Radio Neutrino Observatory Greenland

Prospects for Cosmic Ray Measurements with RNO-G

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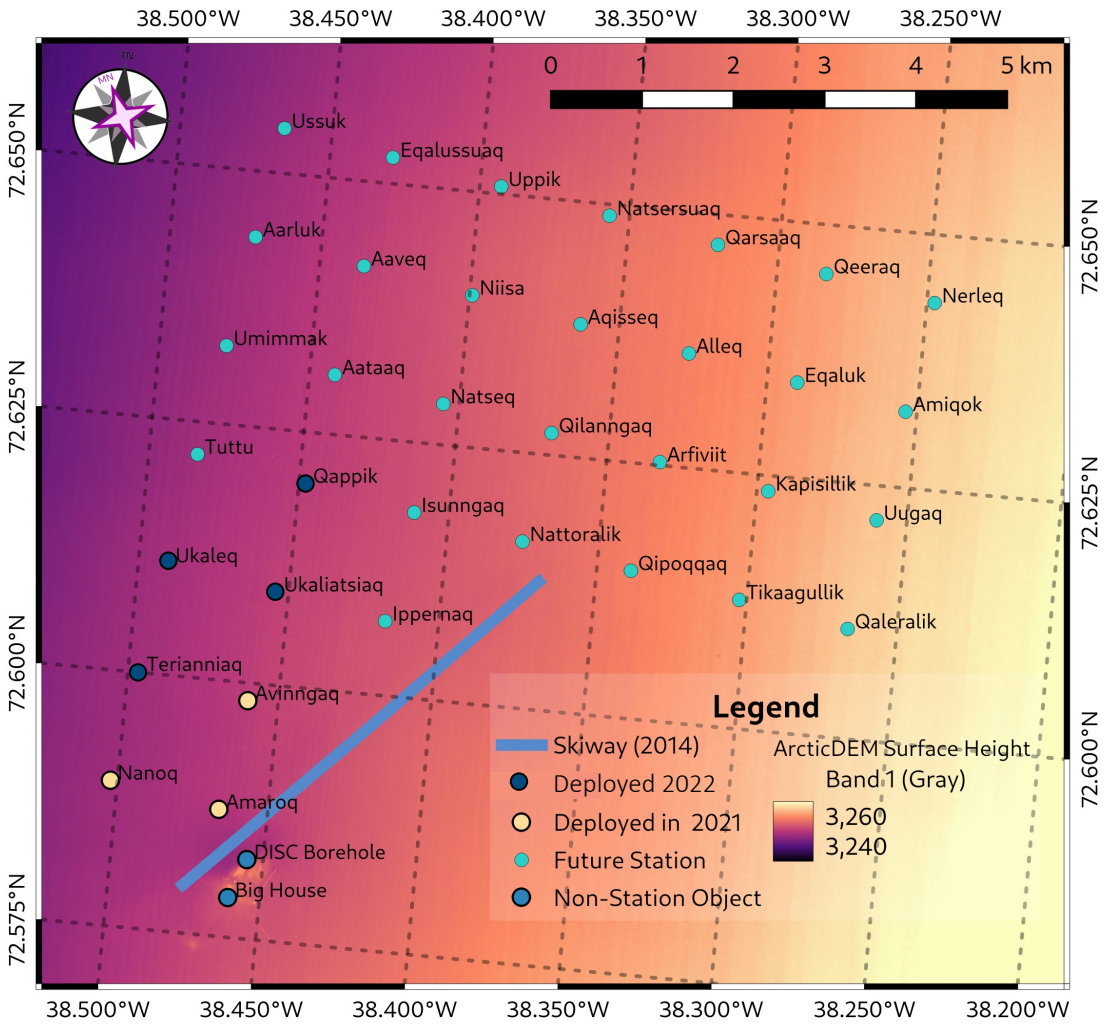
ECRS, Nijmegen, 26.07.2022

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

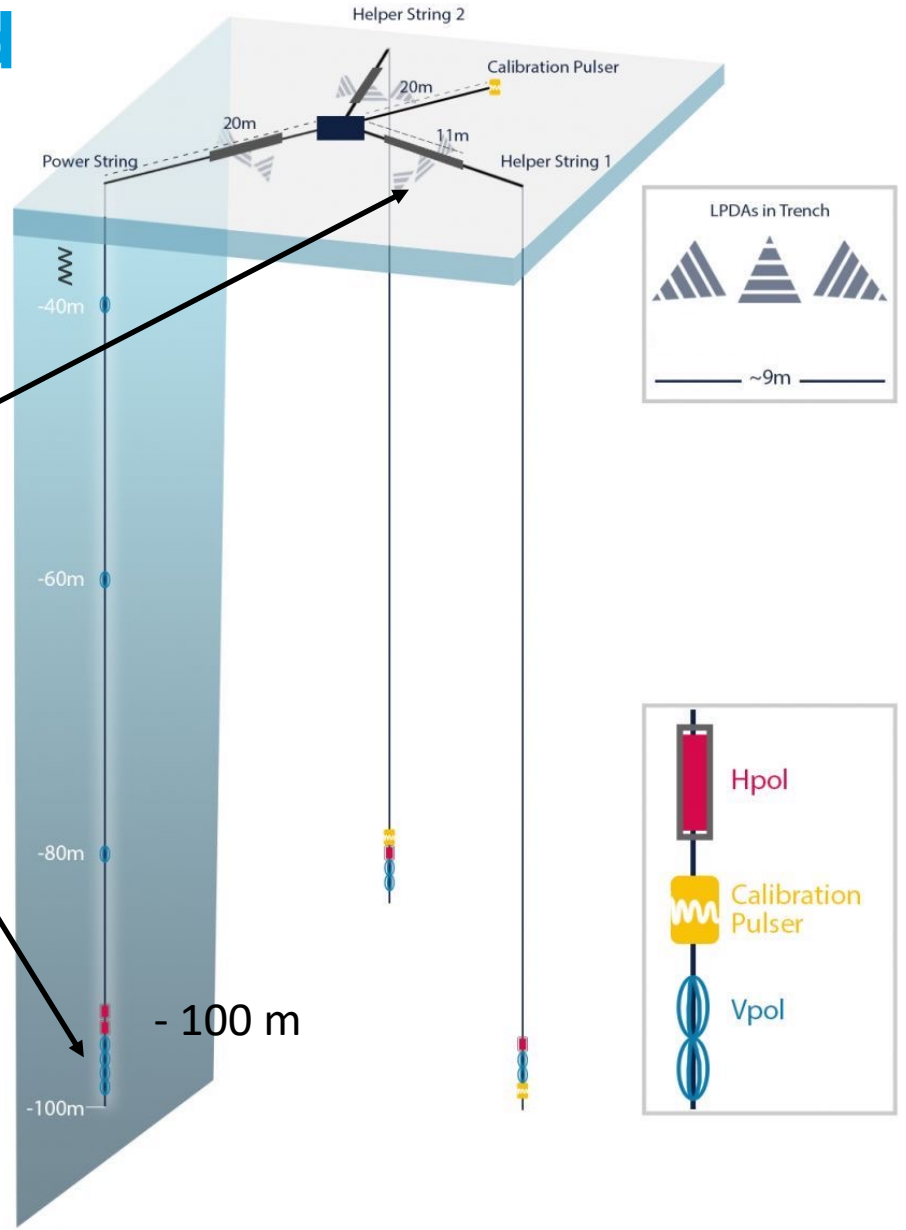
Radio Neutrino Observatory Greenland



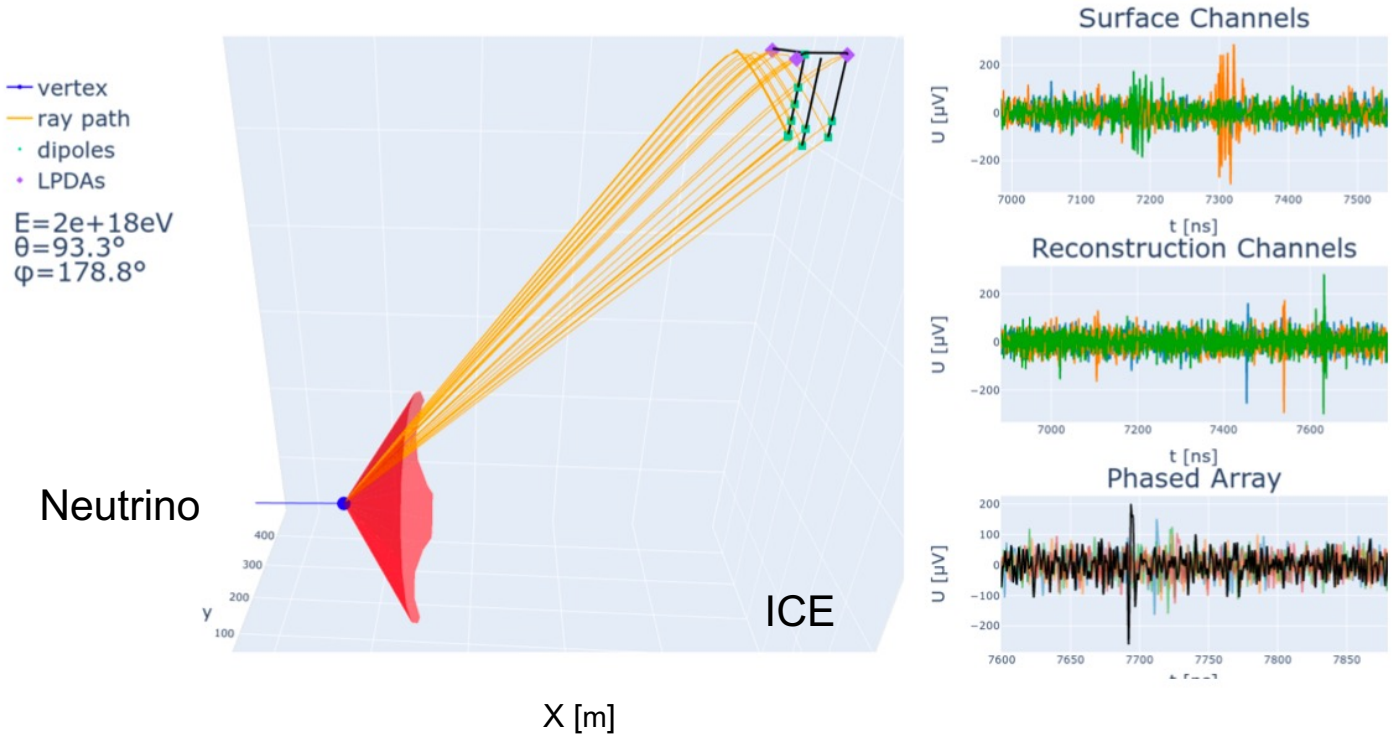
Surface antennas

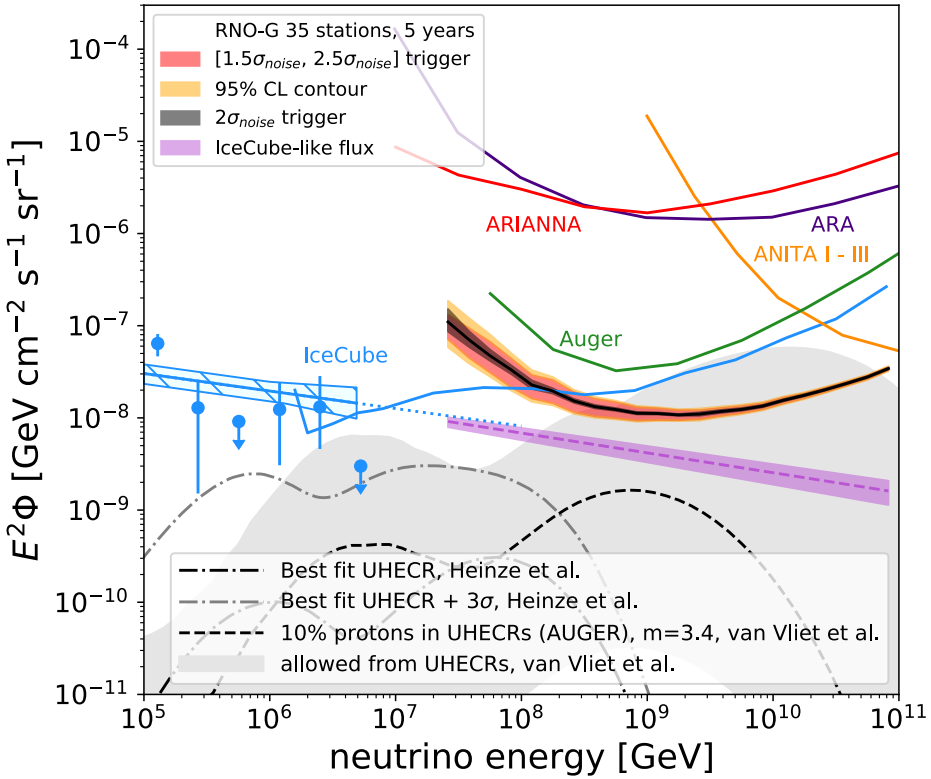
3 upward facing LPDAs for air shower &
6 LPDAs for neutrino trigger and detection

Phased array for in-ice trigger



Neutrino Events

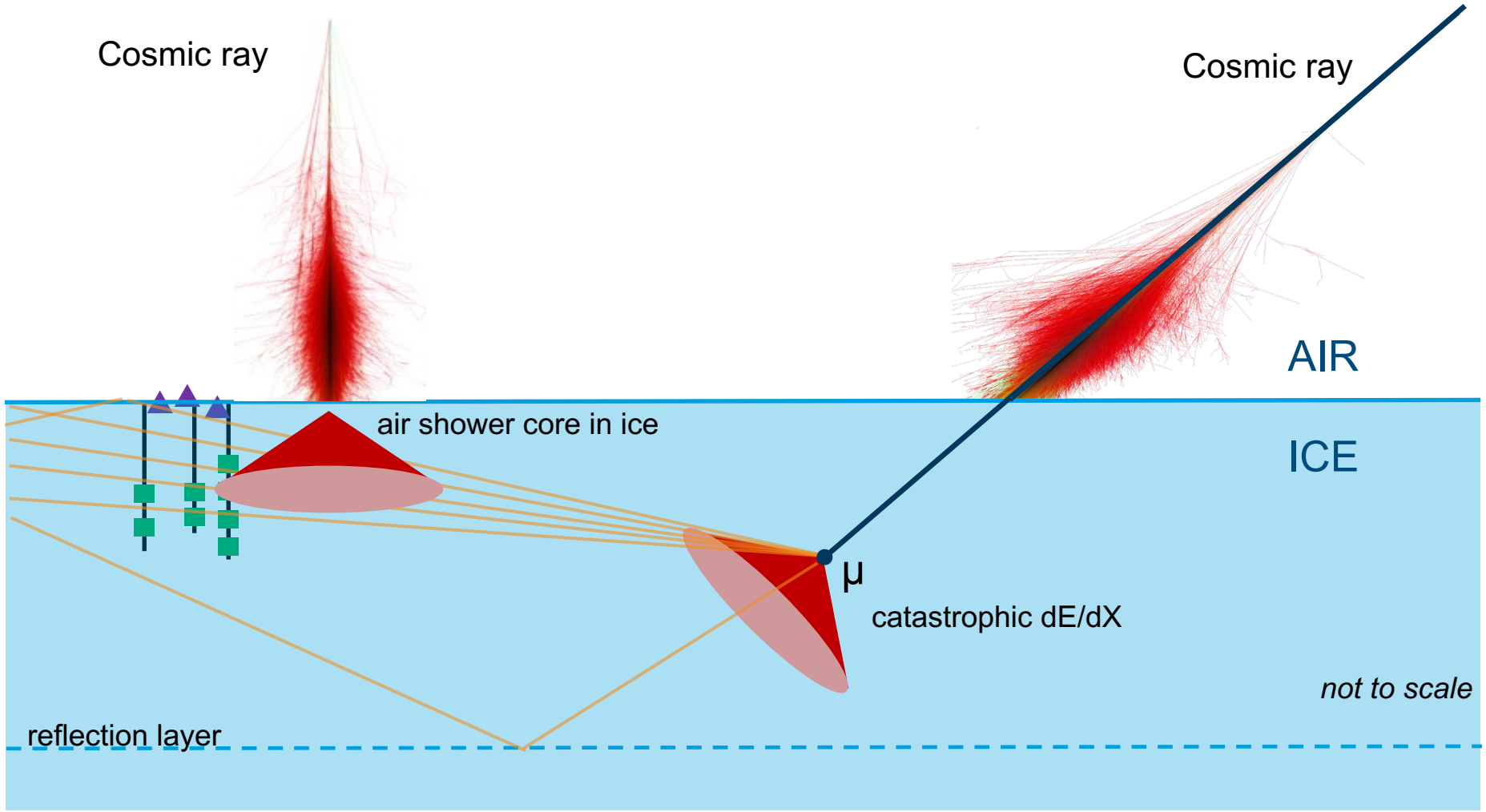




Possible Backgrounds to Neutrino Events

Possible Background to Neutrinos

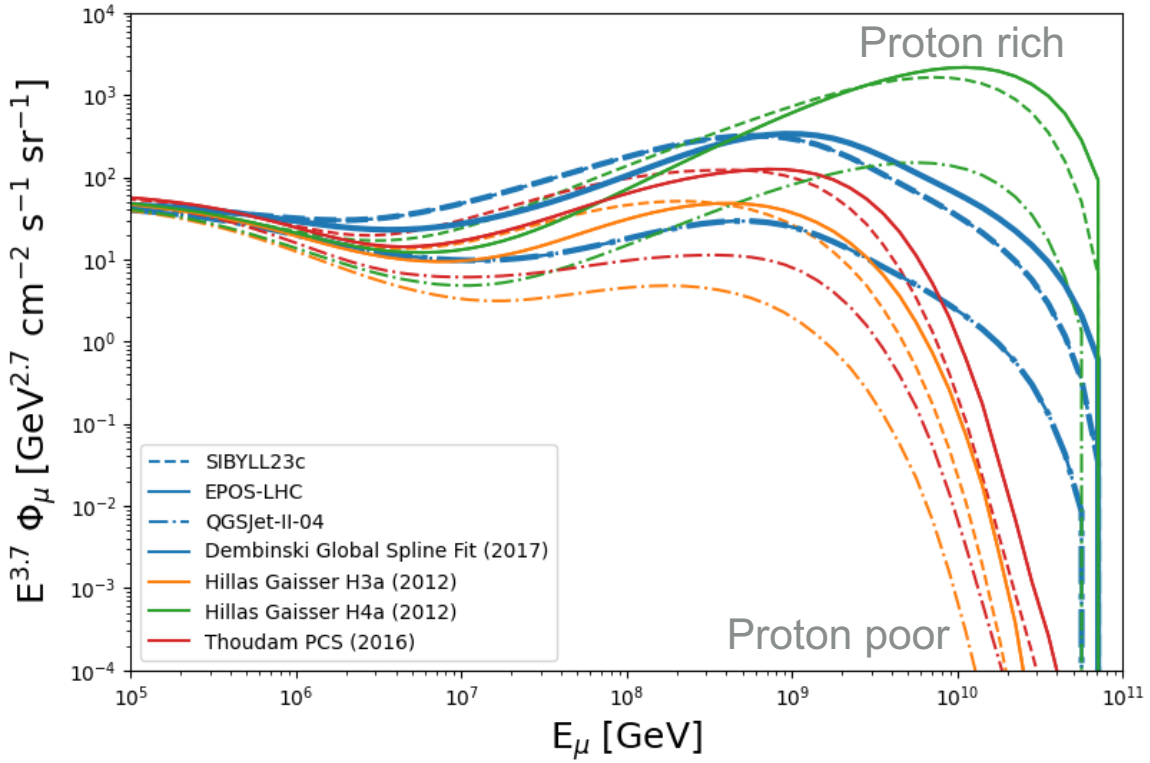
1. Air shower radio emission
2. High energy muons
3. Reflections
4. Shower cores hitting the ice (covered by S. de Kockere arxiv:2202.09211)



The Muon Background

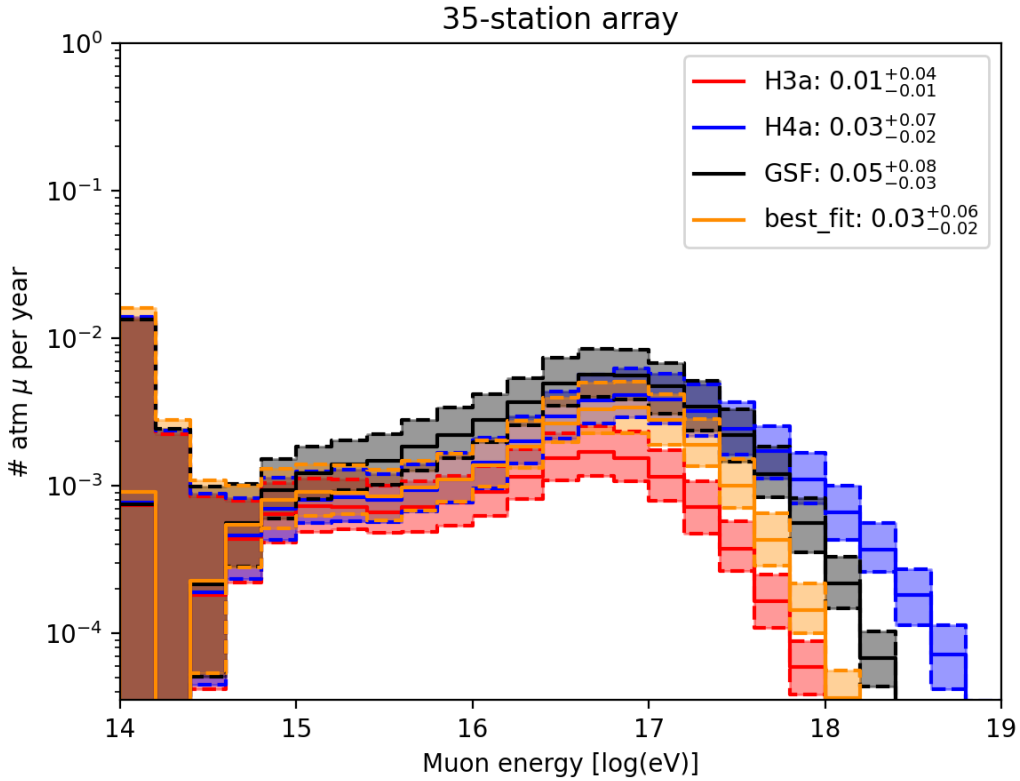
Muon Background

Muon flux for different cosmic ray compositions



→ Muon flux remains the largest uncertainty

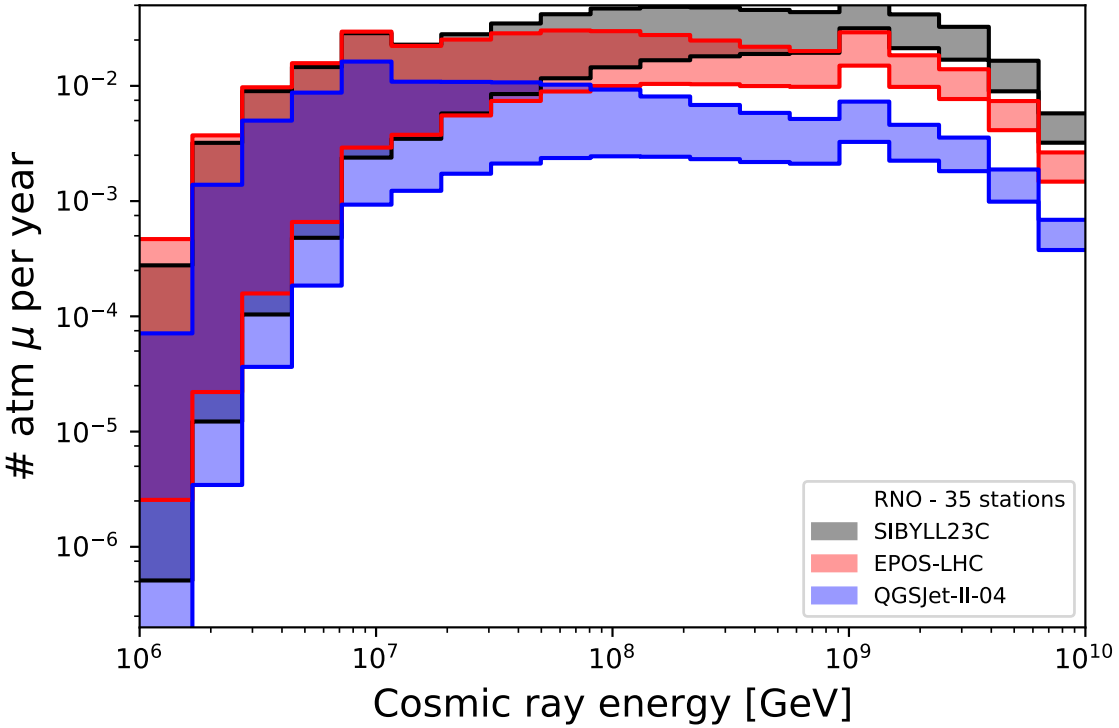
Predicted triggers in RNO-G

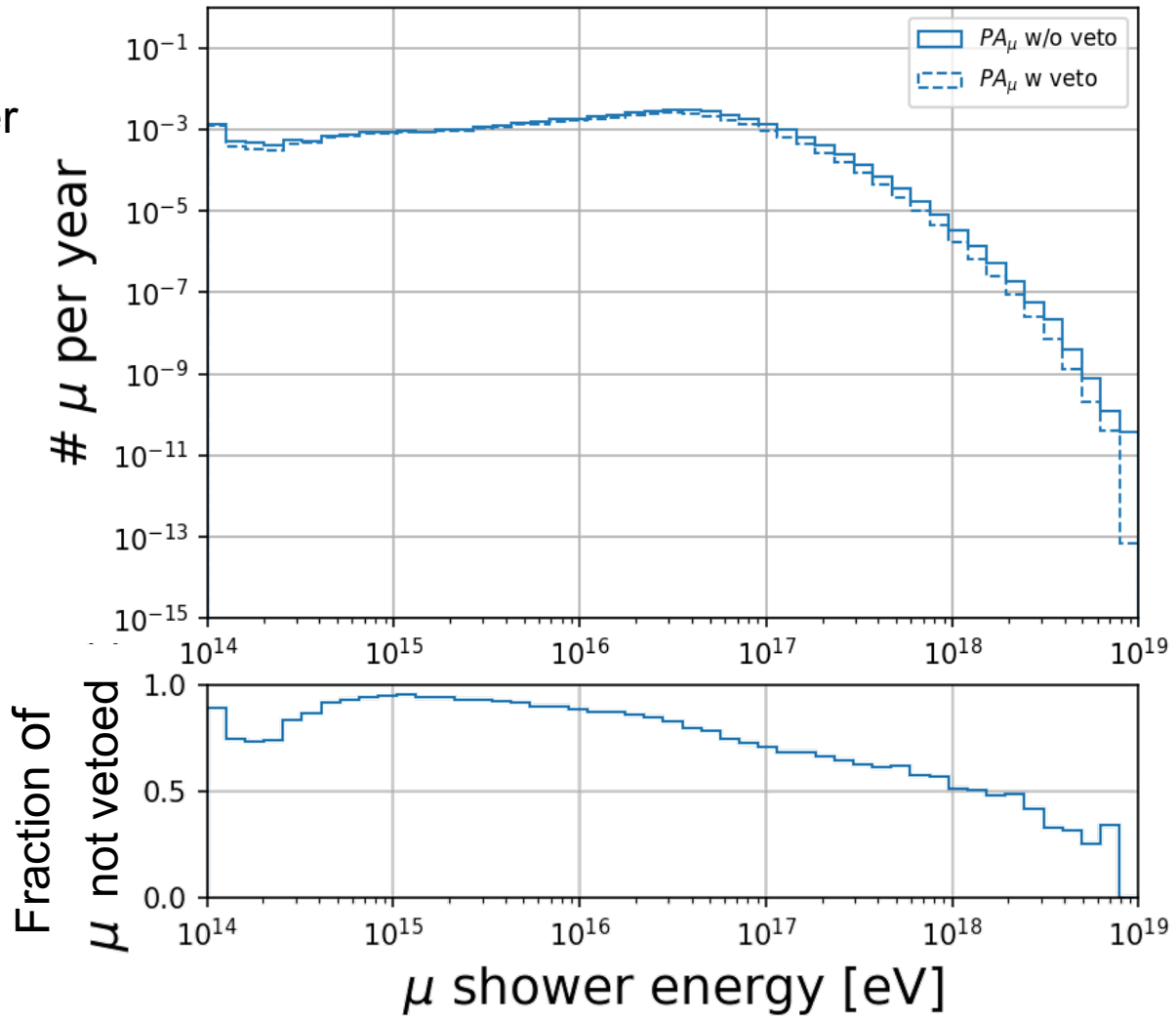


Problem: Same order as expected neutrino events

How to reject Backgrounds?

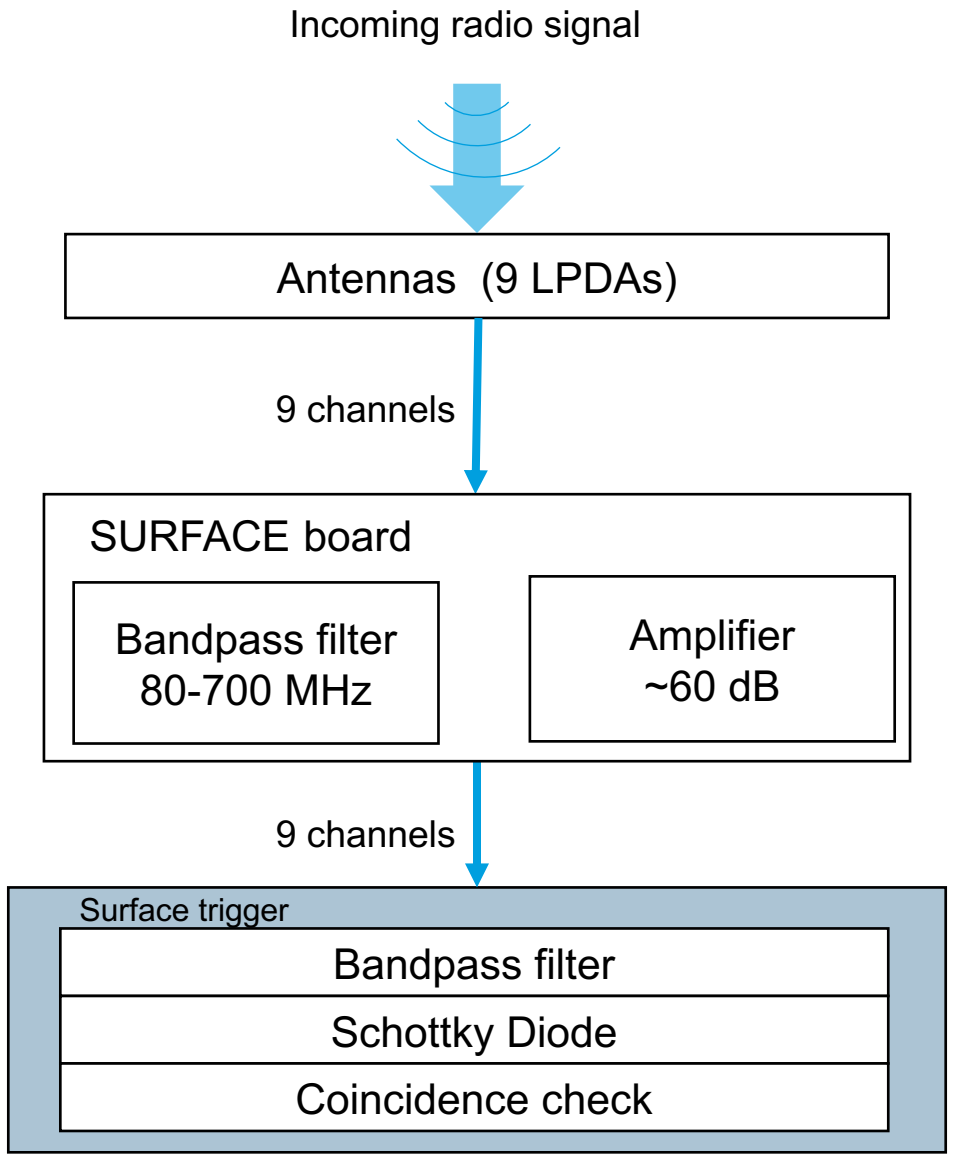
- Idea: muons stem from an air shower
- We can detect the air shower and veto the in-ice trigger
- Air shower tagging better at highest energies, where muons are most dangerous



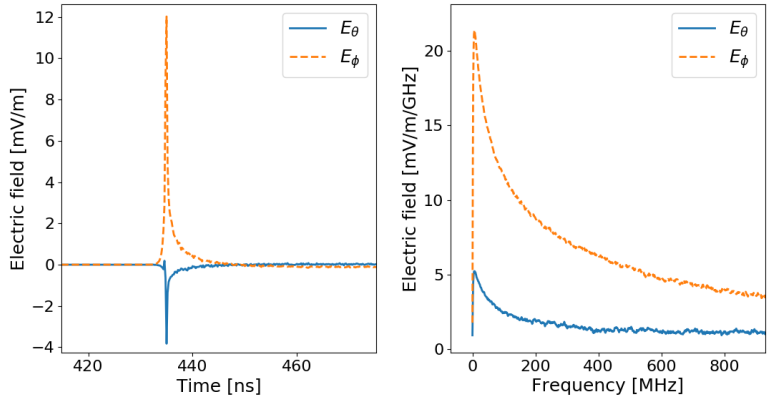


Simulating and Detecting Air Showers with RNO-G

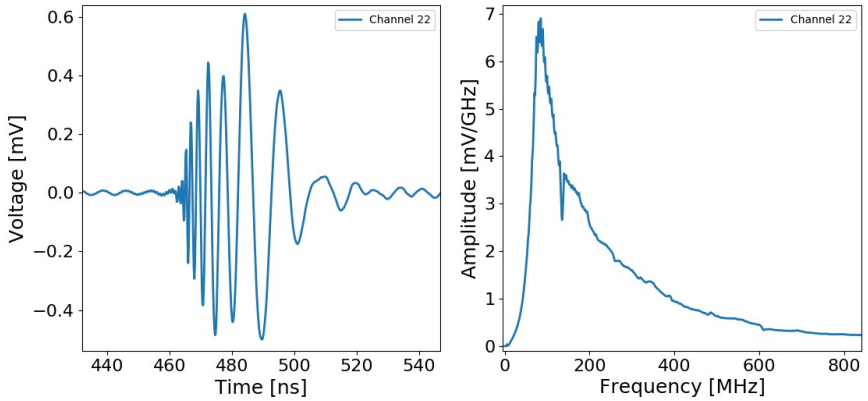
Basic Signal Chain



+ VEL

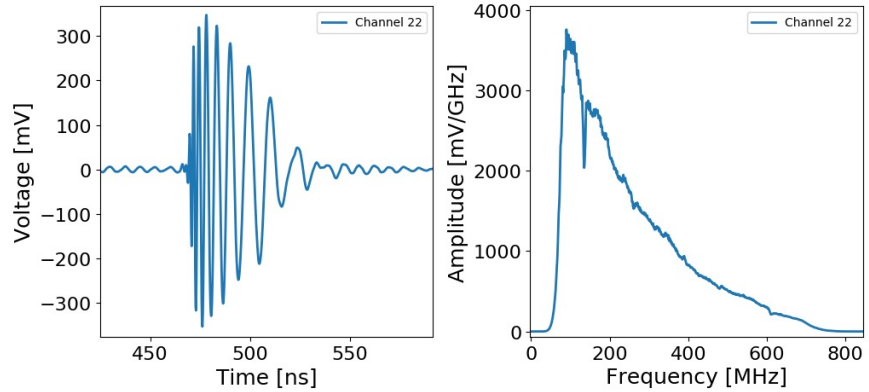


Simulated electric field



Trace before amplification

+ Amplifier



Trace after amplification

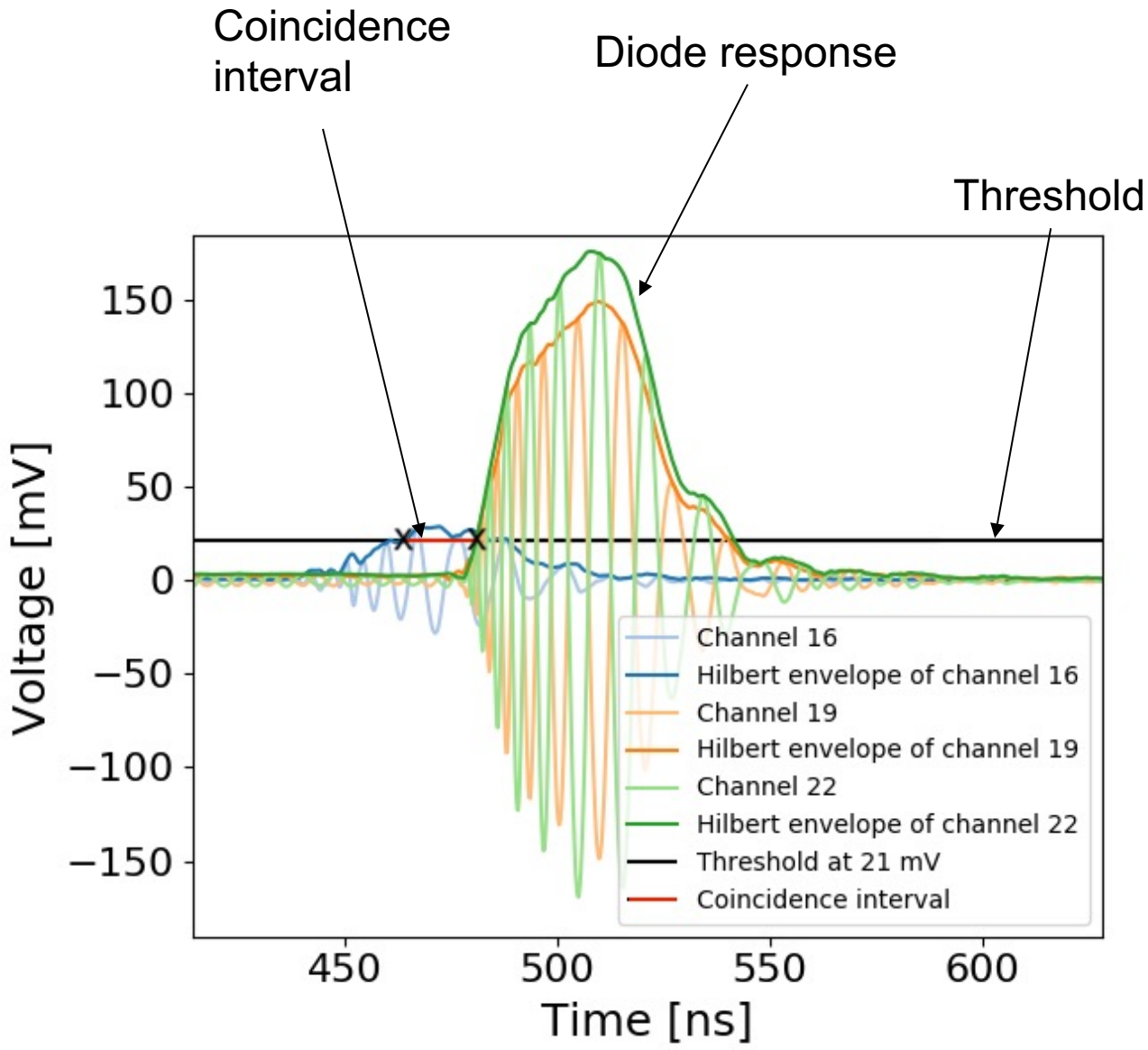
Surface Trigger

Trigger Parameters

- Threshold
- Frequency band
  - Select a sub-region of the frequencies with a bandpass filter (80-180 MHz)

  → Enables lower threshold
- Number of coincidences

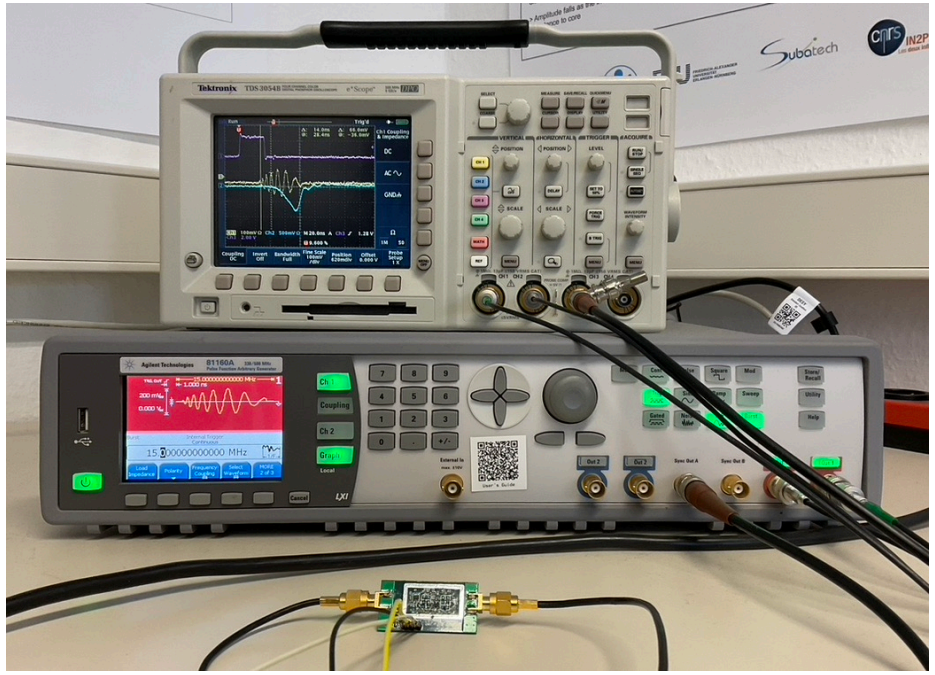
  → Reduces noise trigger rate
- Coincidence window

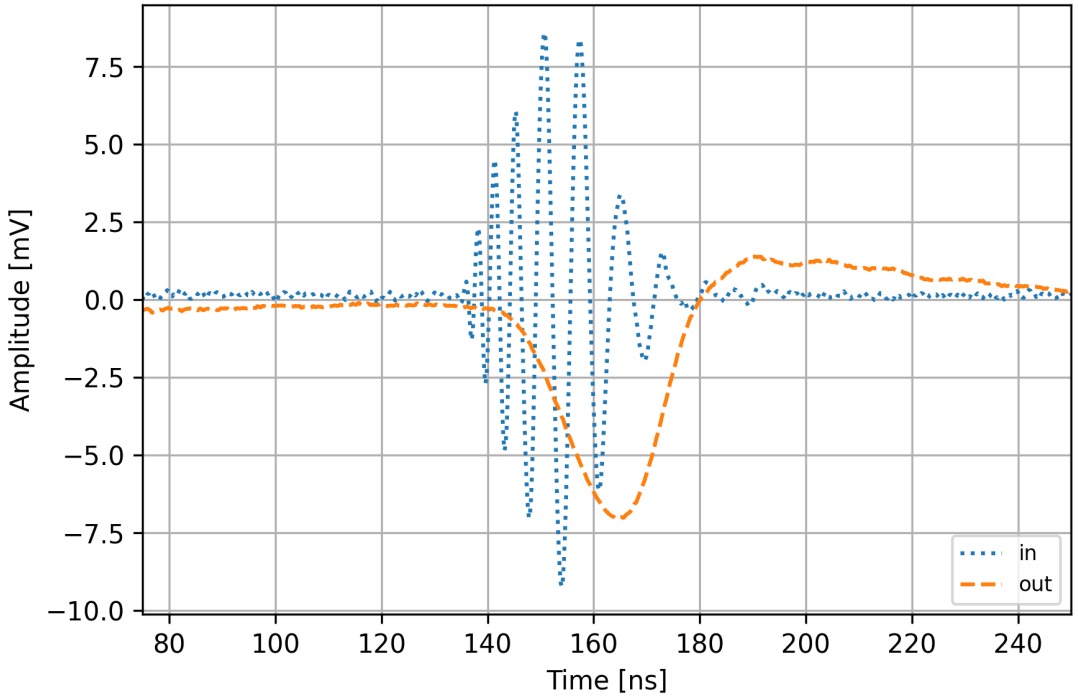


Schottky Diode

A cheap and low power trigger

- FPGA trigger requires a low frequency signal
- Schottky diode is cheap, robust and low in power
- But precise modeling of trigger threshold requires effort
- Initial design had limited sensitivity due to the short development time





Cosmic-Ray Simulations

Optimized hardware compatible trigger settings
(for a noise trigger rate < 0.5 Hz)

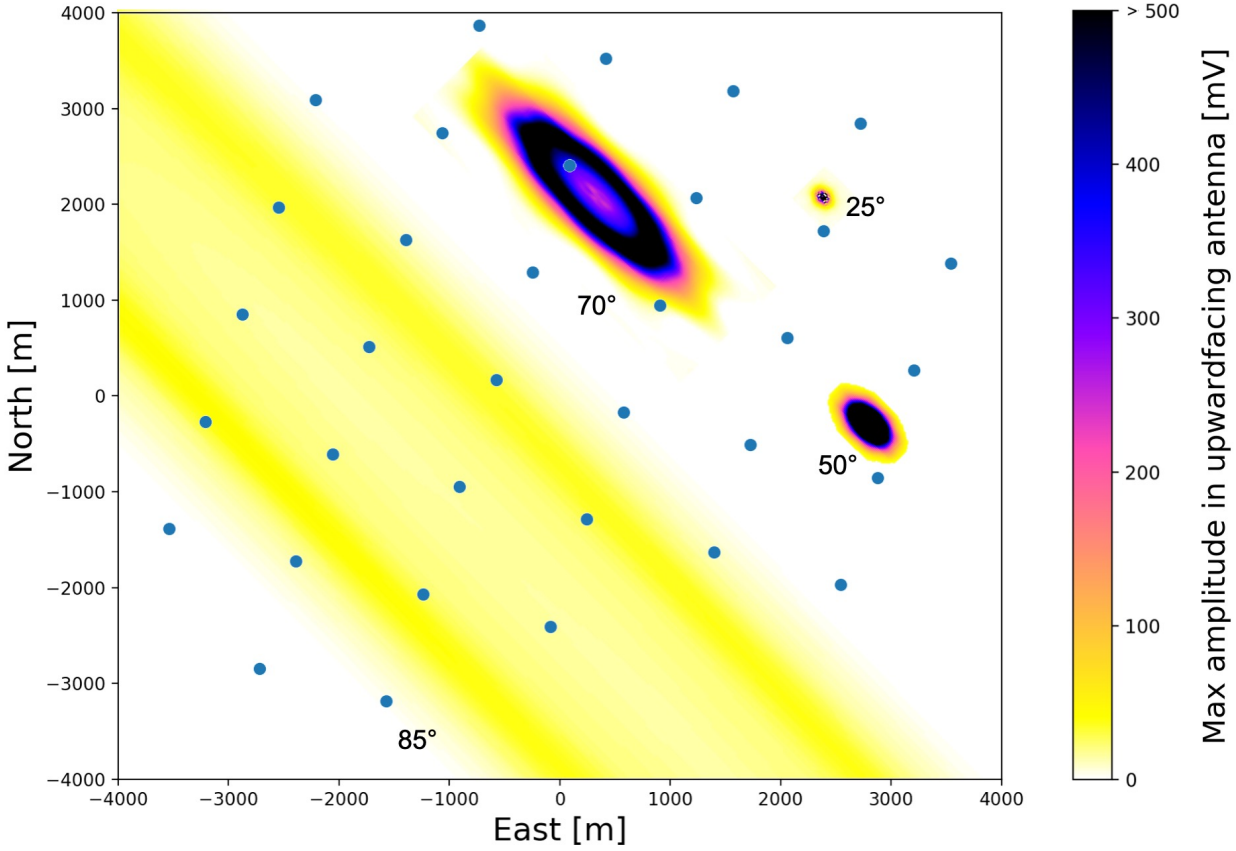
- Passband: 80 - 180 MHz
- Coincidence window: 60 ns
- Number of coincidences: 2 out of 3

Effective area for the full array:

- 407 showers, each shower at 30 core positions

Diode reponse:

- Measured diode (pessimistic)
- Modeled with hilbert envelope (idealized)

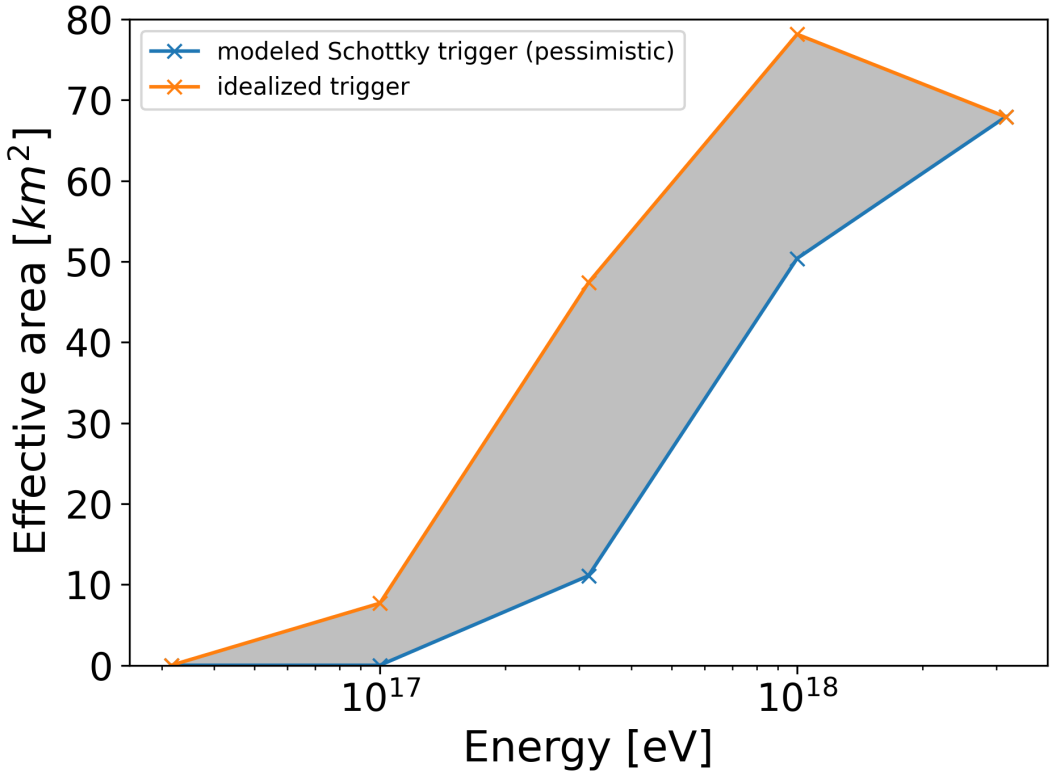


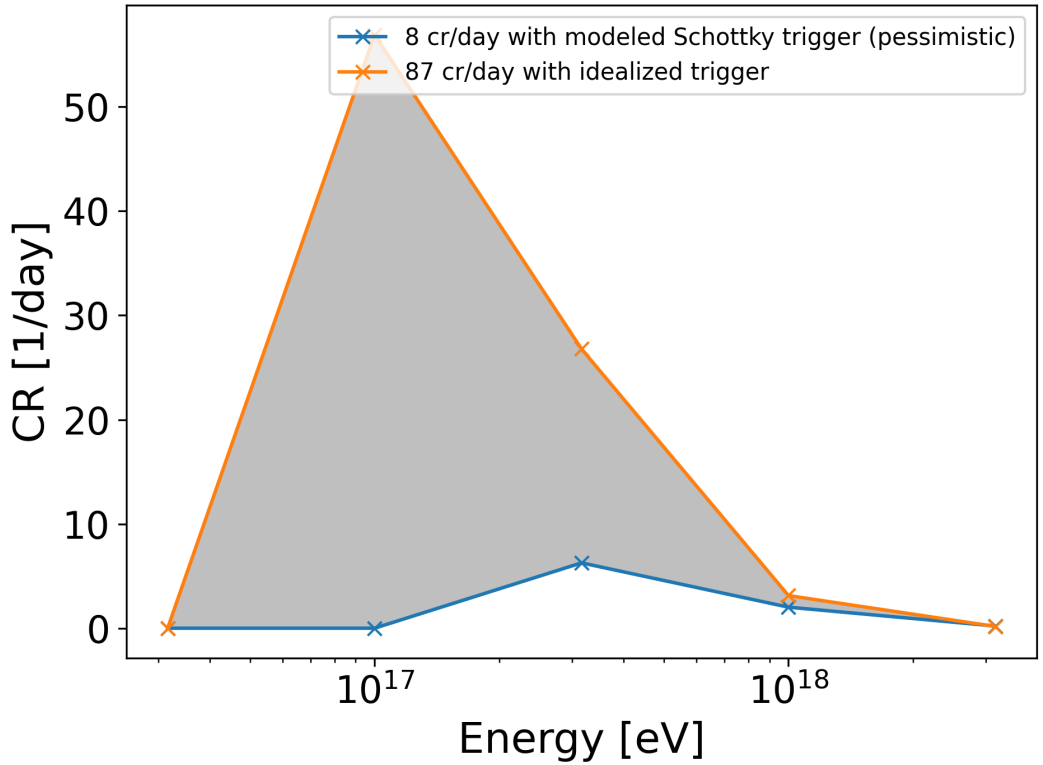
Cosmic-Ray Simulations

Results for different trigger settings

- Effective area depends on detailed trigger characteristics, like response to pulse shape, threshold, bias voltage on diode, temperature
- Flux from $10^{16.5}$ - 10^{20} eV is considered (Auger *arXiv:1909.09073*)

For a 35-station array





Summary

- RNO-G is designed for EeV neutrinos, but also air shower detection
- Effective area at low energies depends on trigger, the details are currently under study
- RNO-G expects air shower induced backgrounds at low energies, predictions have large uncertainties
- Goal: Use cosmic rays as calibration source for neutrino detection
- Cosmic ray search is in progress
- Trigger optimization planned to increase number of cosmic rays,
- and obtain a better calibration