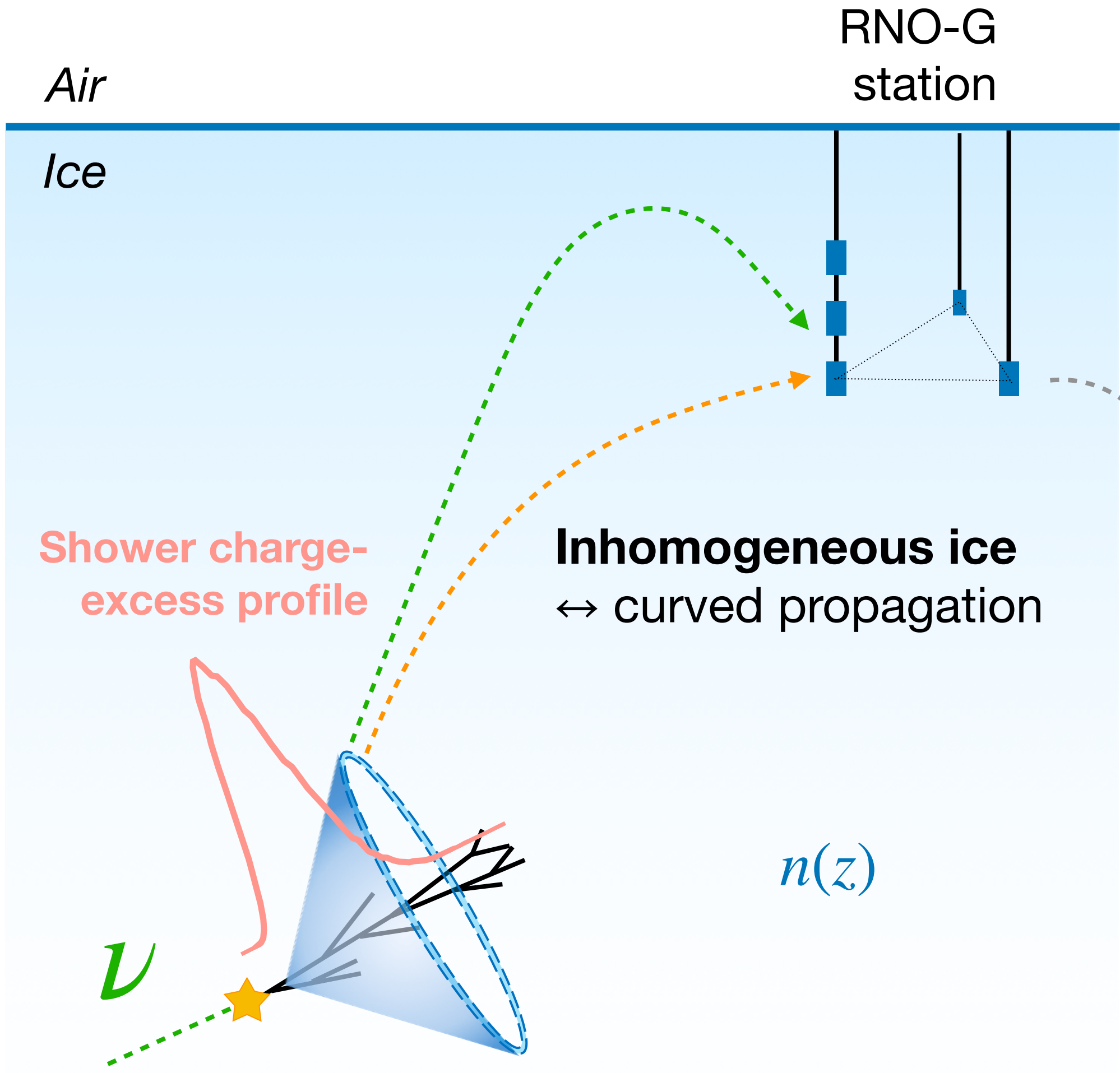
S-parameter characterization of all deployed components



In-situ calibration pulsers:
 Impulsive signals in receiving channels from source with known relative position
 In-situ correction to station geometry and ice refractive index $n(z)$



Simulation

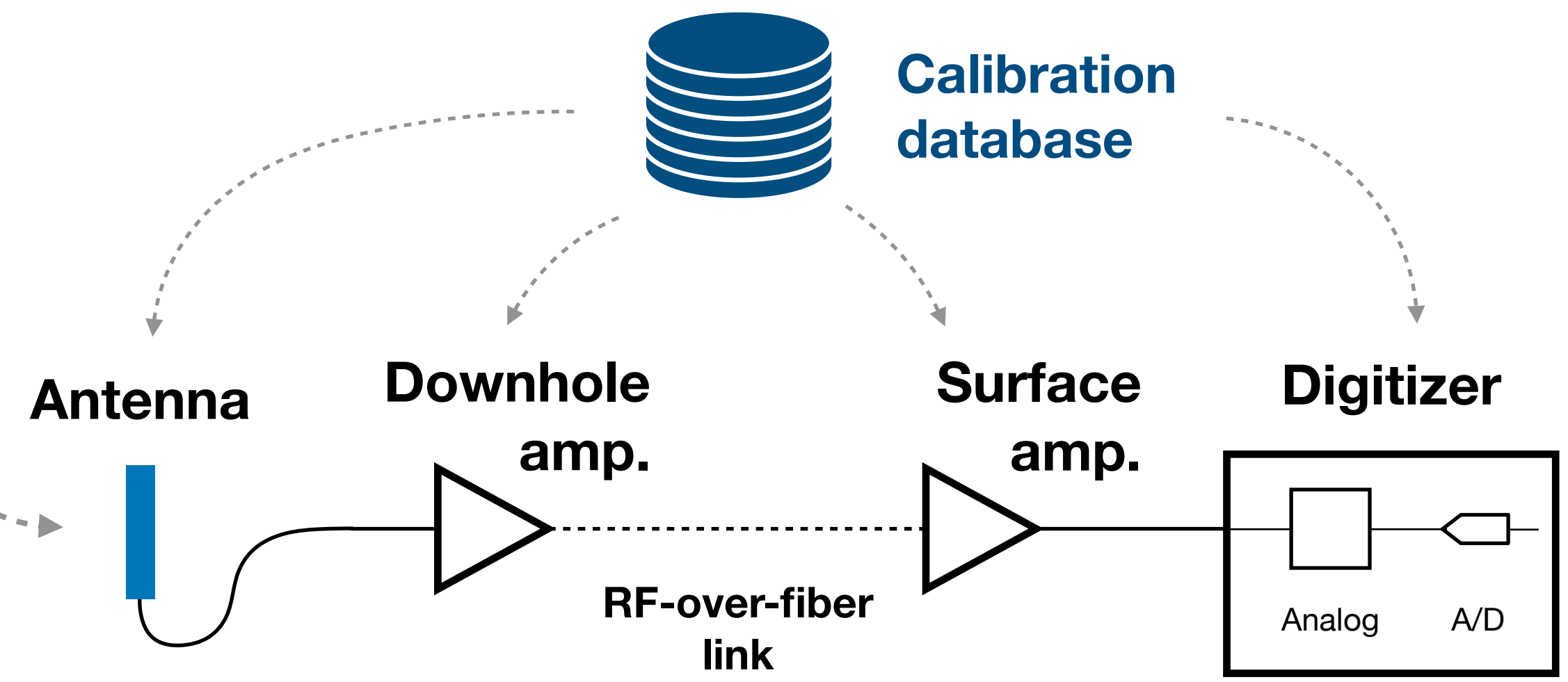


RNO-G is an array built from autonomous stations

Calibration and simulation work hand-in-hand to analyze and interpret data

← Radio emission + propagation (NuRadioMC)

↓ Channel-specific signal chain simulation

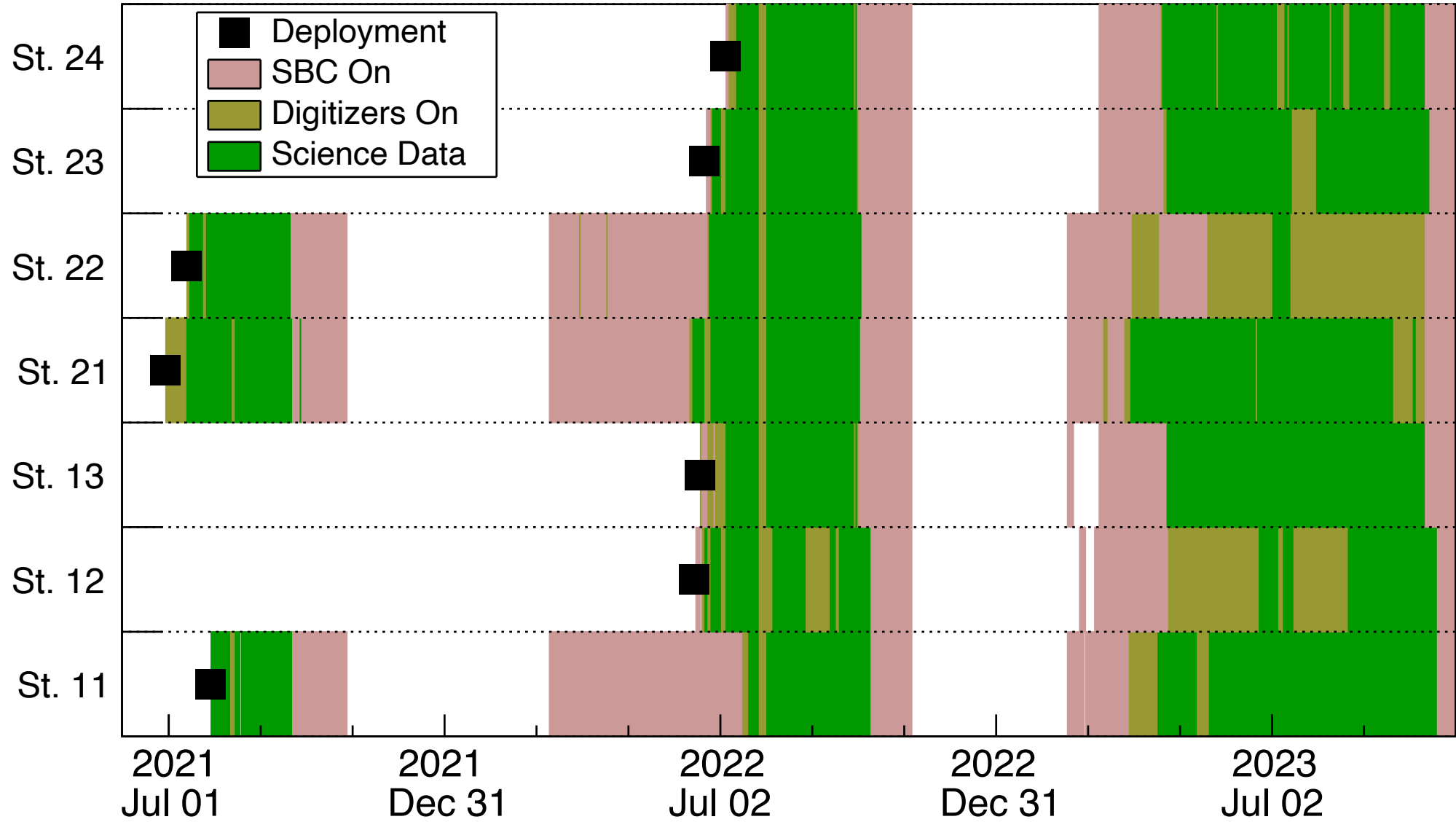


Data-taking status and first results

First deployment in summer 2021;
seven stations currently integrating data

Data set for first neutrino search still blinded

*A broadband radio array is a
very versatile detector!*



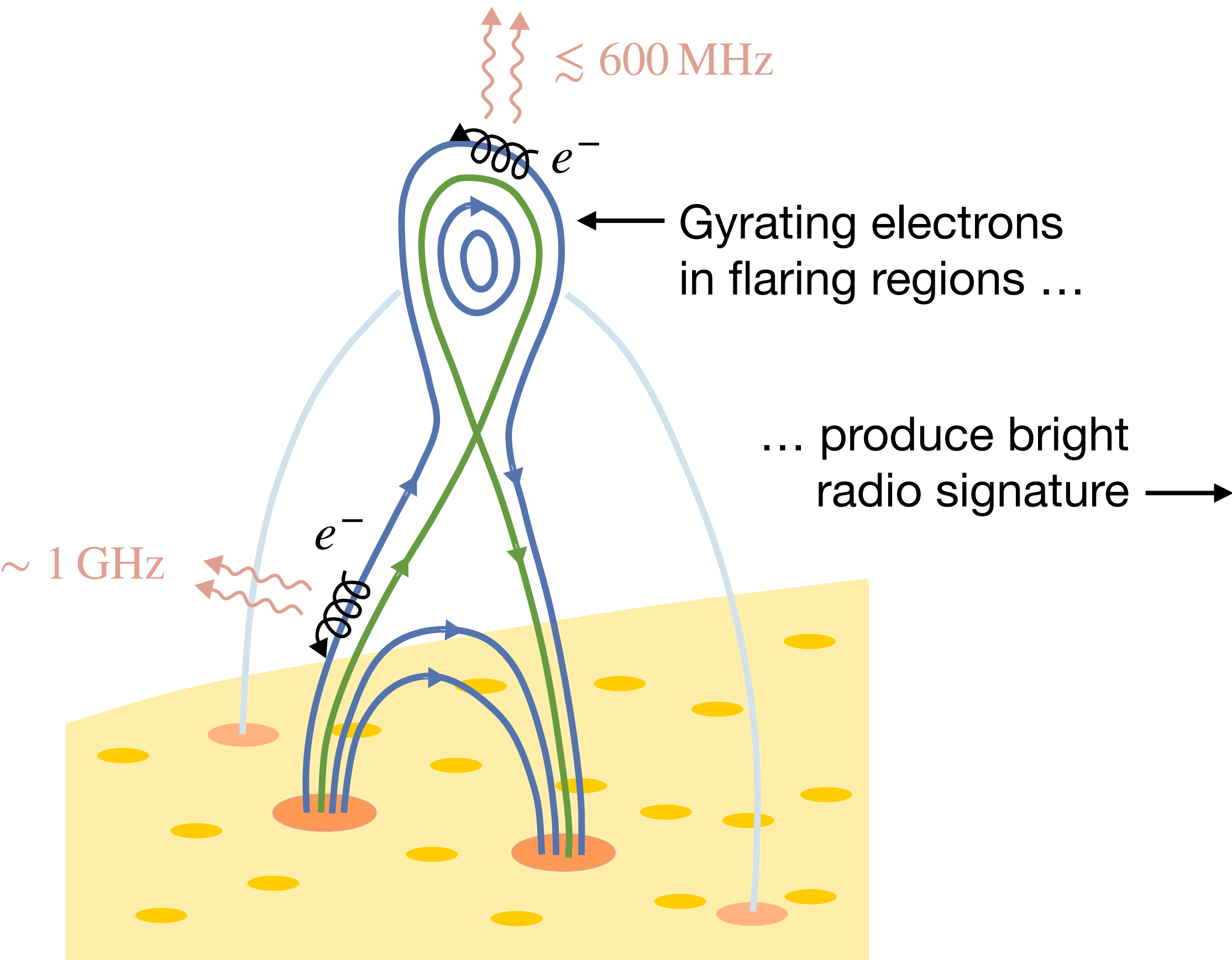
Data-taking status and first results

S. Hallmann, M. Mikhailova

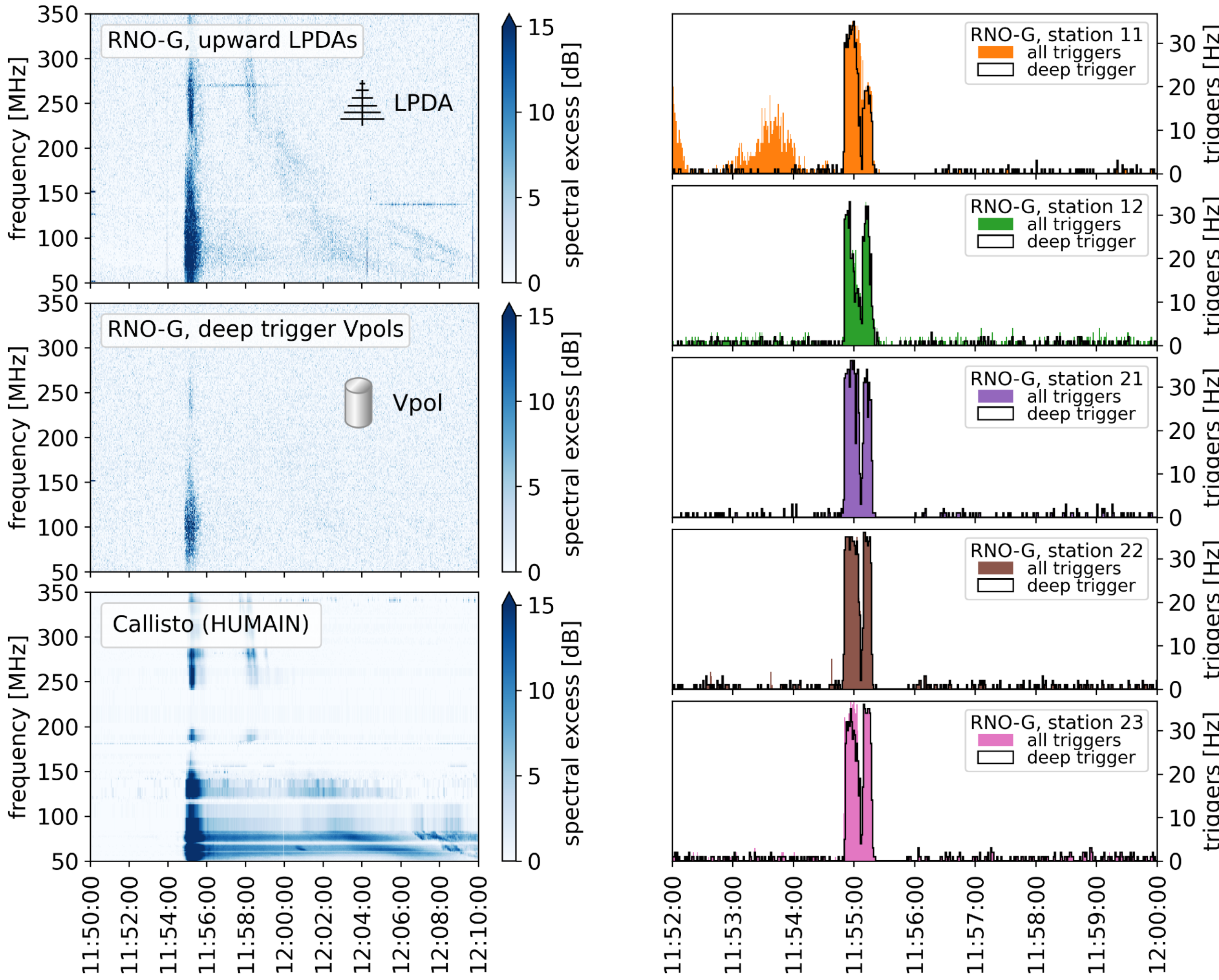
[[arXiv:2404.14995](https://arxiv.org/abs/2404.14995)]

First deployment in summer 2021;
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Observation of solar radio bursts in RNO-G



solar flare on 2022-09-29 (RNO-G Sun zenith angle: 78.8 deg)

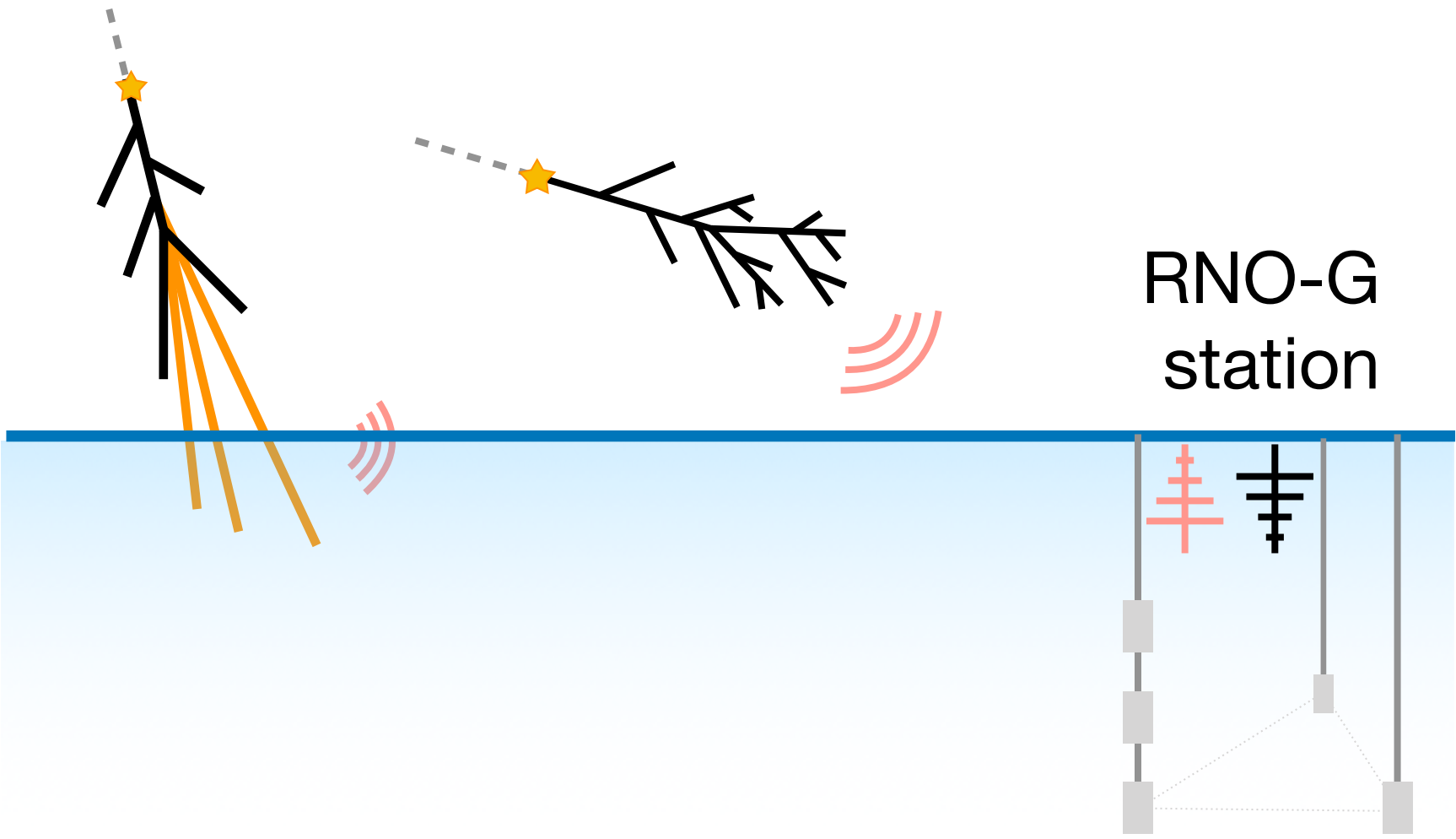


Data-taking status and first results

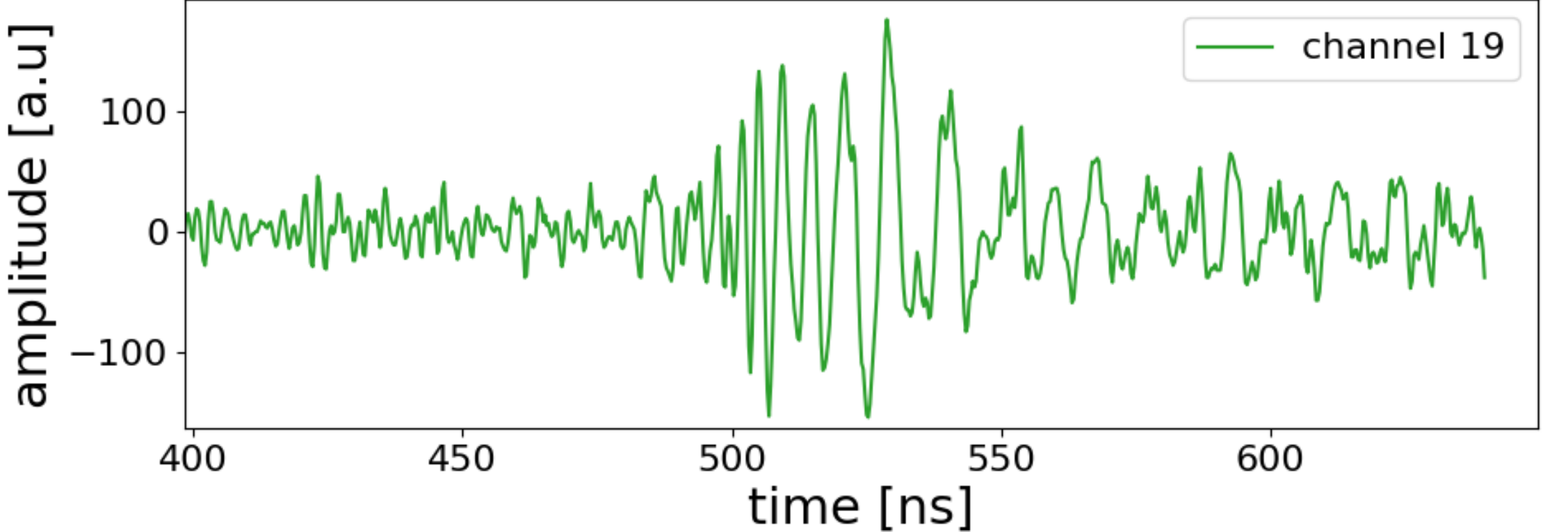
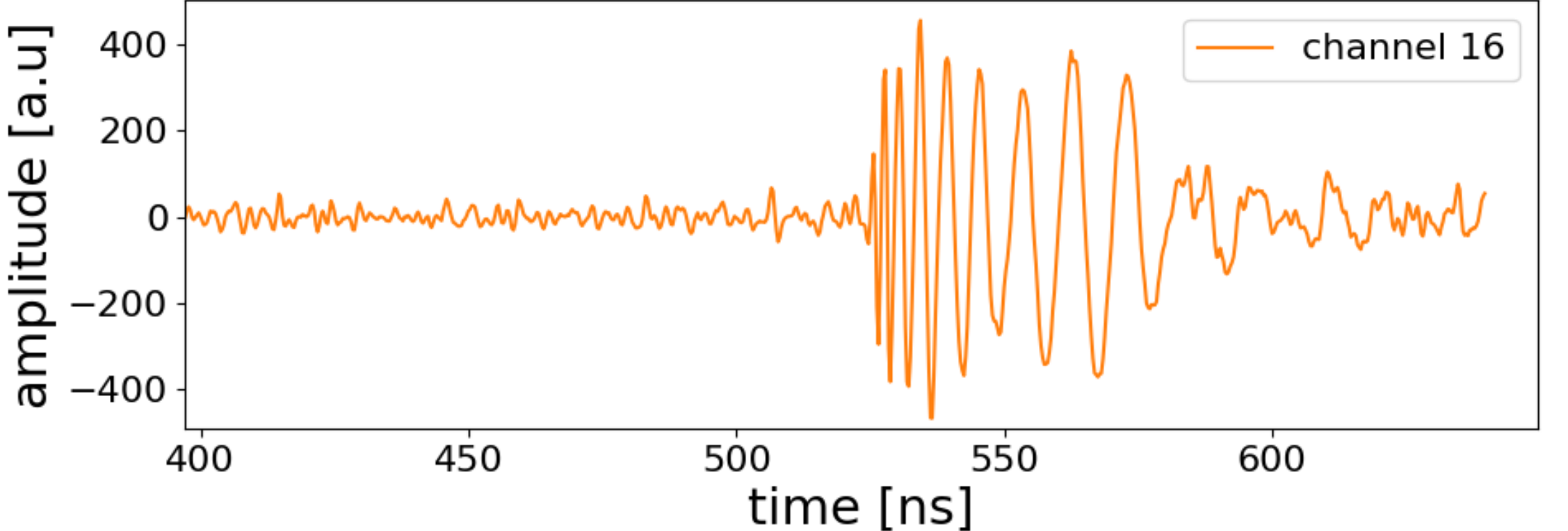
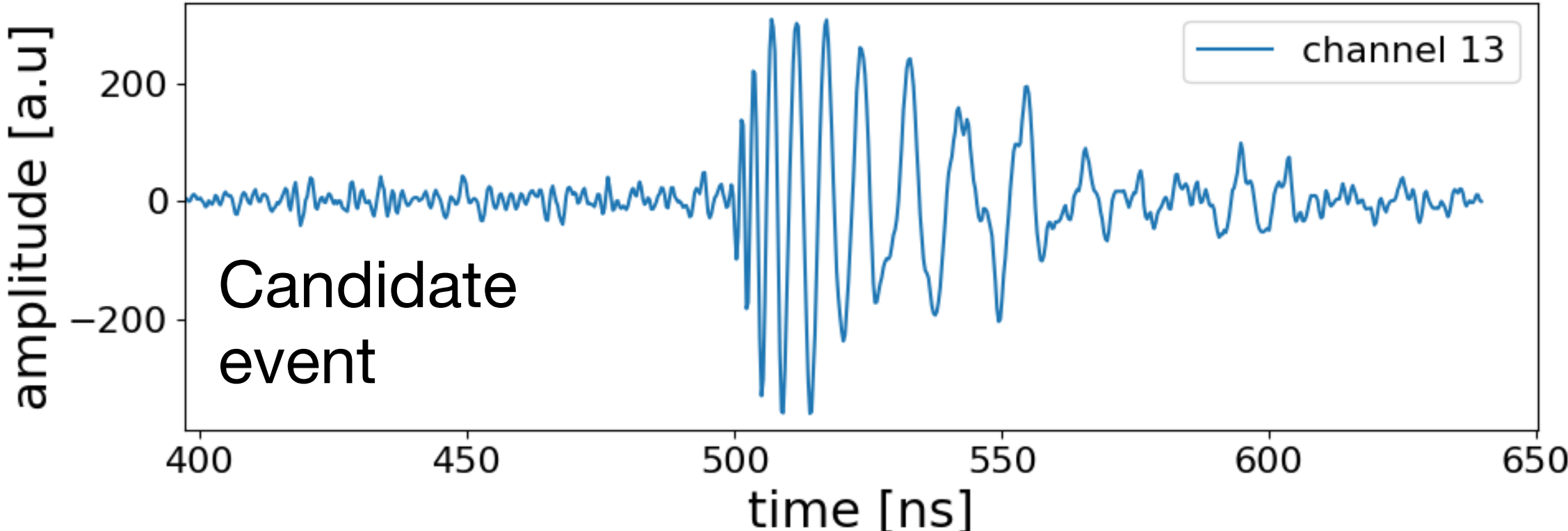
**First deployment in summer 2021;
seven stations currently integrating data**

Cosmic ray air showers

*Search for down-going signals in
surface antennas*



Full analysis / detector modeling work in progress



Building for the future

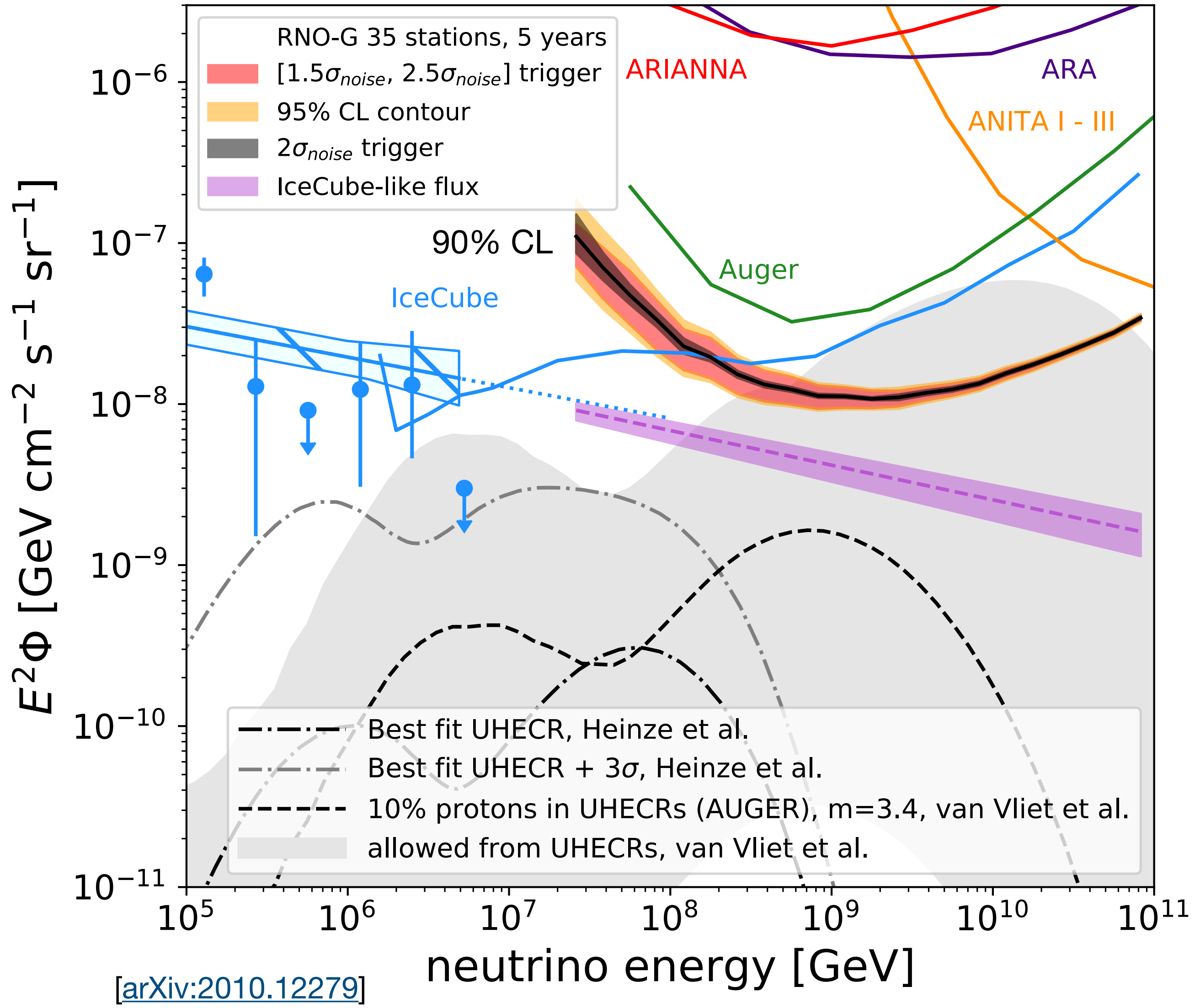
RNO-G array currently undergoing deployment at Summit Station, Greenland

Seven stations already taking data, 28 more firmly planned (and fully funded)

World-leading sensitivity to neutrinos around 1 EeV

35-station array starts probing optimistic cosmogenic neutrino models and hard astrophysical component

Exciting times ahead!

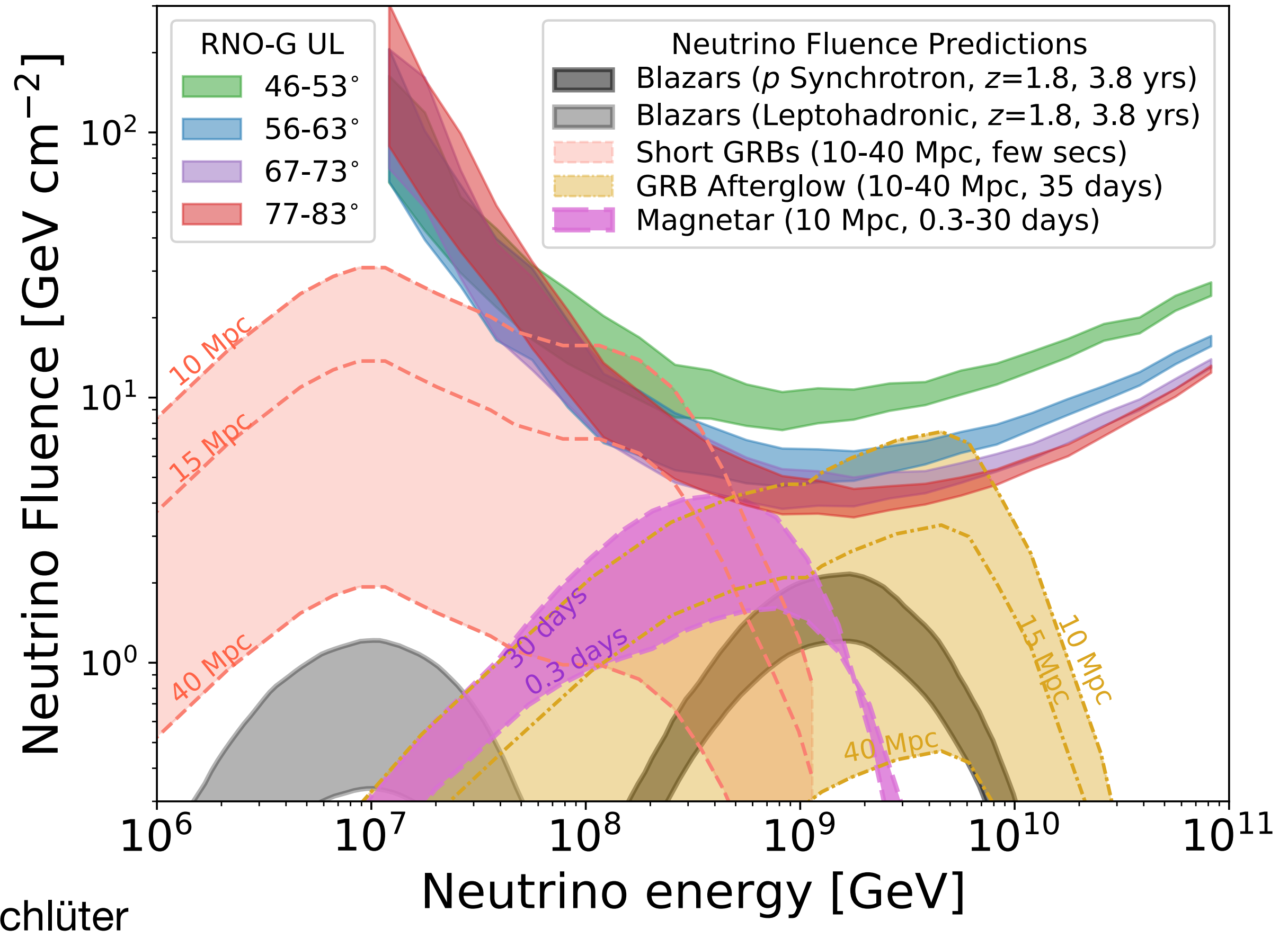
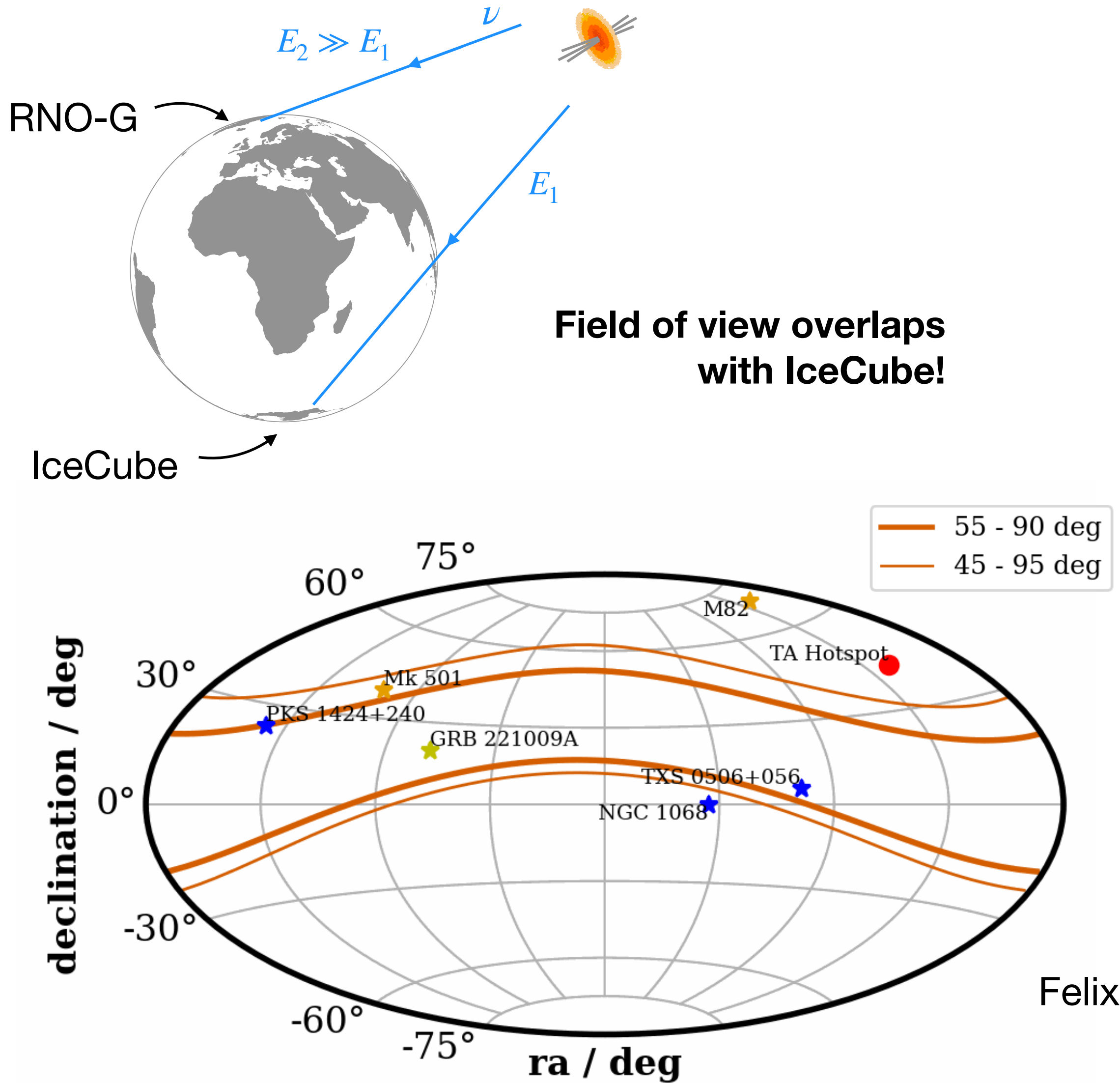




RNO-G
Collaboration
April 2024

Backup

RNO-G sensitivity to flaring sources



Felix Schlüter

Ice at Summit

