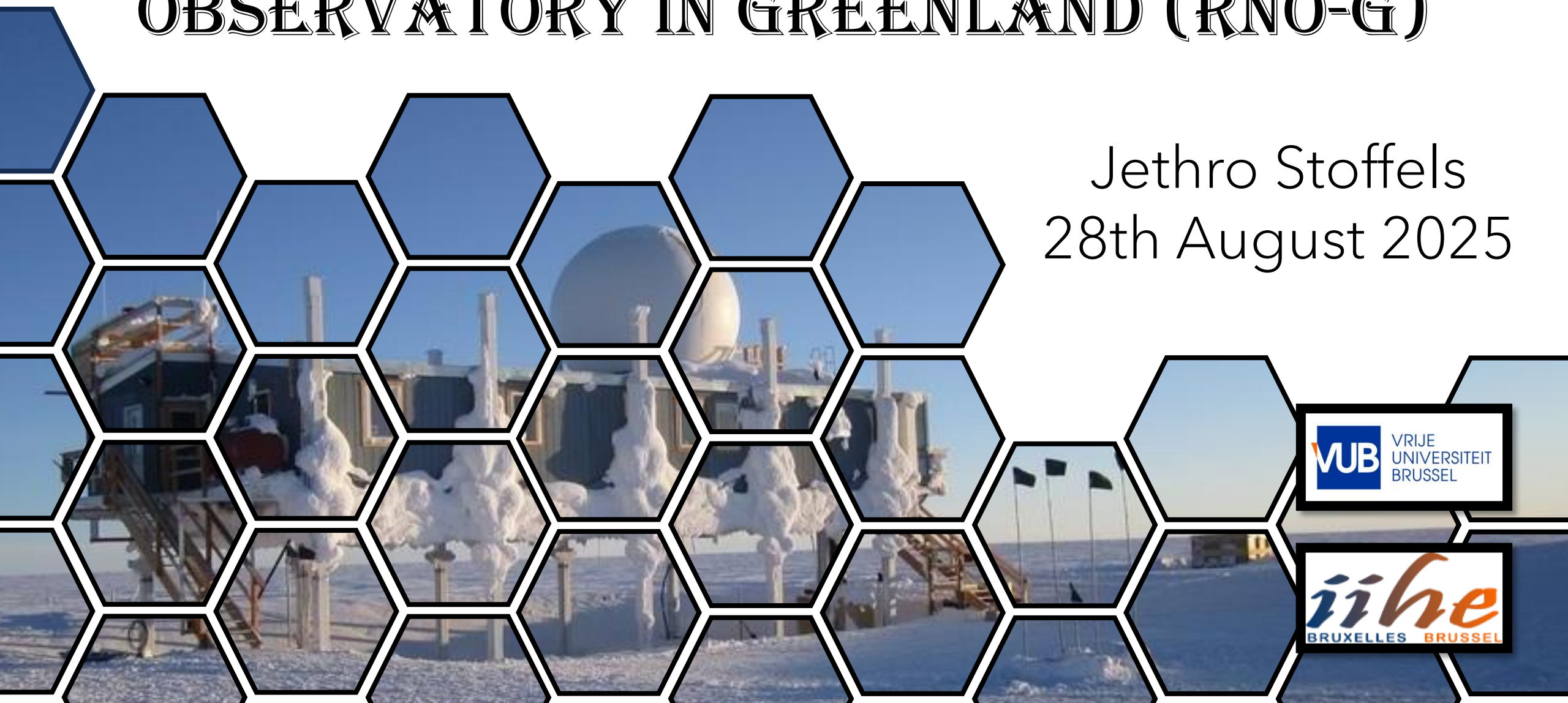
Overview of the Radio Neutrino Observatory in Greenland (RNO-G)



Jethro Stoffels

28th August 2025

VUB VRIJE UNIVERSITEIT BRUSSEL

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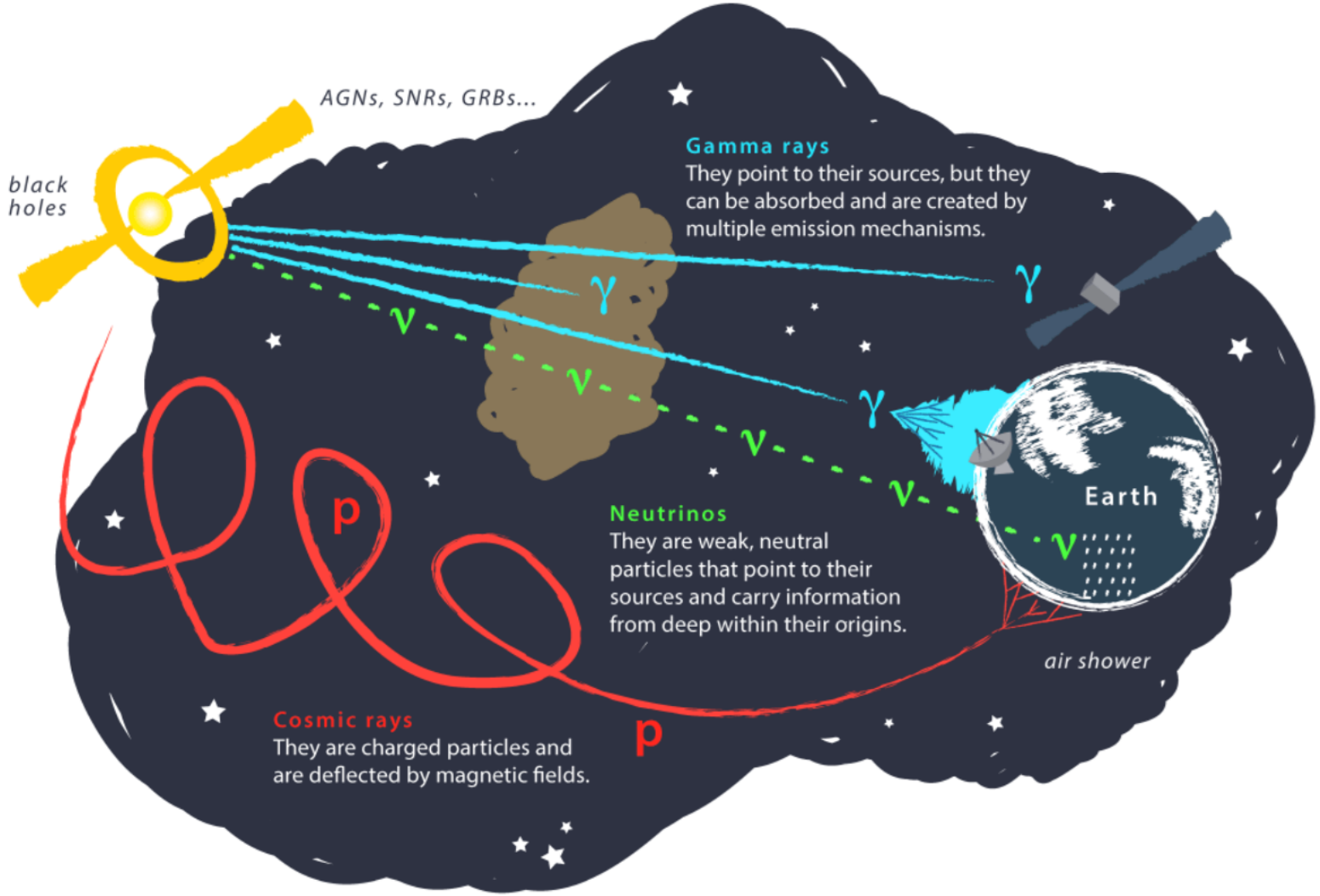
INTRODUCTION

Neutrino astronomy



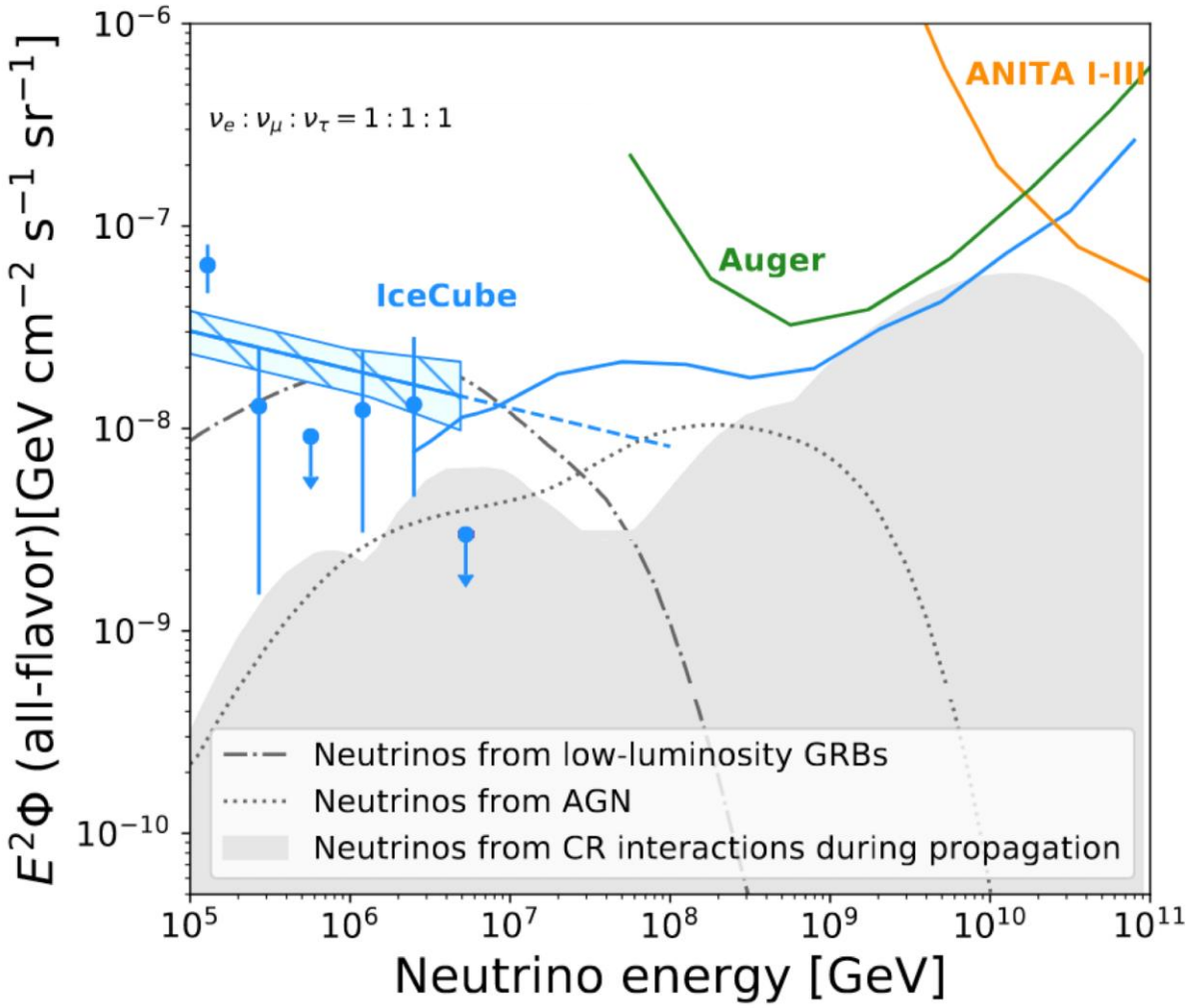
Source: Juan Antonio Aguilar and Jamie Yang. IceCube/WIPAC

Neutrino astronomy

- E < 10PeV: IceCube
  > 10PeV: Terra Incognita

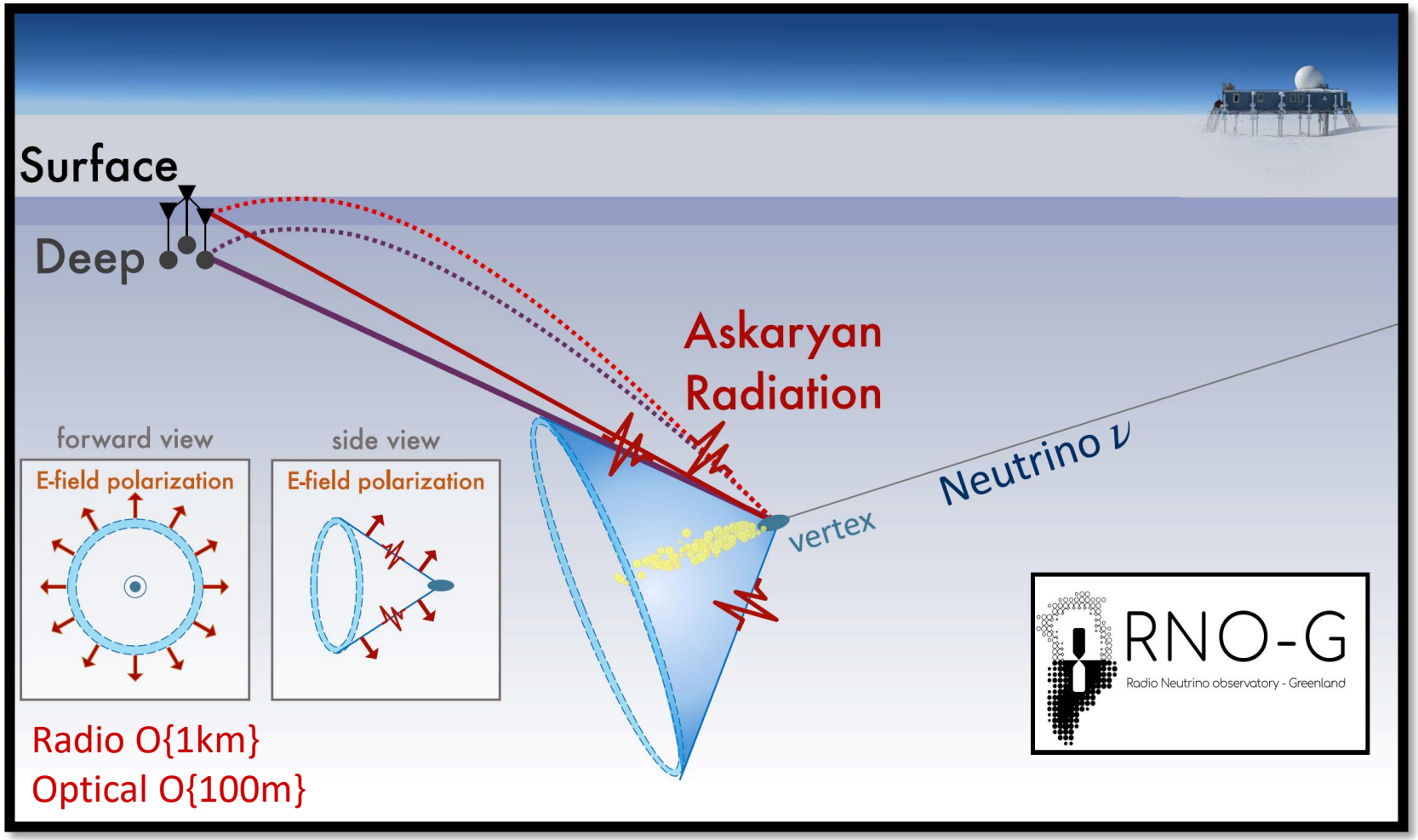
- Models predict Ultra high energy (100PeV – 10EeV) neutrino flux
  ⇒ want to observe flux or place limit

- Higher energy ⇒ Lower flux
  ⇒ 100 IceCubes required!
  ⇒ Search for alternatives

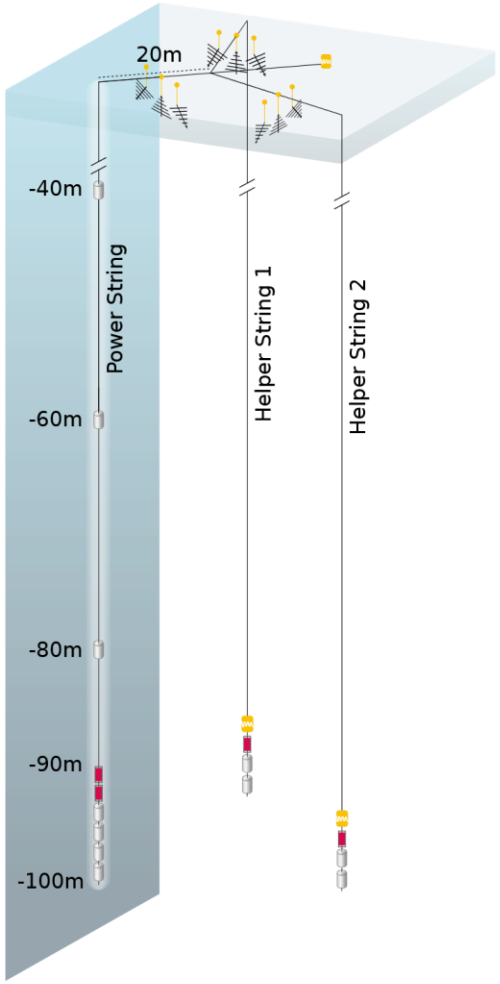


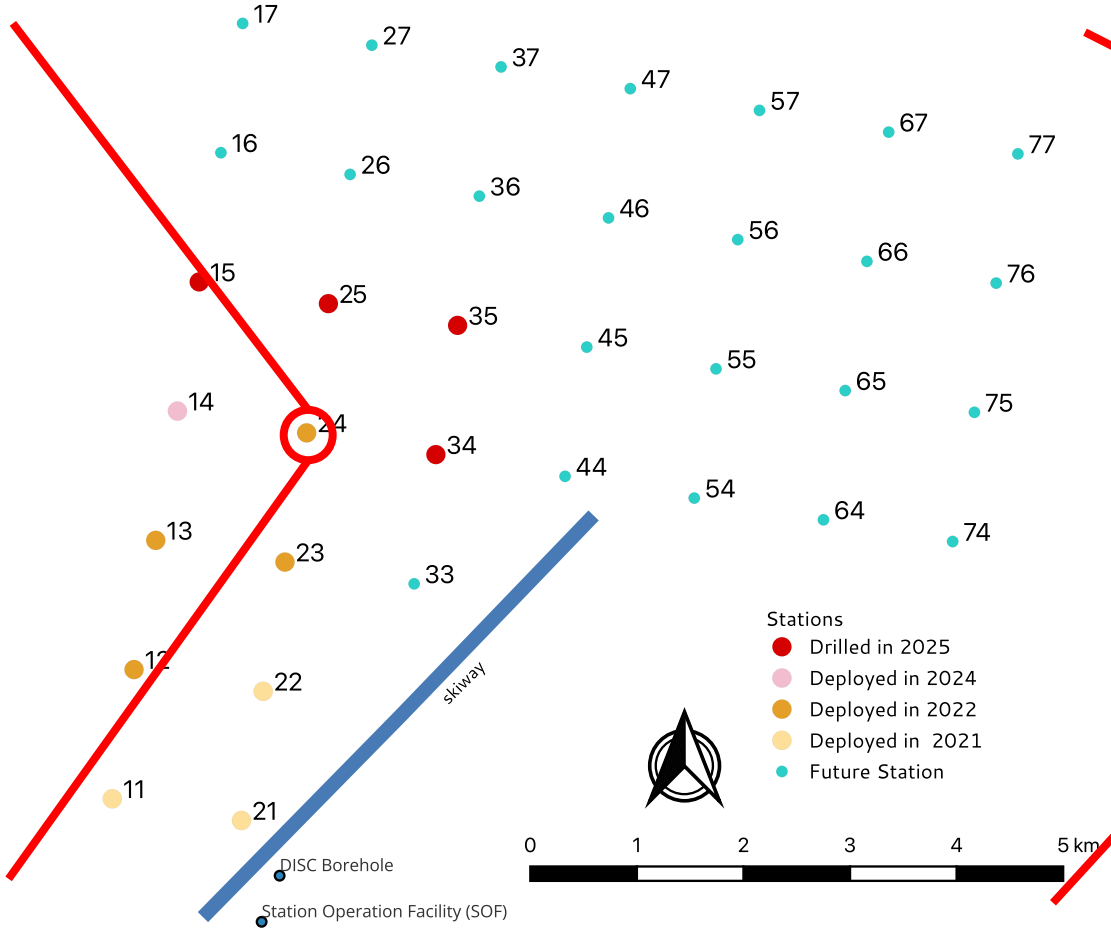
Detection principle

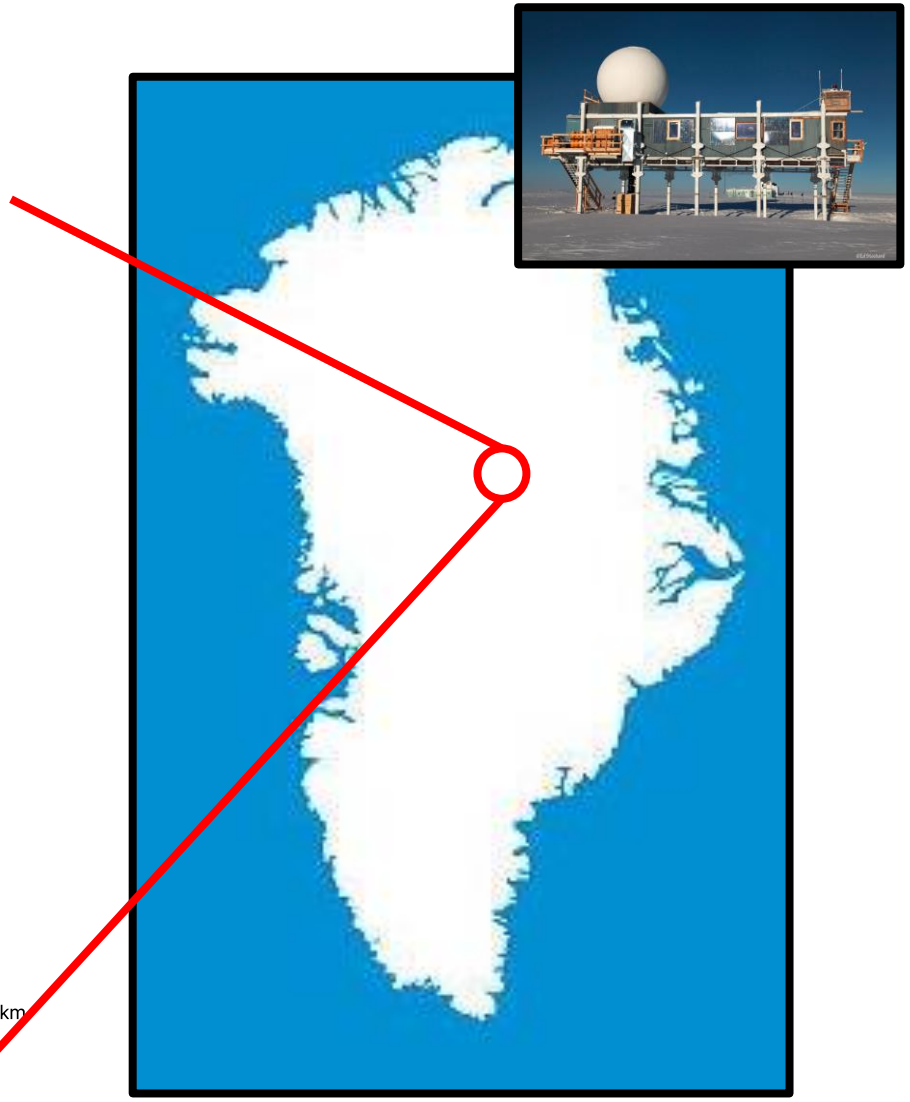
- Interference ⇒ cone shape
- Charge asymmetry ⇒ Askaryan radiation



The detector







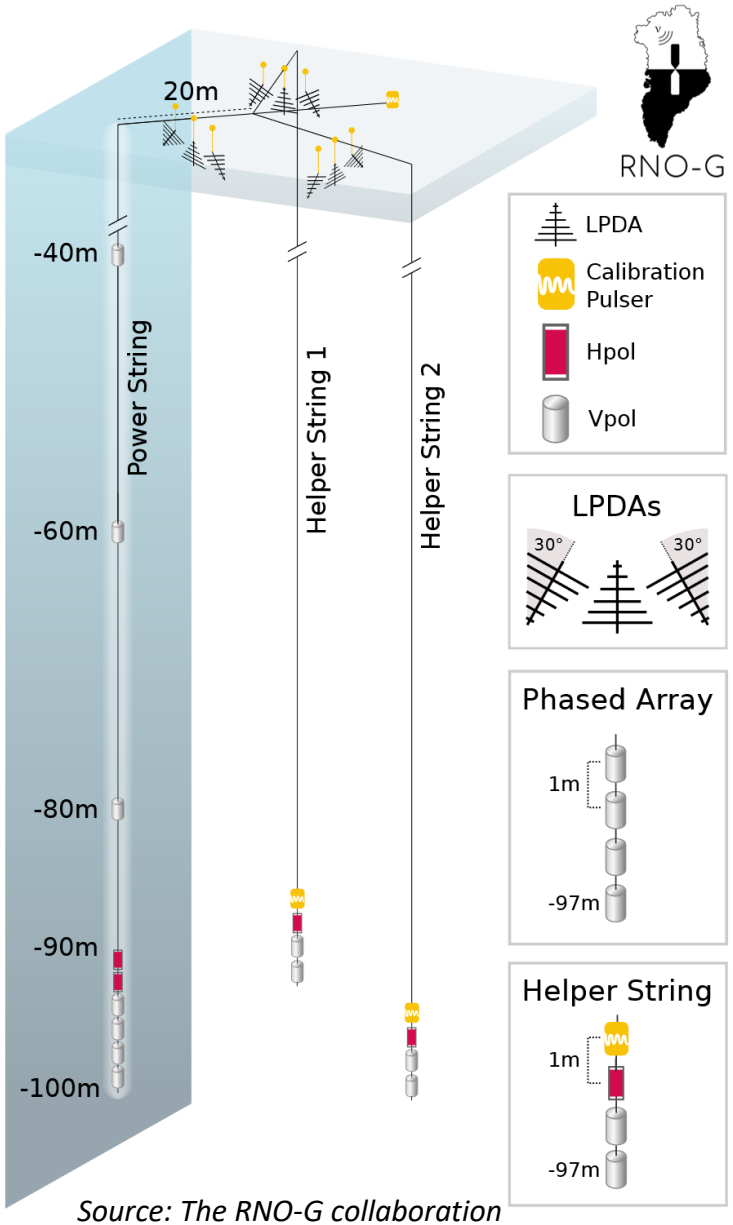
Source: The RNO-G collaboration

Station design

- 24 antennas/station
  => 9 surface antennas -> CR veto/detection
  => 15 in-ice antennas:
    - Low threshold trigger
    - Phased array interferometry
    - Calibration pulsars

- Solar powered
  => 7 months operational
  => Wind power (WIP)

- Highly scalable!

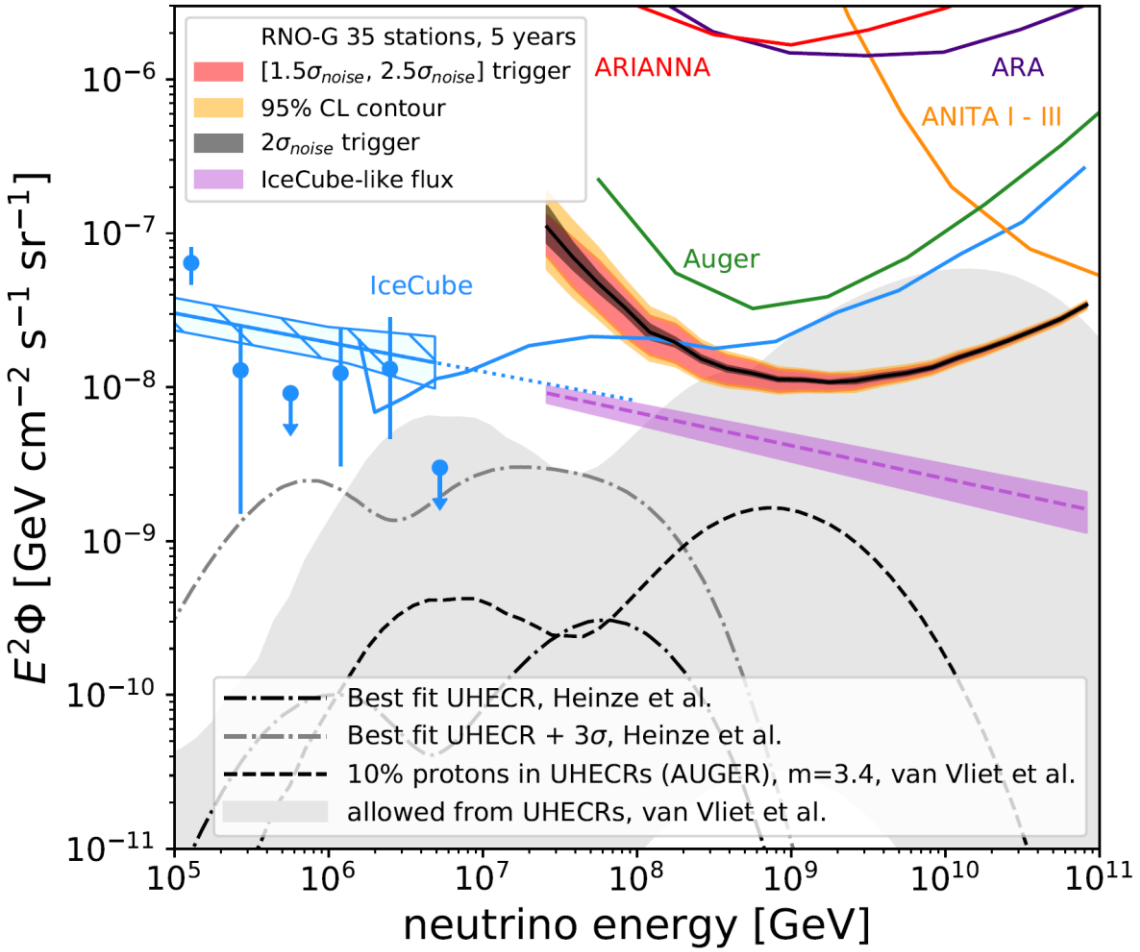


Source: The RNO-G collaboration

SENSITIVITY

Neutrino landscape

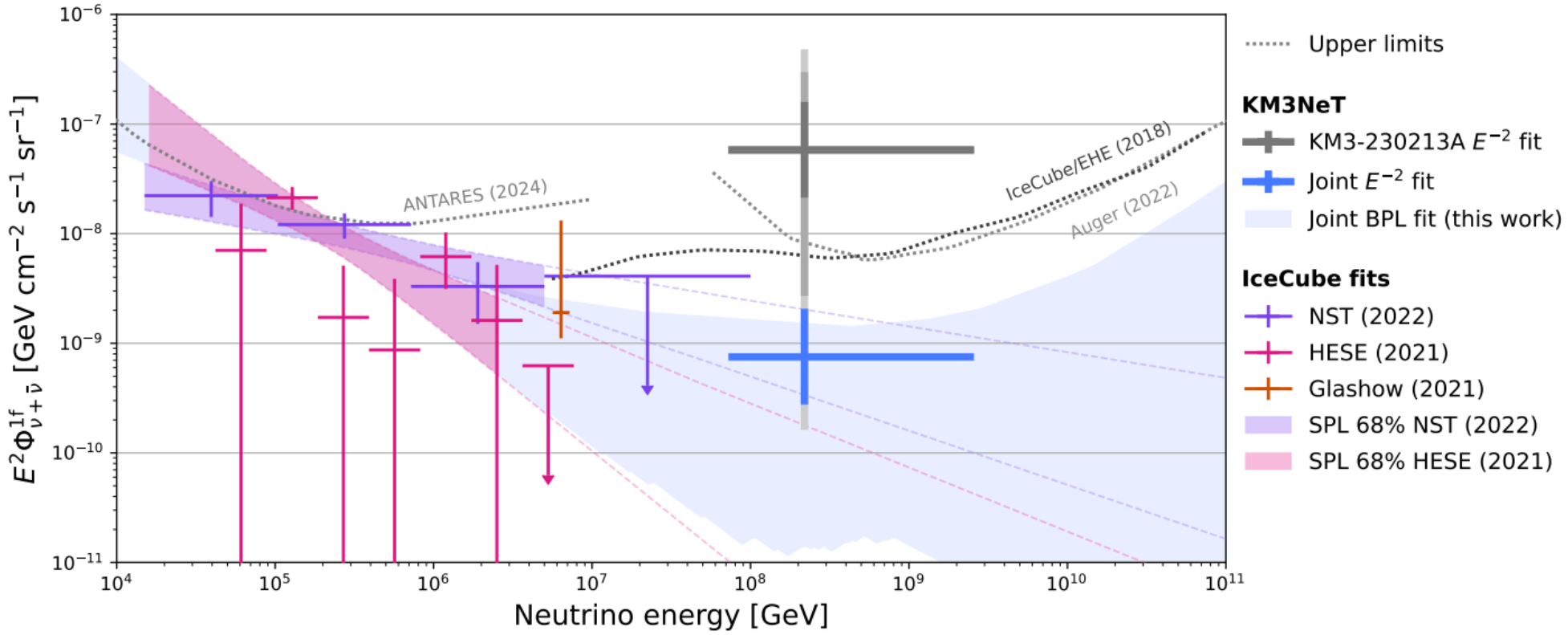
- Testing optimistic cosmogenic GZK neutrino models
- Testing hard astrophysical component
- Testing extension of astrophysical flux measured by IceCube



Source: The RNO-G collaboration

SENSITIVITY

KM3NET event



- Take KM3NET-only like flux and do full MC simulation to investigate RNO-G sensitivity to such an event

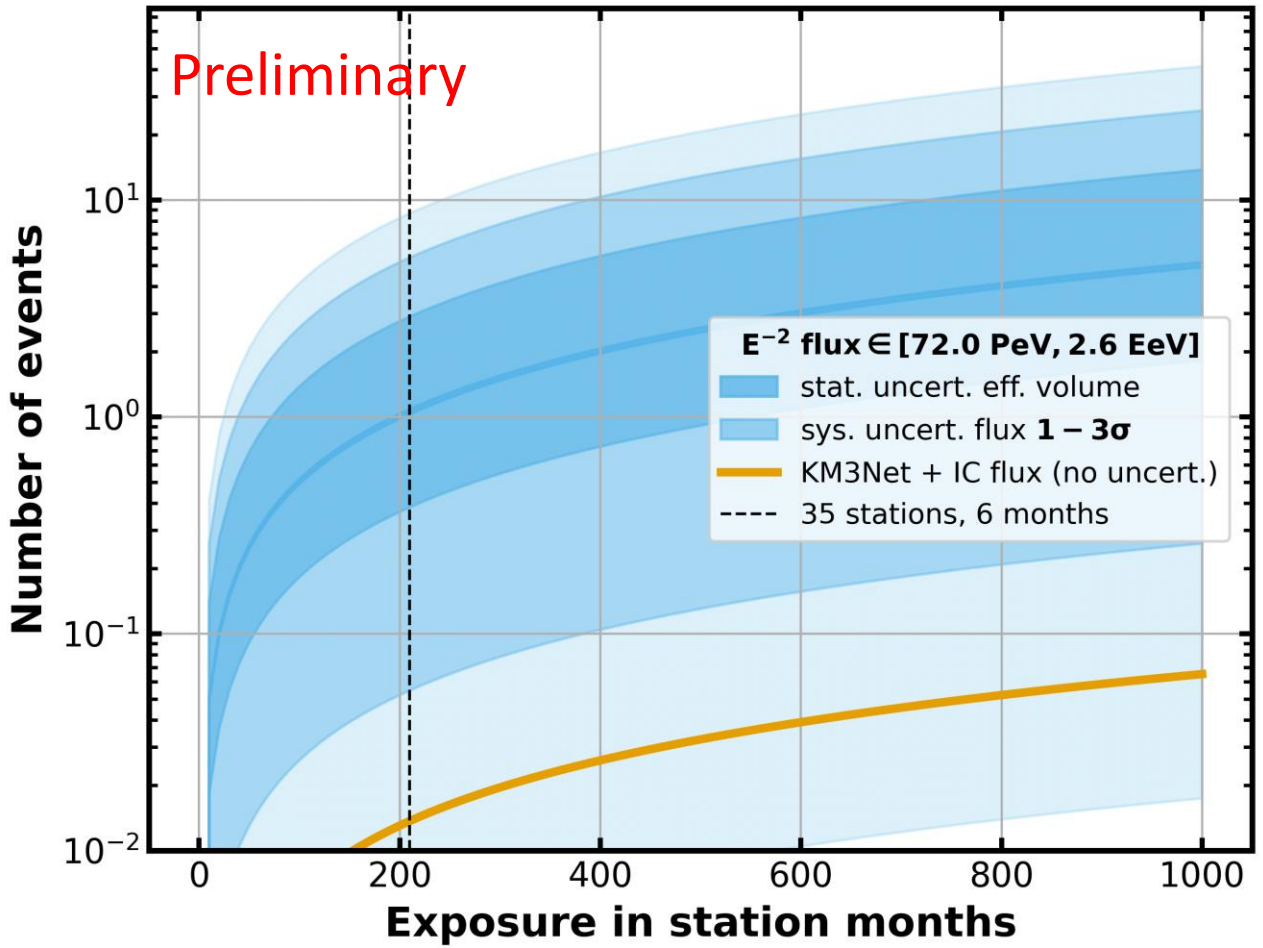
SENSITIVITY

For RNO-G like detector

- Central (90%) energy range: 72PeV - 2.6 EeV -> simulated energy range

- In one summer of the completed RNO-G array, expect 1 neutrino from KM3NET-only flux value

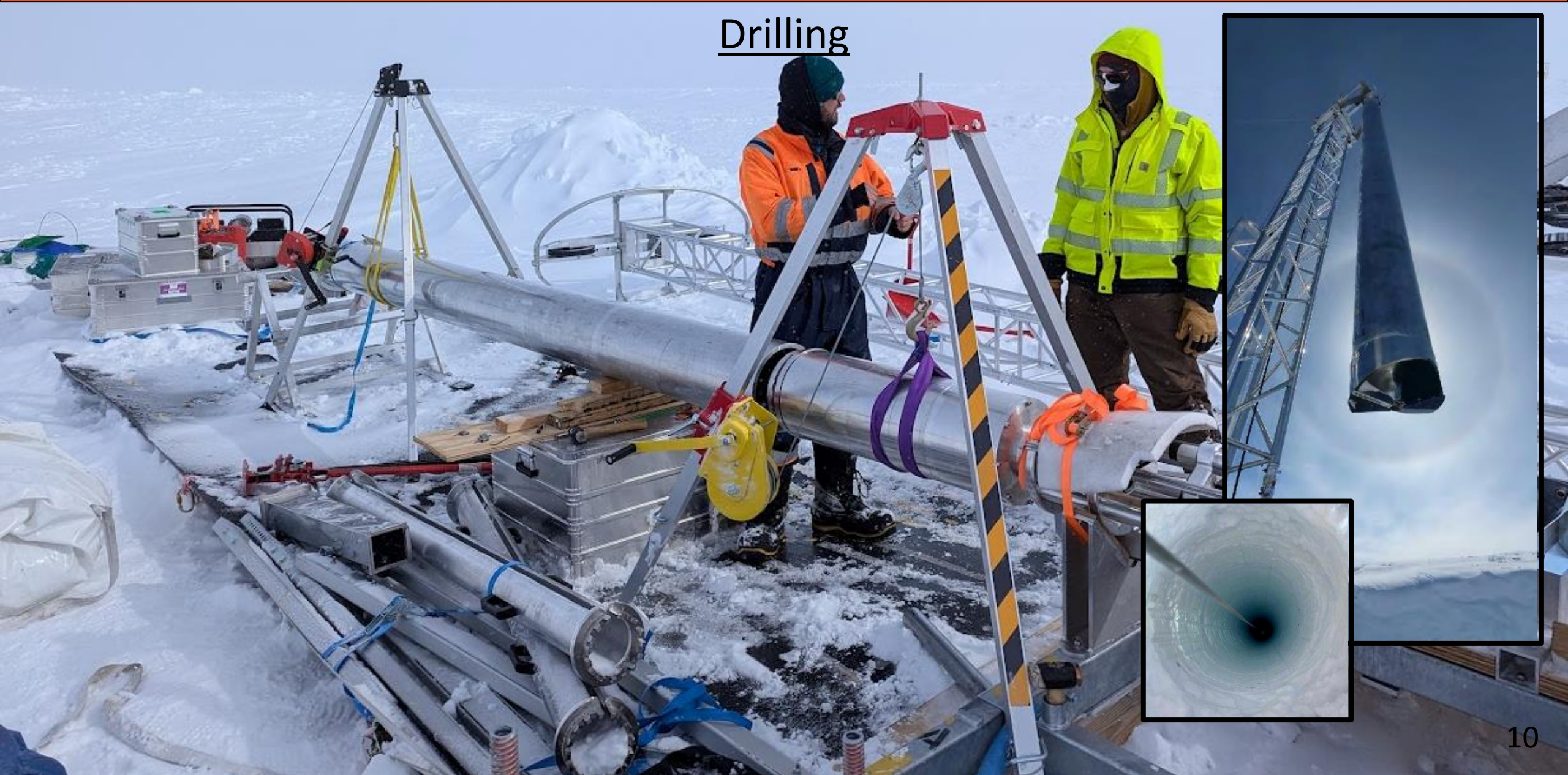
KM3NET-only flux estimate



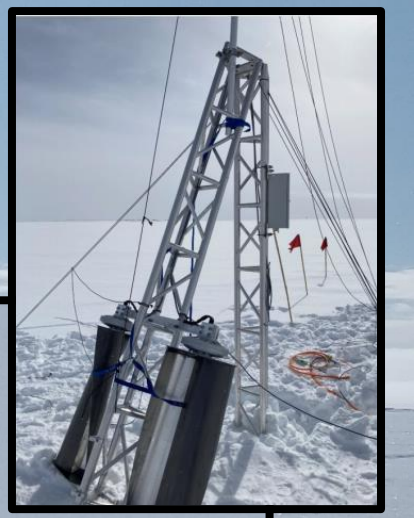
Source: A. Nelles et al (RNO-G), ICRC 2025, PoS(ICRC2025)1129

DEPLOYMENT

Drilling

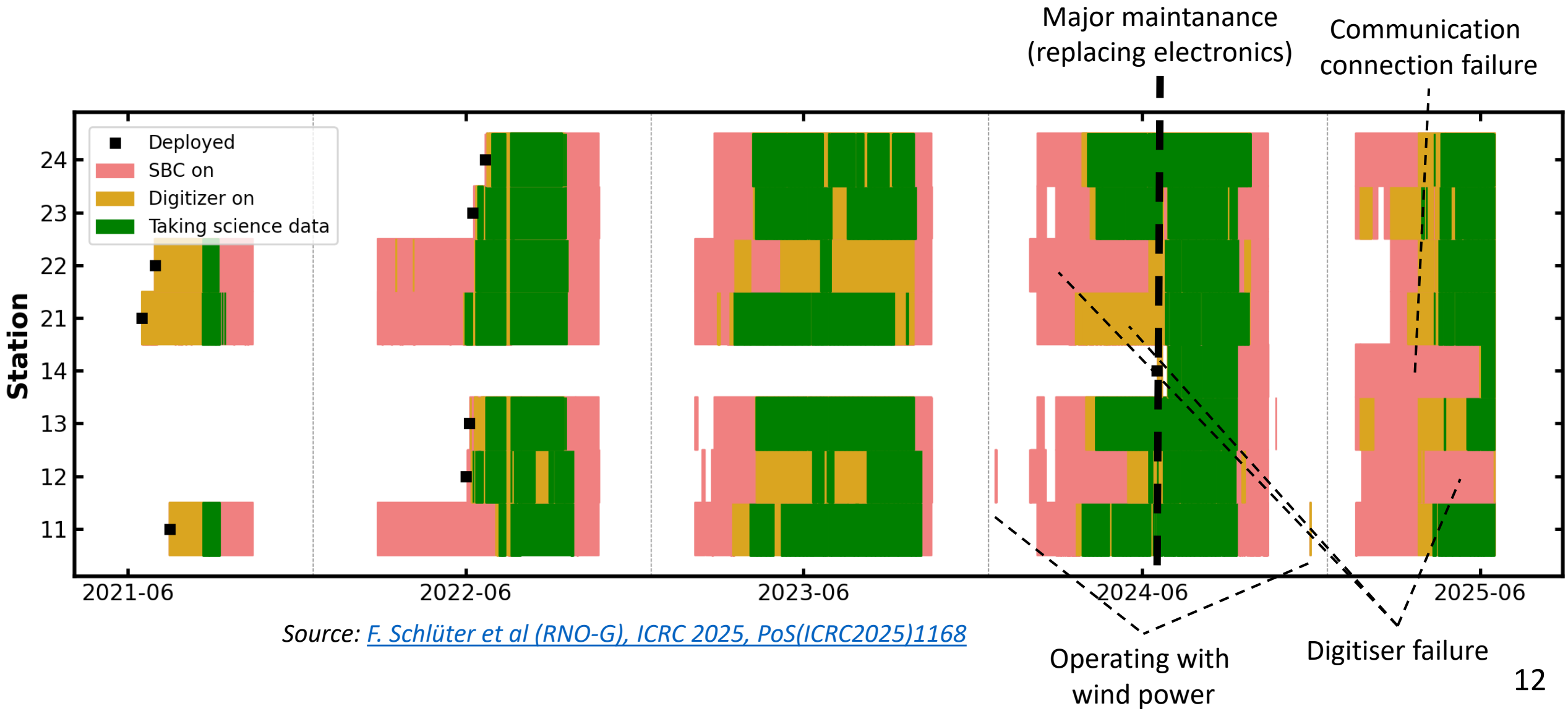


Deployment



CURRENT RESULTS

Performance

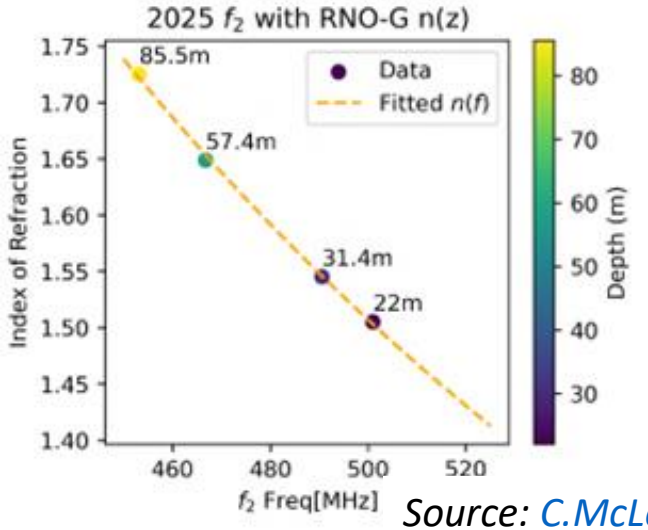


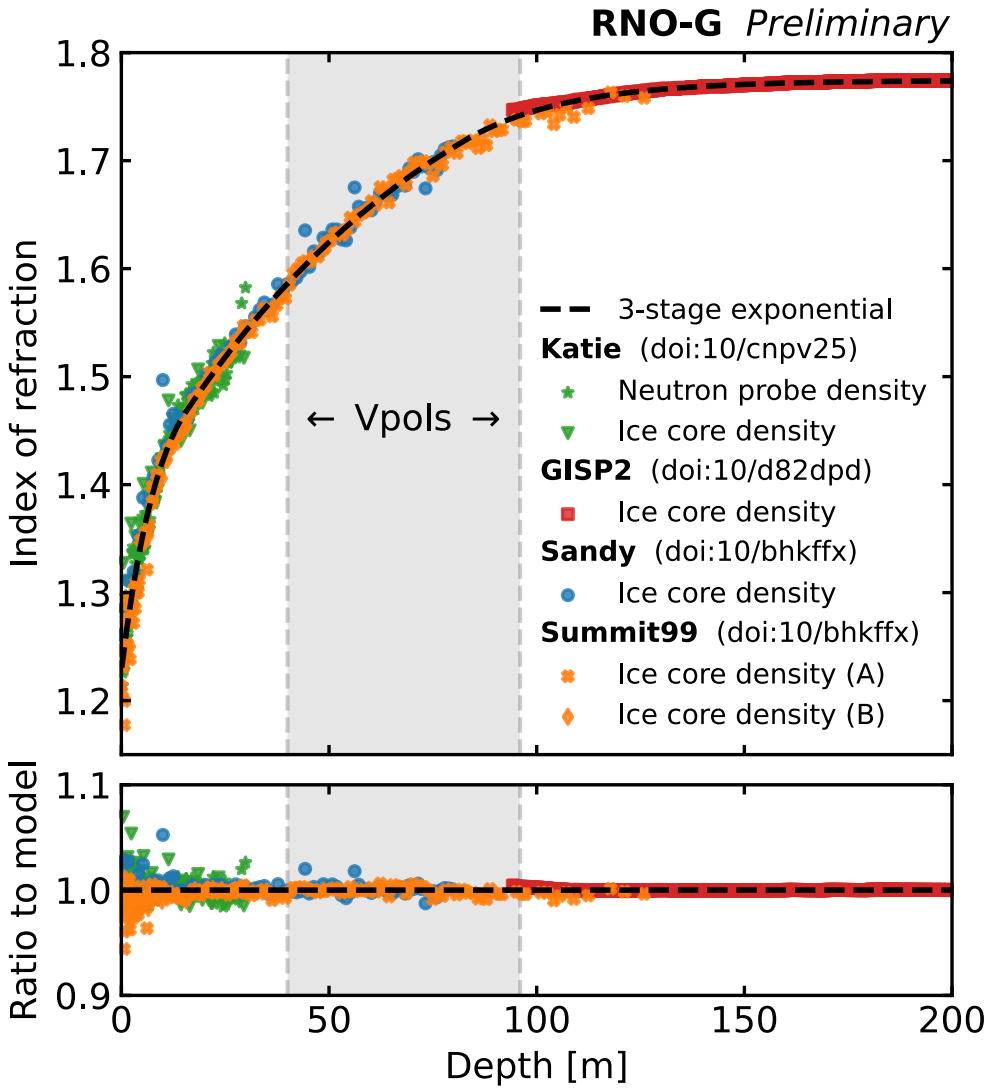
Source: [F. Schlüter et al (RNO-G), ICRC 2025, PoS(ICRC2025)1168]

Index of refraction

- Charting ice properties for correct signal propagation.

- Refractive index profile extracted from in-situ measurements
  ⇒ Most difficult in firn layer





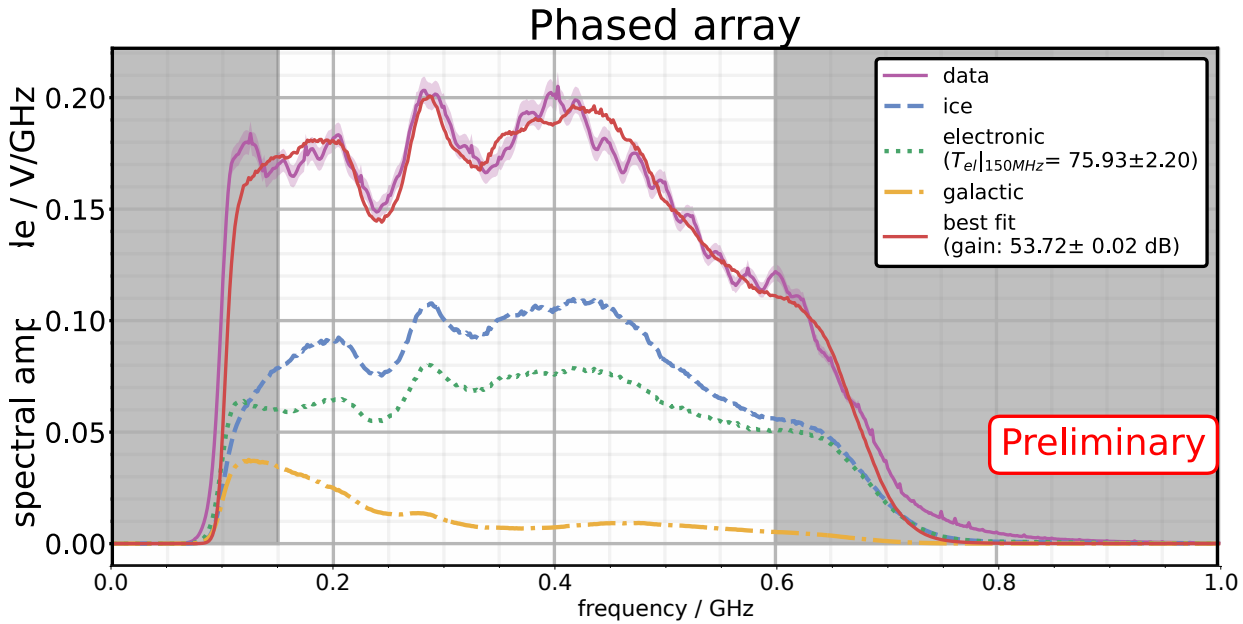
Source: [C.McLennan et al (RNO-G), ICRC 2025, PoS(ICRC2025)1121]

CALIBRATION

Thermal and Galactic noise

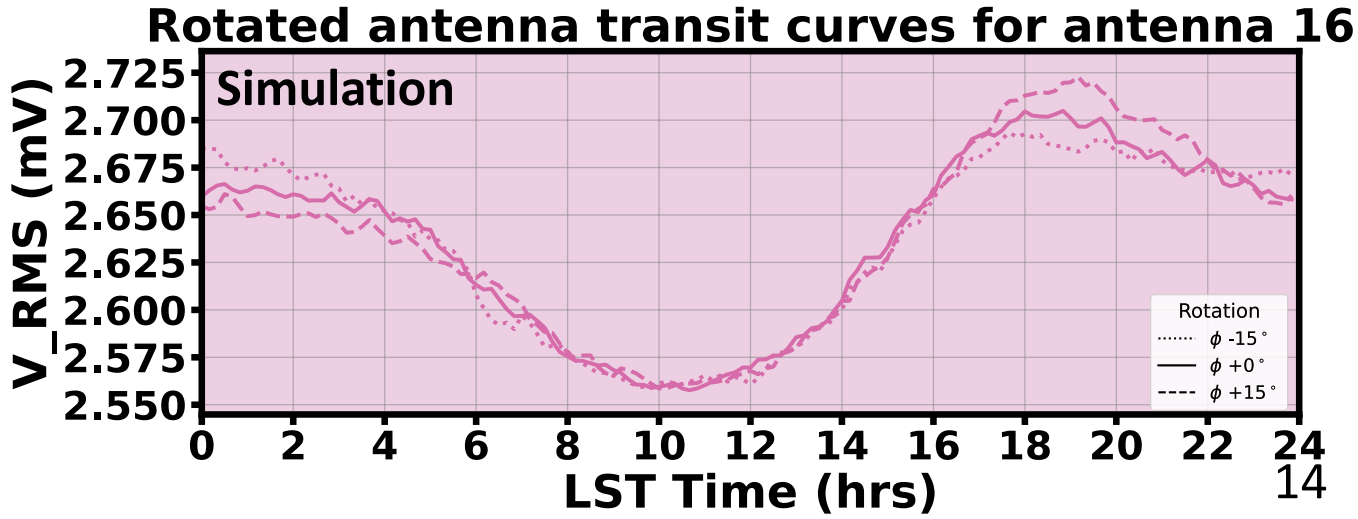
- Absolute calibration of signal amplitude using thermal noise

Source: R. Camphyn et al (RNO-G), ICRC 2025, PoS(ICRC2025)1003



- Investigating surface antenna orientation using Galactic noise

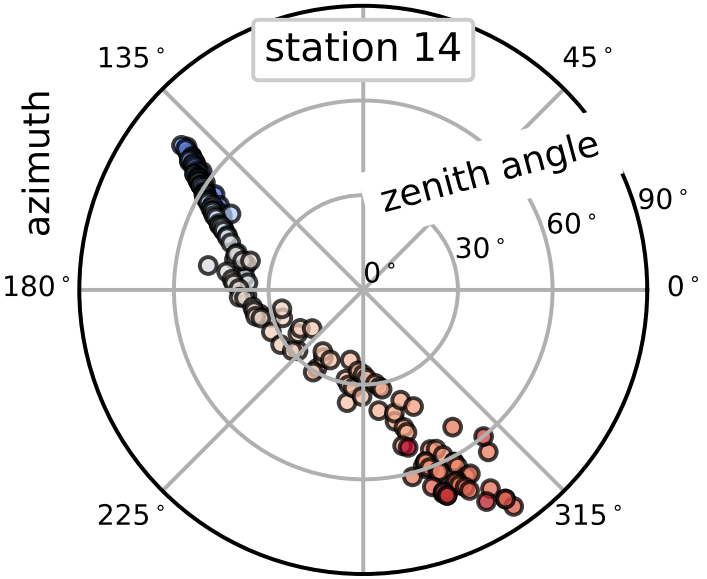
Source: J. Stoffels et al (RNO-G), ICRC 2025, PoS(ICRC2025)1189

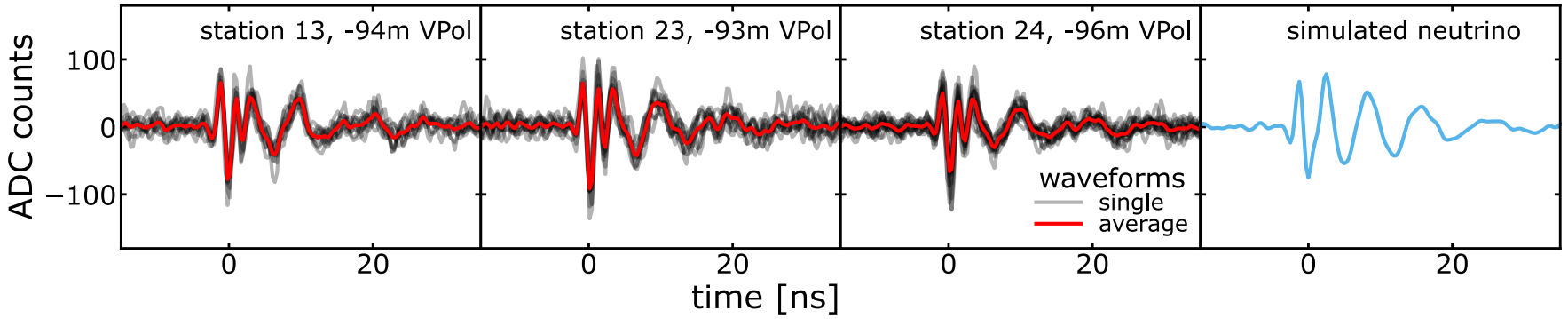


CURRENT RESULTS

Signals from airplanes

- Multiple flights pass by RNO-G per day
- Important to tag for neutrino searches
- Valuable calibration signal for timing and directional accuracy





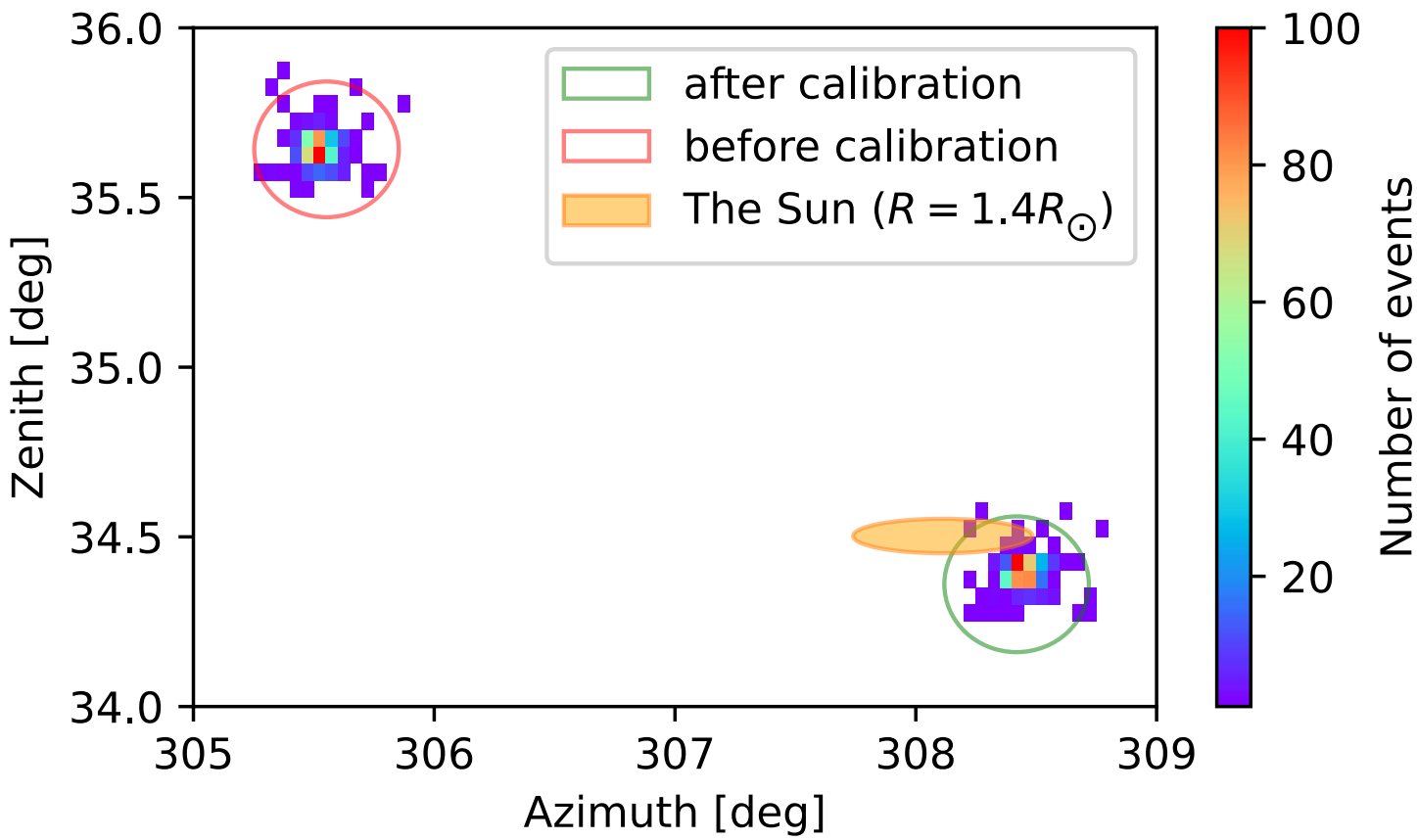
Source: [S. Hallman et al (RNO-G), Radio emission from airplanes as observed with RNO-G]

CURRENT RESULTS

Solar flares

- Frequently observed in both surface & in-ice antennas
- Pointing: degree accuracy!

Source: *M. Mikhailova et al (RNO-G), Solar flare observations with the Radio Neutrino Observatory Greenland (RNO-G)*



Poster: Observation of solar radio bursts in the Radio Neutrino Observatory Greenland (RNO-G); M. Mikhailova

CURRENT RESULTS

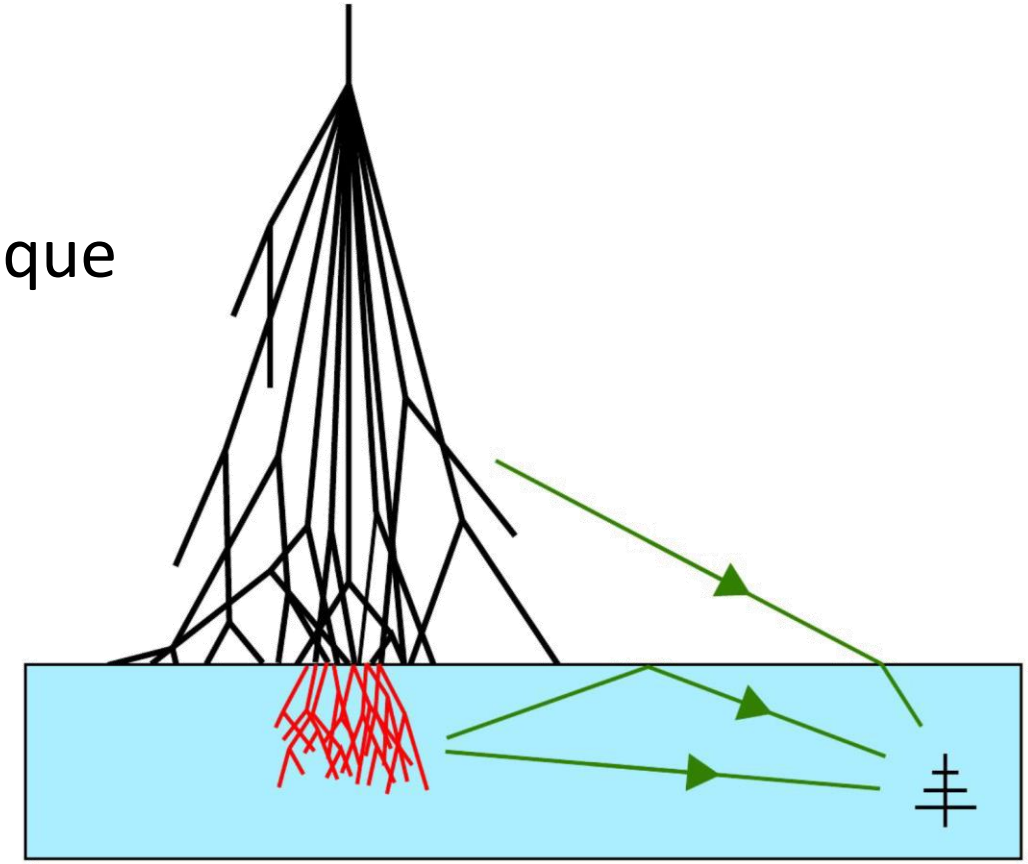
Cosmic ray searches

- Cosmic ray (CR) airshowers continue propagation through ice

- CR flux > neutrino flux
  ⇒ validation of in-ice radio detection technique

- Study CR signals to discriminate from neutrino signals

- Provide valuable calibration source

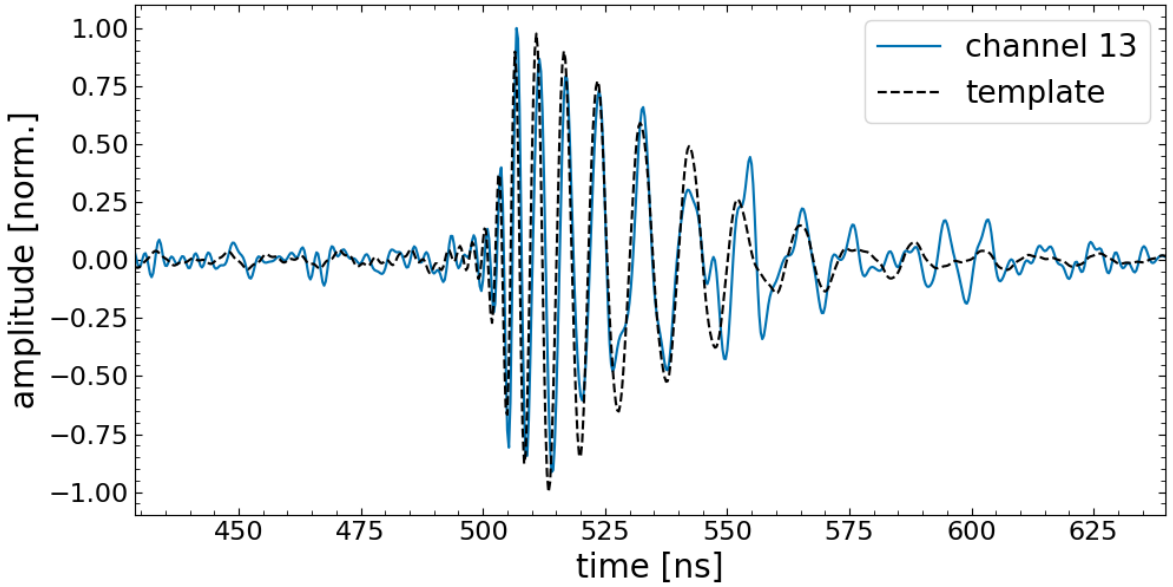


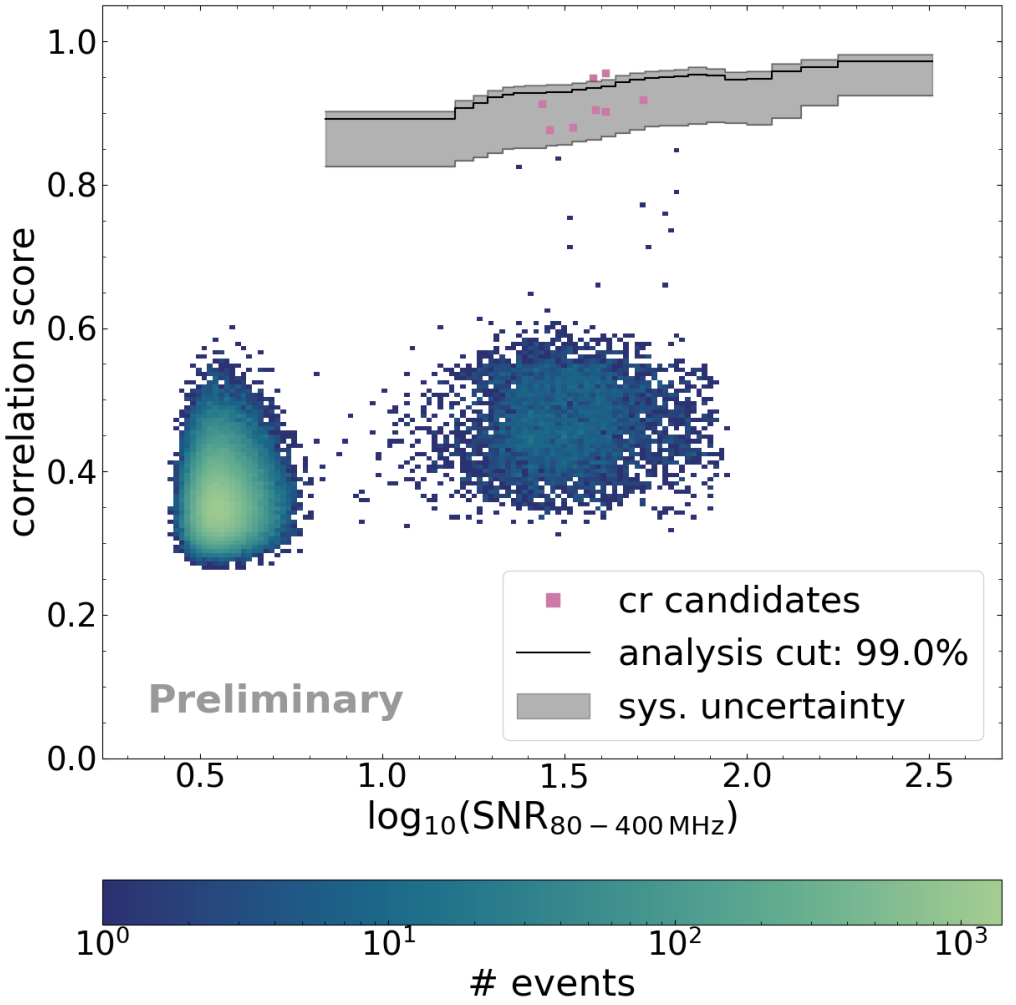
Credits: Simon De Kockere

CURRENT RESULTS

CR in air shower search

- Using broadband surface component
- Apply cut in correlation score vs SNR space
- Matches expected signal shape





Source: J. Henrichs et al (RNO-G), ICRC 2025, PoS(ICRC2025)288

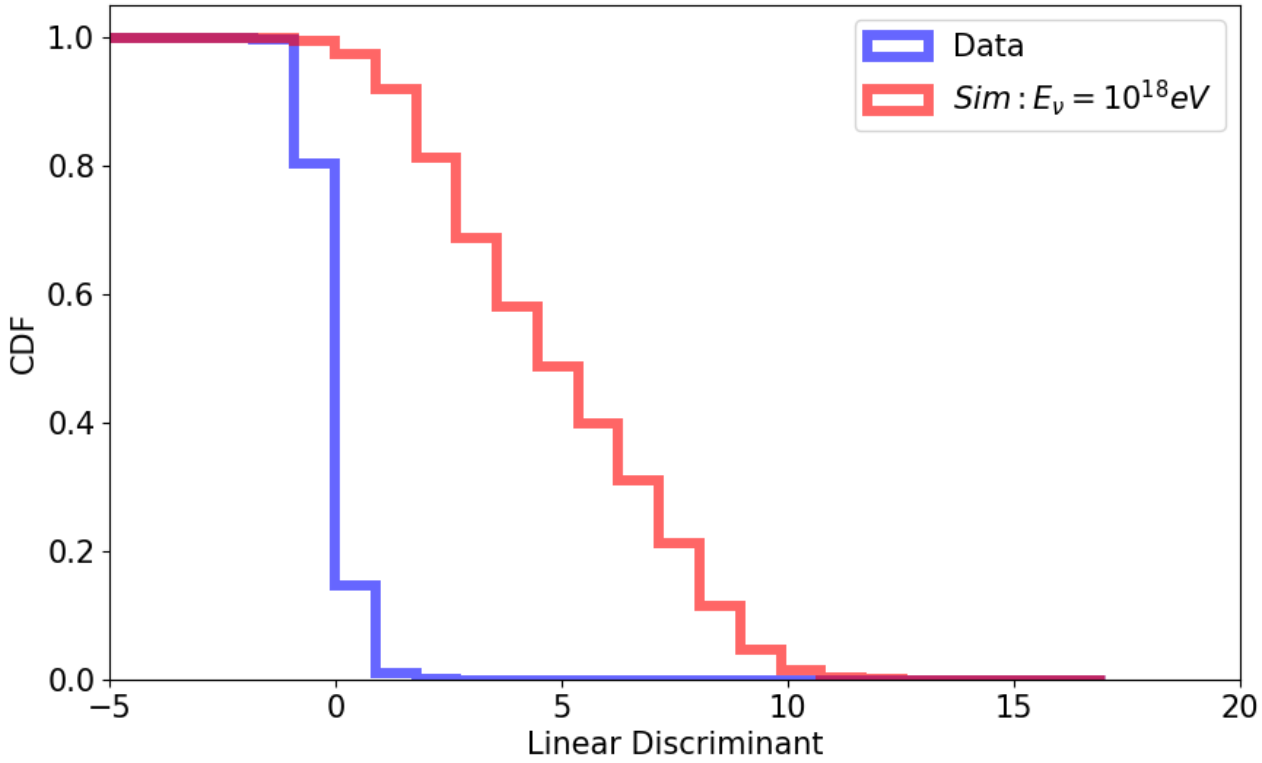
CURRENT RESULTS

In ice shower search

- Linear Discriminant Analysis (LDA) to search for CR's and neutrinos in initial dataset

- Analyses easily extended to future years/data

- On the horizon:
  - Finish first neutrino search
  - Combine searches in deep and shallow components



Source: *A. Vijai et al (RNO-G), ICRC 2025, PoS(ICRC2025)1204*

Source: *B. Hendricks et al (RNO-G), ICRC 2025, PoS(ICRC2025)1057*

COLLABORATION

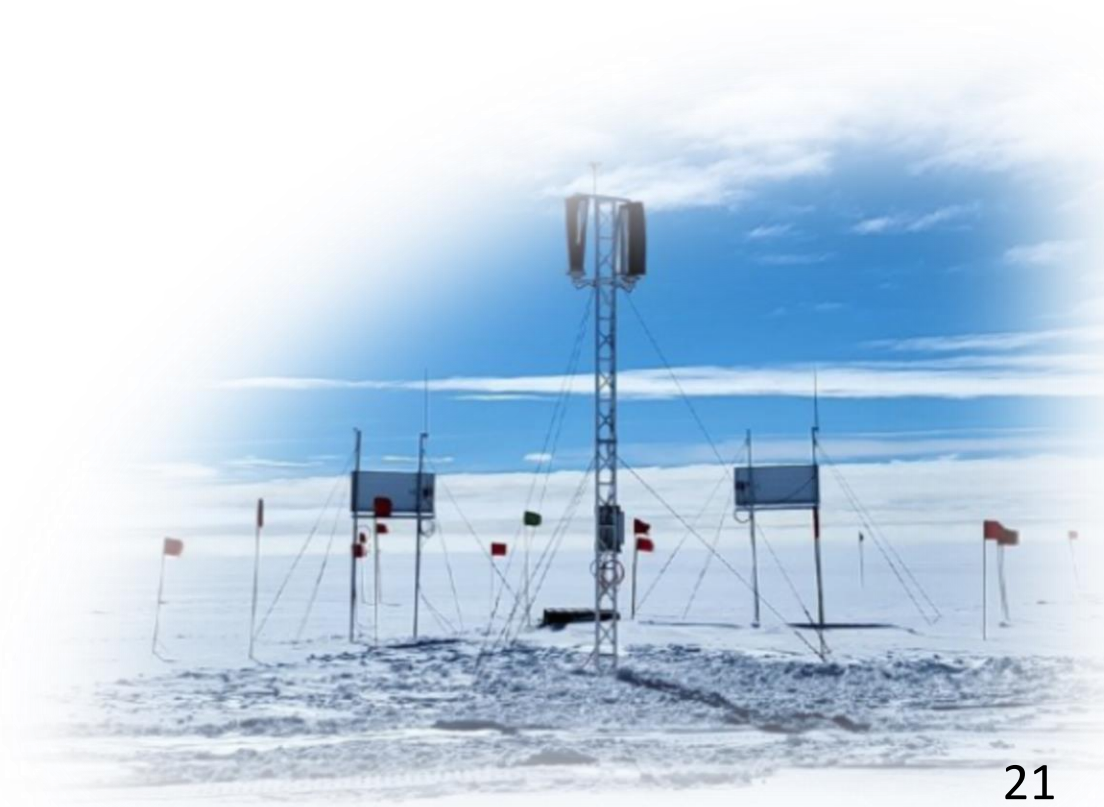
HELMHOLTZ DFG fnrs NSF Swedish Research Council fwo Funded by the European Union erc European Research Council

RNO-G Collaboration May 2025

THE UNIVERSITY OF CHICAGO WISCONSIN VUB VRIJE UNIVERSITEIT BRUSSEL ULB UNIVERSITÉ LIBRE DE BRUXELLES DESY. FAU Friedrich-Alexander-Universität Erlangen-Nürnberg KU THE UNIVERSITY OF KANSAS PennState THE OHIO STATE UNIVERSITY UNIVERSITY OF MARYLAND THE UNIVERSITY OF ALABAMA WHITTIER COLLEGE GHENT UNIVERSITY BERGISCHE UNIVERSITÄT WUPPERTAL UPPSALA UNIVERSITET UNIVERSITY OF DELAWARE Radboud University UNIVERSITY OF Nebraska Lincoln

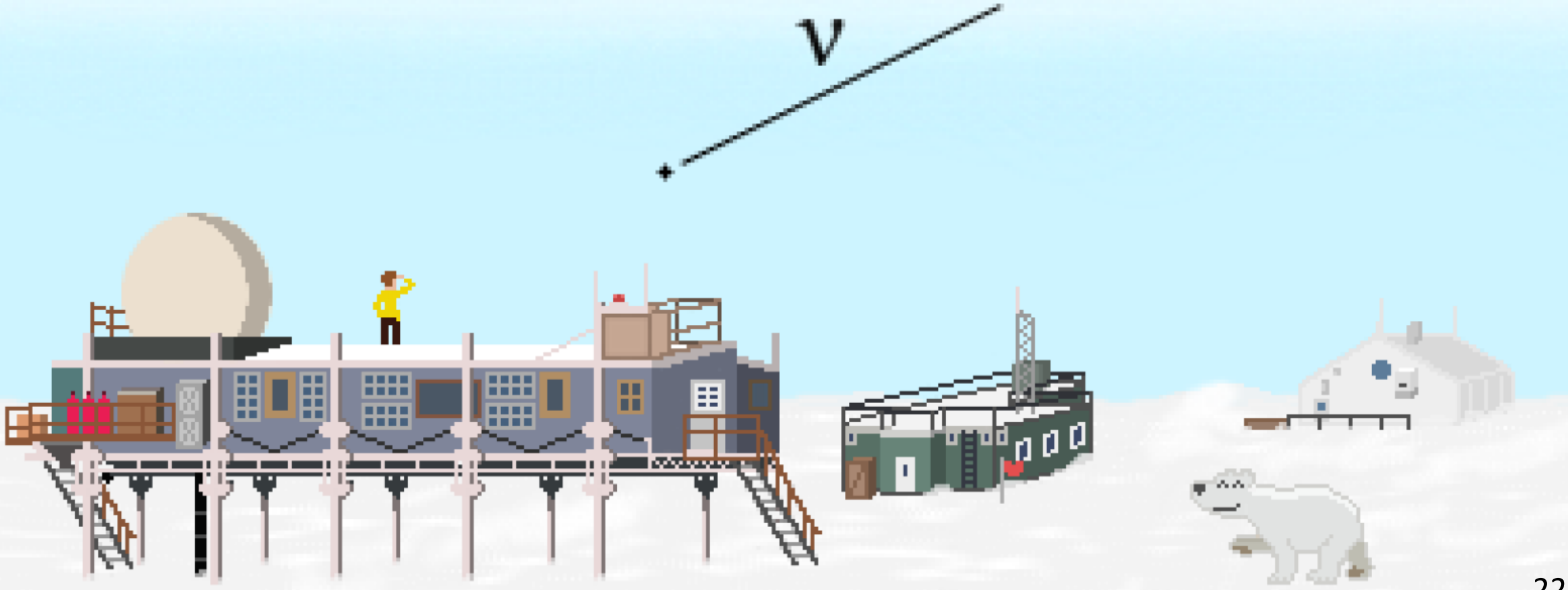
SUMMARY

- RNO-G:
  - 35 Stations (eight installed)
  - Array planned to be completed in a few years
- Initial science analyses have started:
  - Cosmic ray searches
  - Extensive calibration campaigns
- On the horizon:
  - Completing and improving deployment
  - Further understanding detector
  - Working towards neutrino searches
- Strong case for multi-messenger astronomy

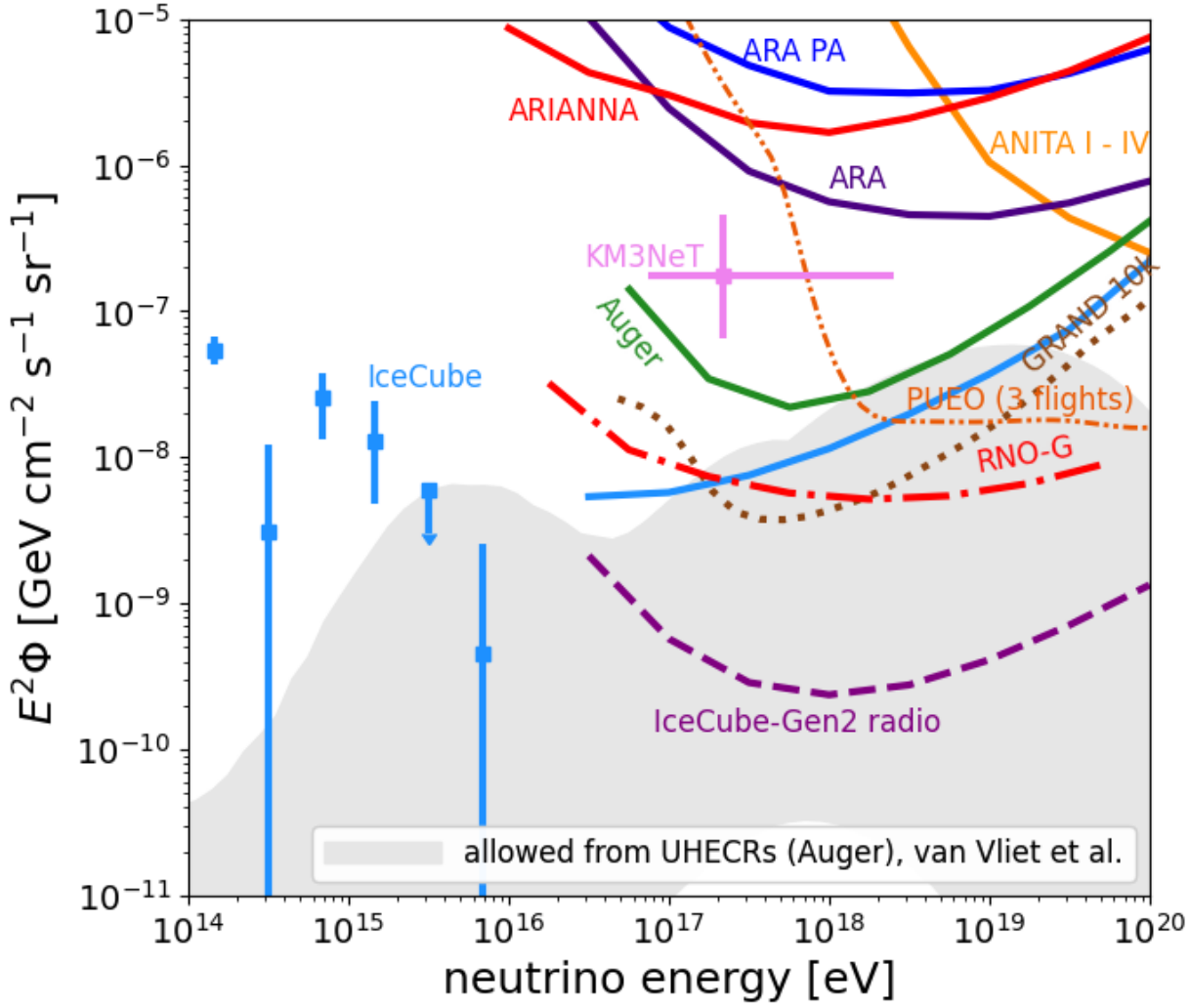


RNO-G NOISE BACKGROUNDS

Questions



Gen2 sensitivity plot



Solar flares