Towards Neutrino Detections with the Radio Neutrino Observatory Greenland

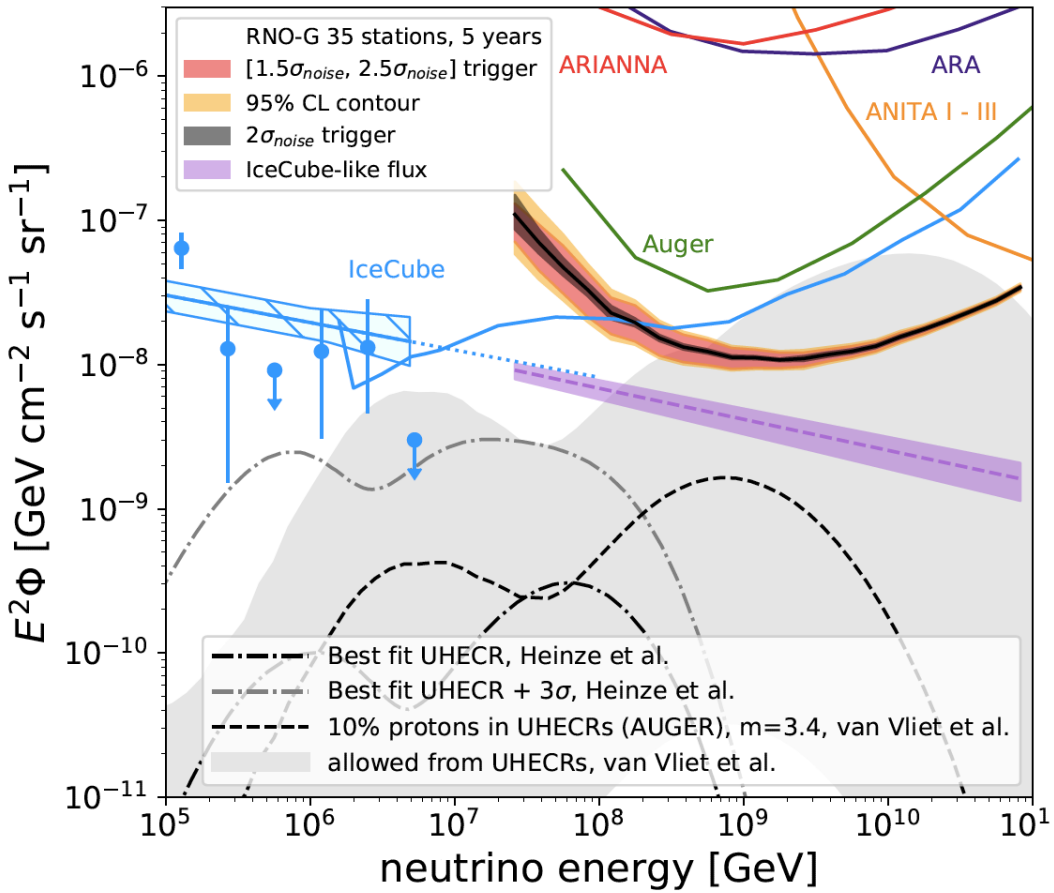
Ilse Plaisier for the RNO-G collaboration

RNO-G

Radio Neutrino Observatory - Greenland

A Step Forward in Detecting UHE Neutrinos

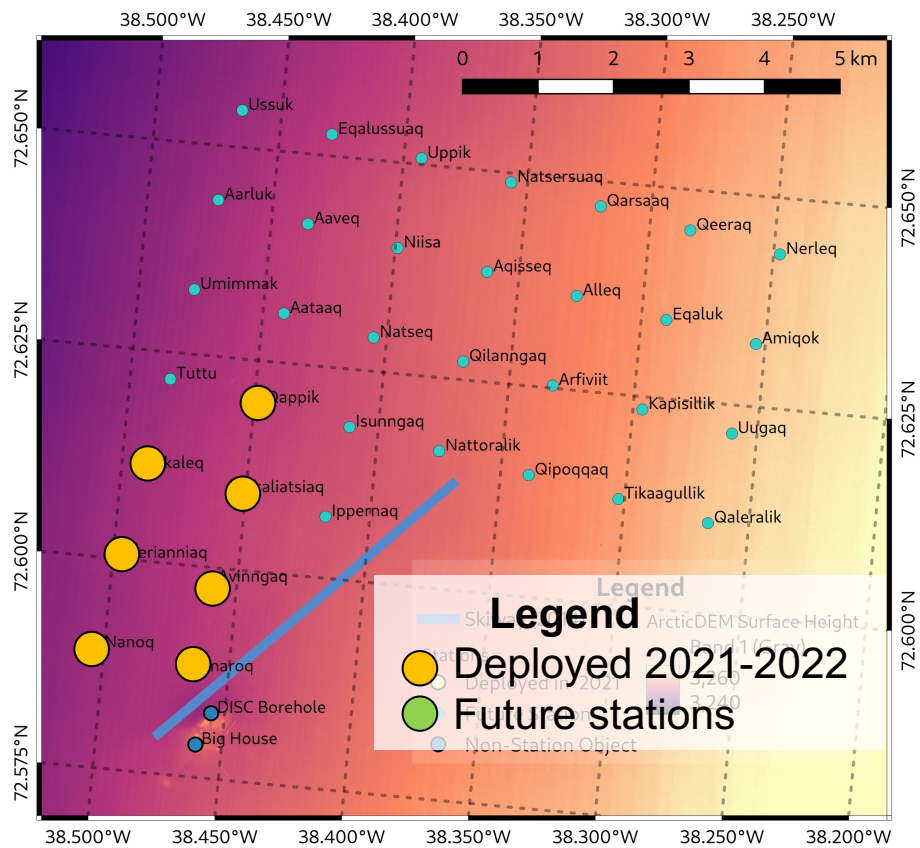
- Aiming for UHE, cosmogenic and astrophysical ν's beyond PeV scale
- Larger detectors than the current ones are needed for low flux at these energies
- Sparse arrays can be built due to attenuation length of O(1km).
- Sensitive to northern sky

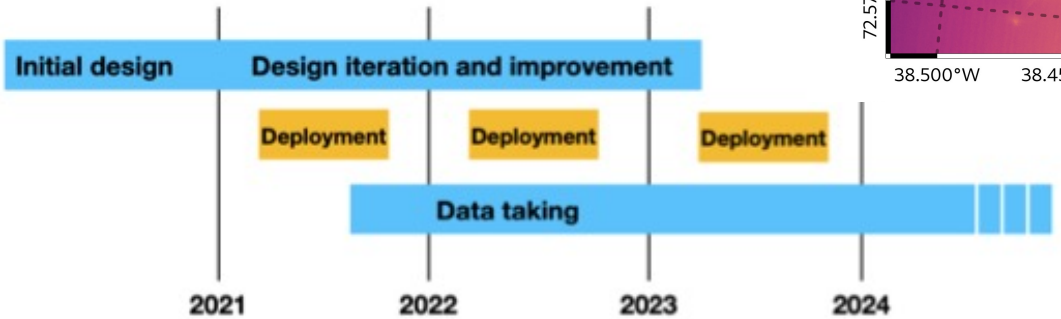


RNO-G Whitepaper arXiv:2010.12279

RNO-G Planned Layout

- Current funding for 35 stations
- Located at Summit Station, Greenland
- 3 km ice-sheet
- 1.25 km spacing to maximize effective volume
- RNO-G stations are scalable





RNO-G Station Design

Shallow Component

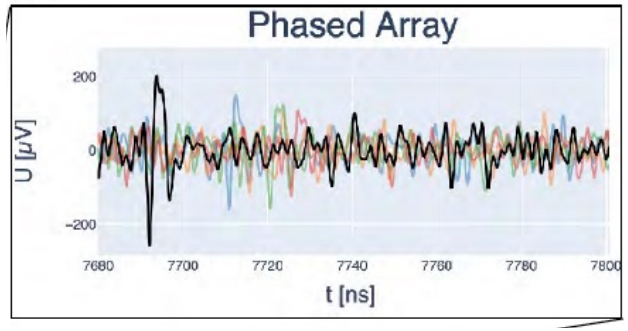
- talk tomorrow 17:15 Lilly Pyras

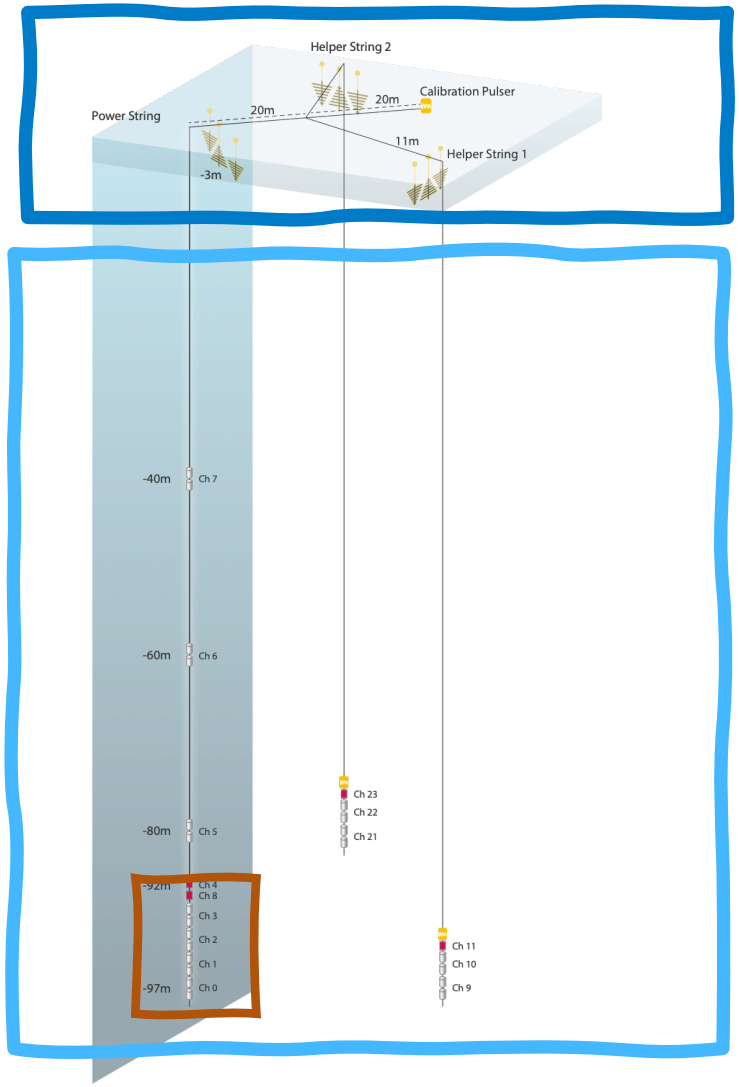
Deep Component

- Three 100 m deep strings
- 1 *power string:* trigger and antennas along the full string
- 2 *helper strings:* for azimuthal reconstruction

Phased Array Trigger

- For low-threshold triggering to maximize effective volume





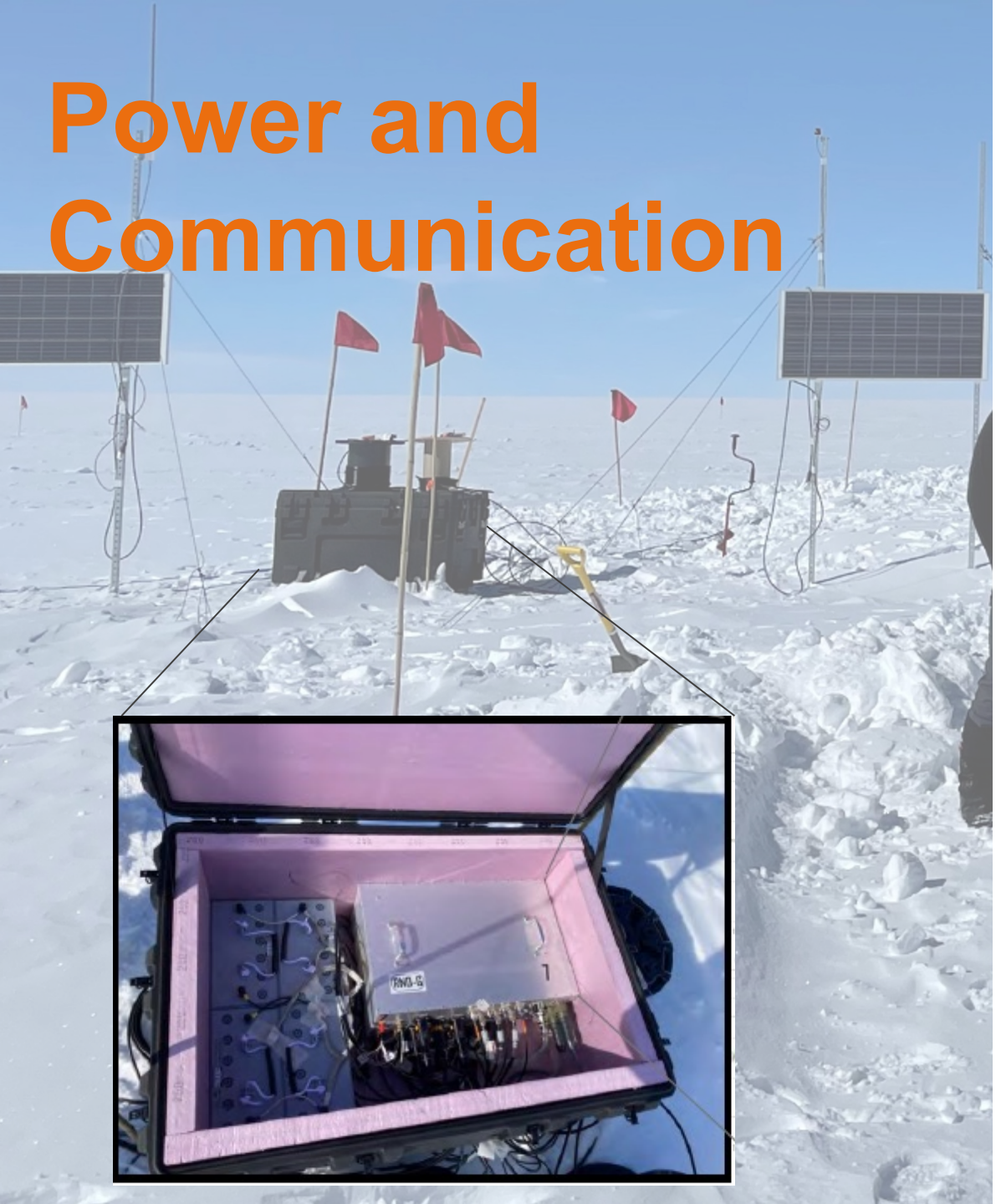
Drilling

100 meter deep
and 300 years old ice

- Custom mechanical drill developed by the British Antartic Survey for RNO-G
- Possible to drill a 100 meter hole per day

String Deployment

Power and Communication



Autonomous stations using solar panels

Wind turbines are added right now!

LTE and LoraWAN communication to Summit Station

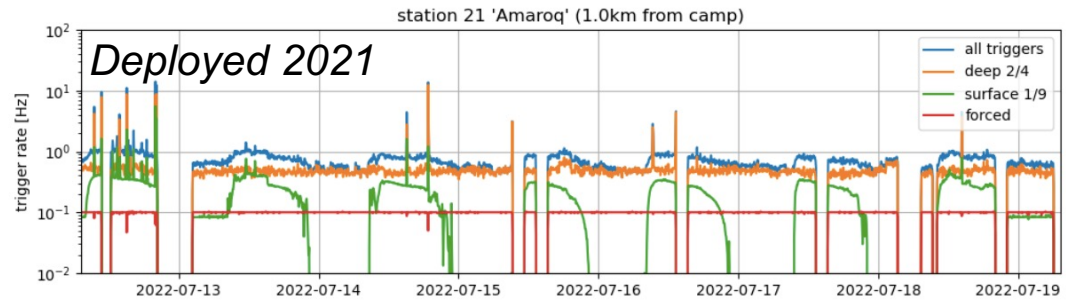
First year of data taking…

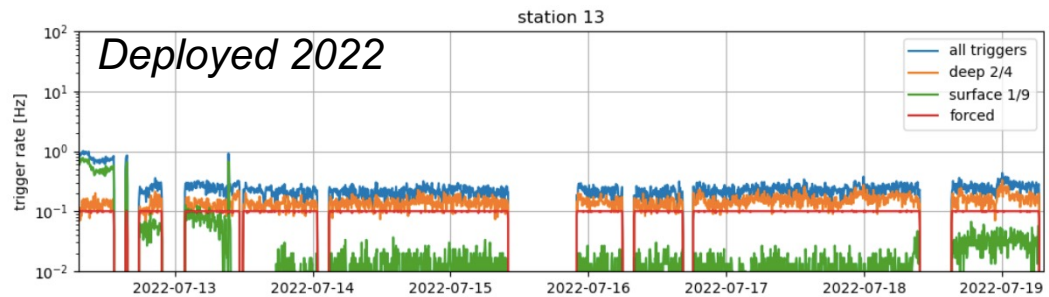
- Stations deployed first season had self-induced noise *(communication antenna and batteries)*

Resolved for new stations

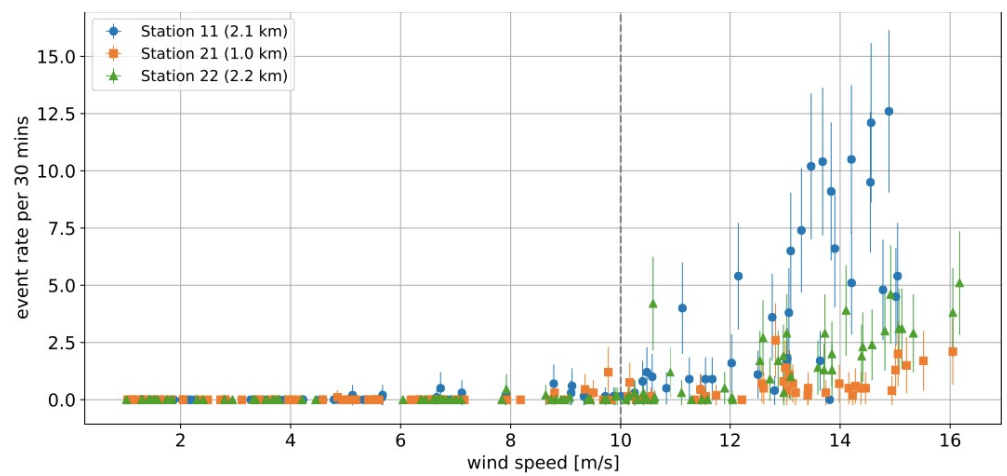
- CW events (hand radios, aircraft)
- snow mobiles

- Higher event rate for days with higher winds





Wind events arXiv:2103.06079



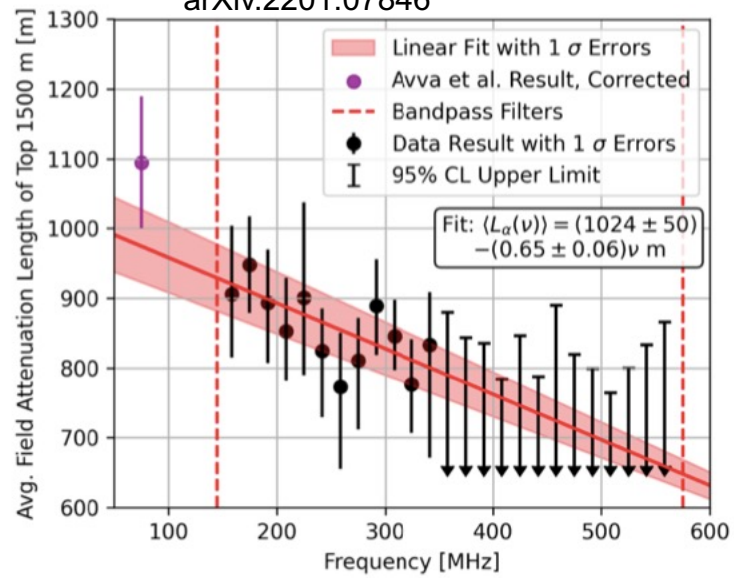
Calibration Data

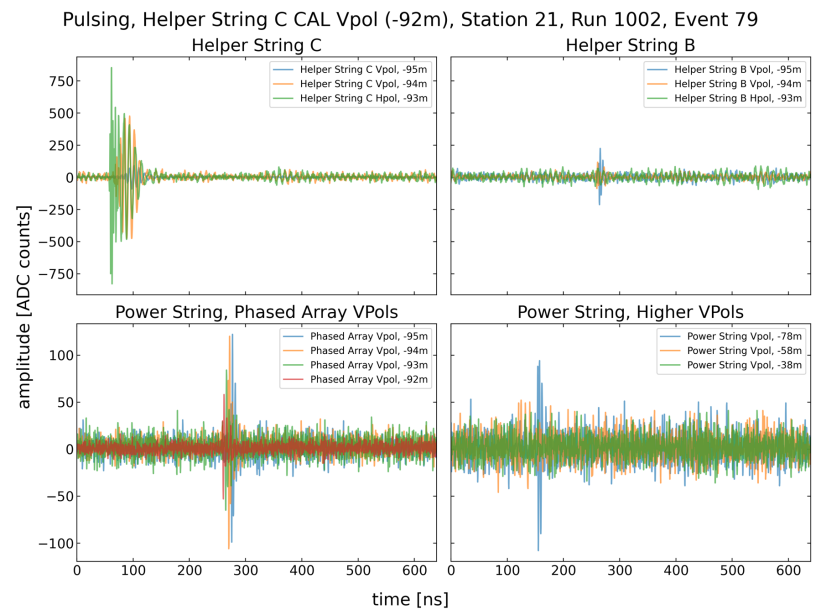
- Published attenuation length of the Greenlandic ice

- New data taken this year (at the moment):
  - azimuthal response antennas
  - reflective layers

- Surface pulser and Deep pulser per station for
  - antenna positions
  - snow accumulation

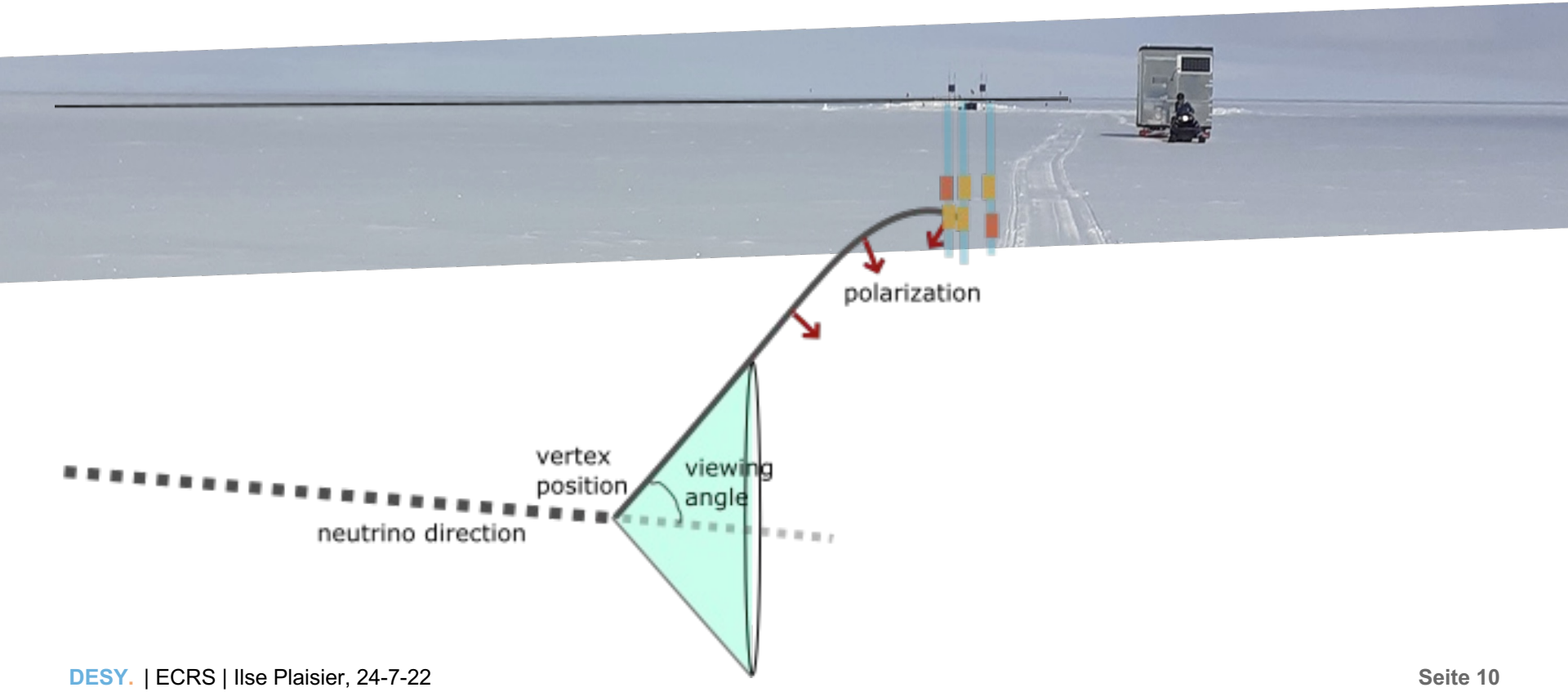
arXiv.2201.07846





Direction Reconstruction

Shower Geometry

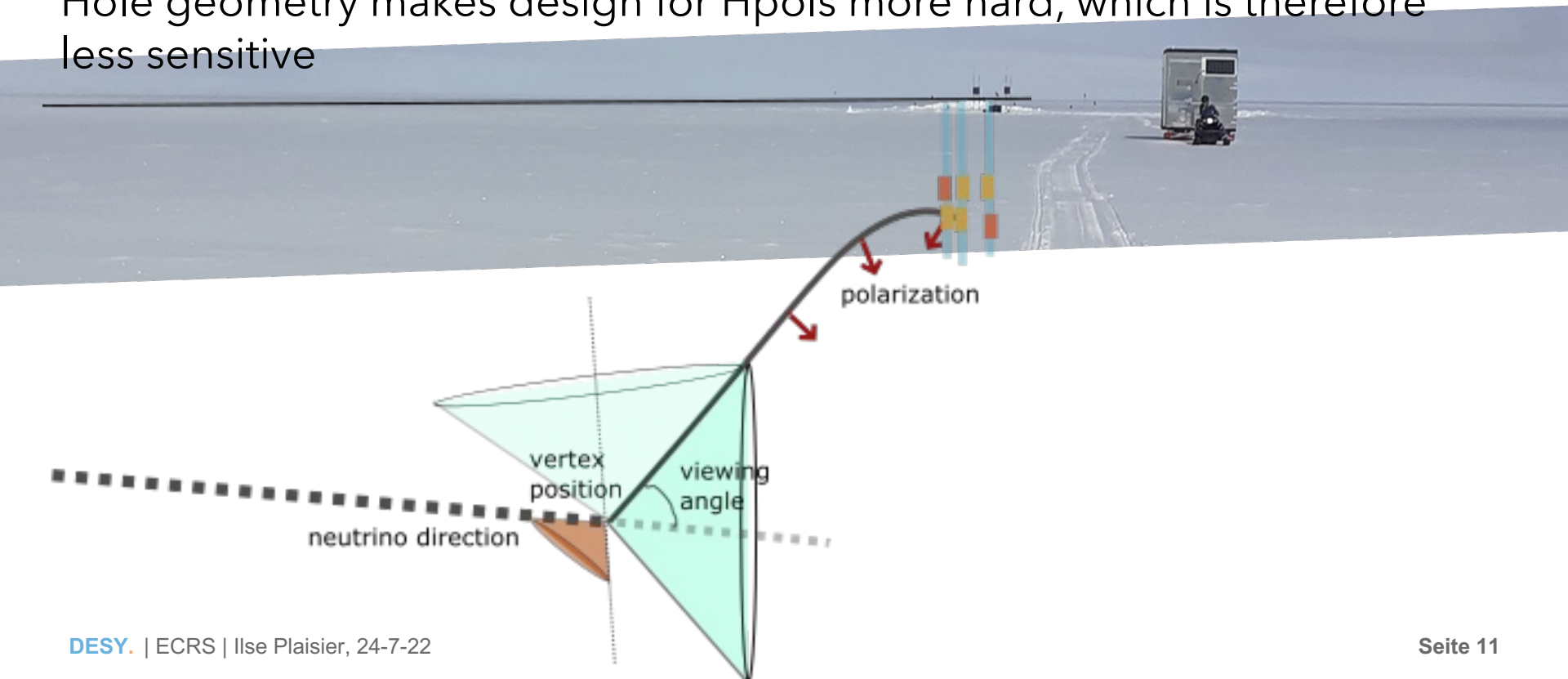


Shower Geometry

The **signal direction**, **viewing angle** and **polarization** are needed to pin-point the neutrino direction

Antennas for horizontaly and vertically polarizated electric-field are needed (Hpols and Vpols)

Hole geometry makes design for Hpols more hard, which is therefore less sensitive



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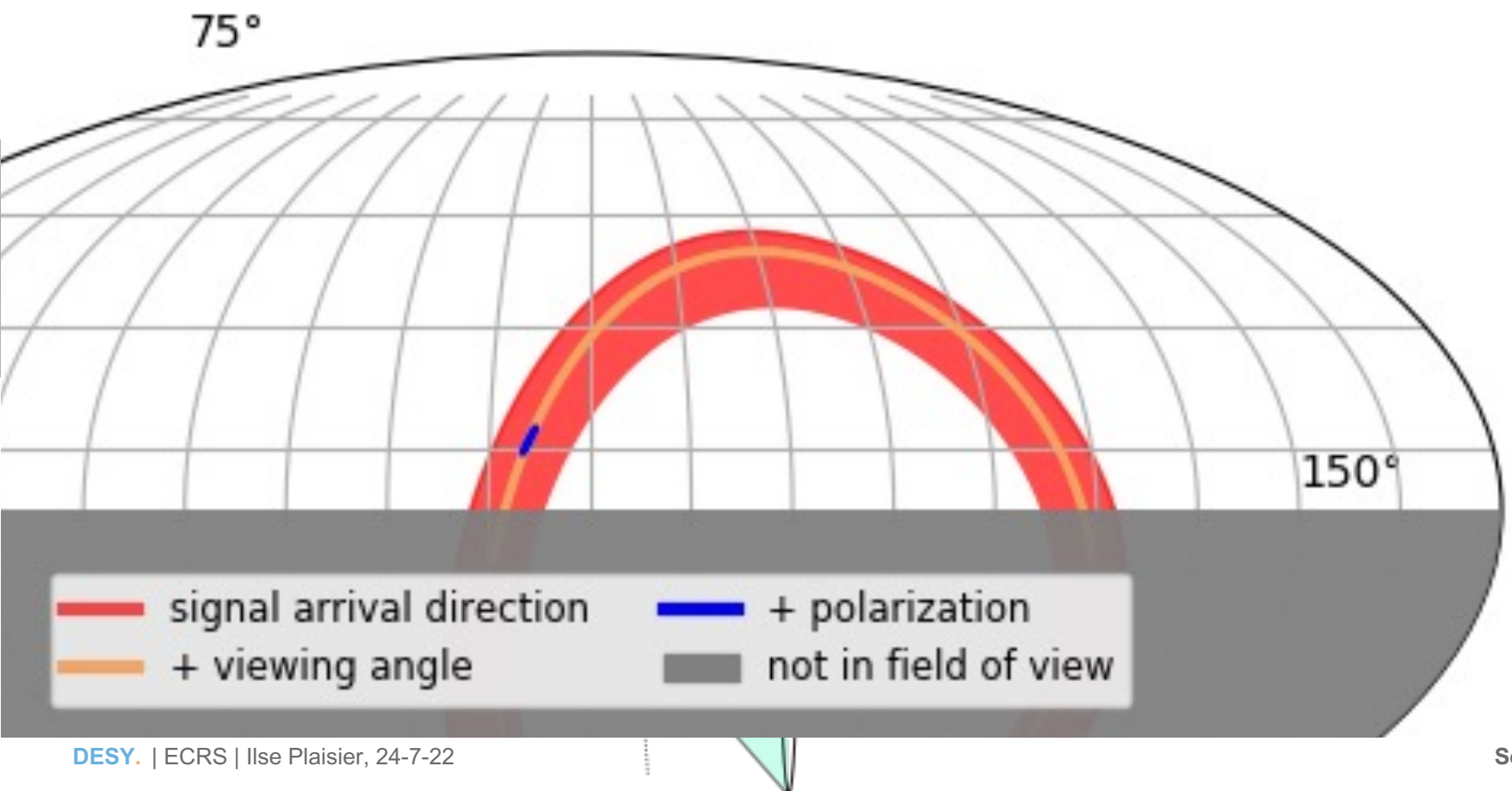
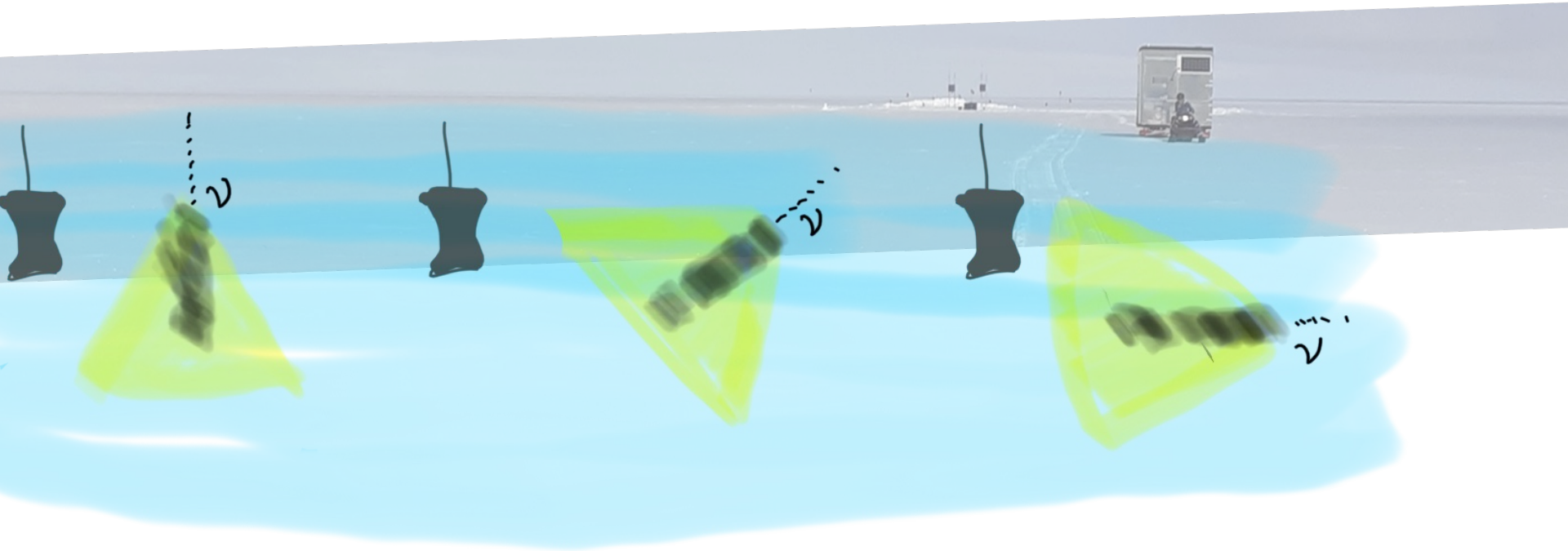


Neutrino Zenith Dependence

- RNO-G not sensitive to vertical showers
- Bigger part of the cone is detectable for horizontal showers; more polarization options



Relevant Quantities for Angular Resolution

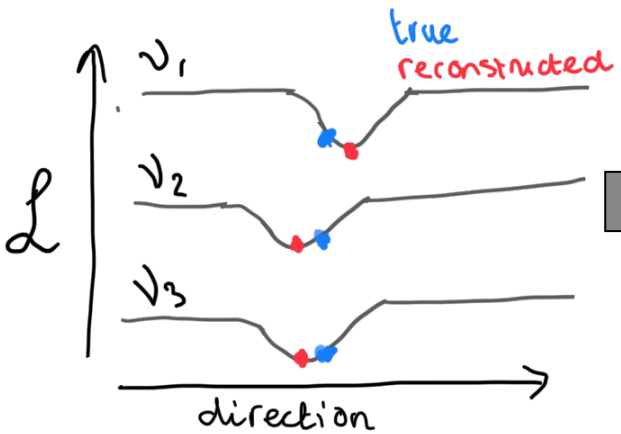
What is the probability of detecting a neutrino given a source?

Point Spread Function

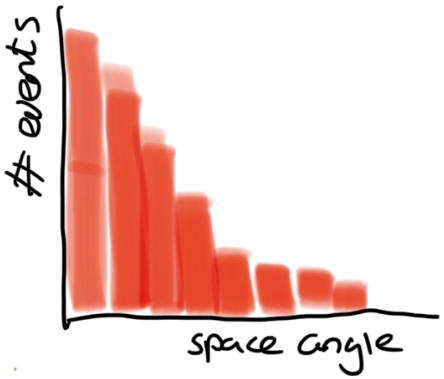
What is the probability of a source given a detected neutrino? **Single-Event Uncertainty Contours**

The Simple 1D Case

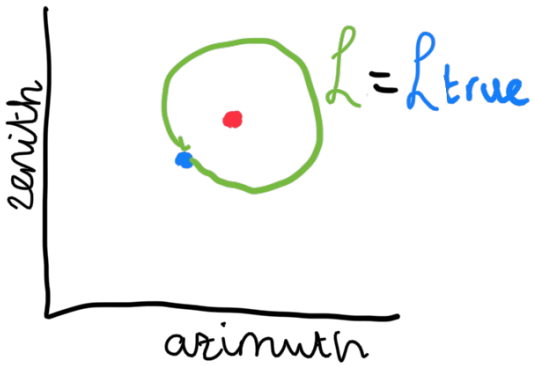
Minimization Landscapes



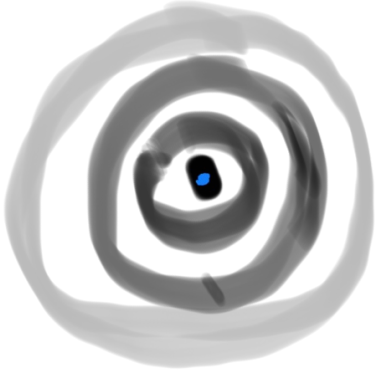
Space Angle



Sky Area



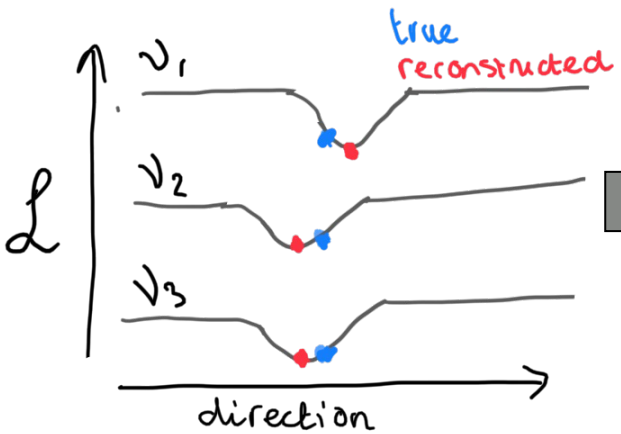
Point Spread Function



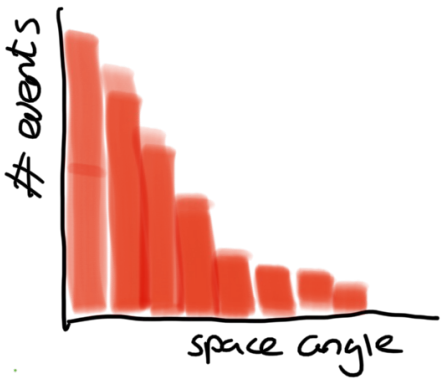
In the Radio Case

Contours not 1D but ellipse-like.

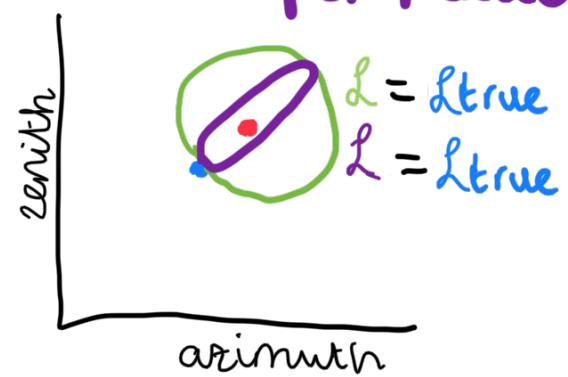
Minimization Landscapes



Space Angle



Sky Area for radio

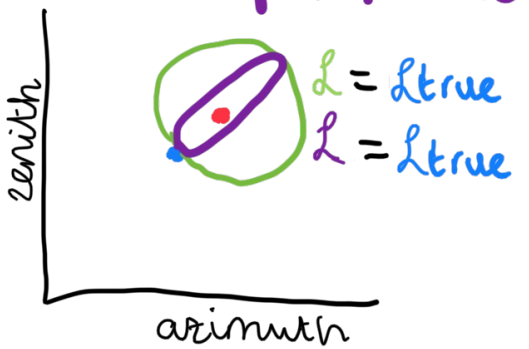


Point Spread Function for radio

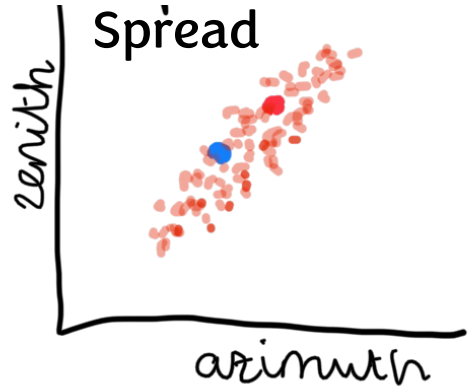
PSF is not 1D, due to shower geometry

From Sky Area to Uncertainty Contours

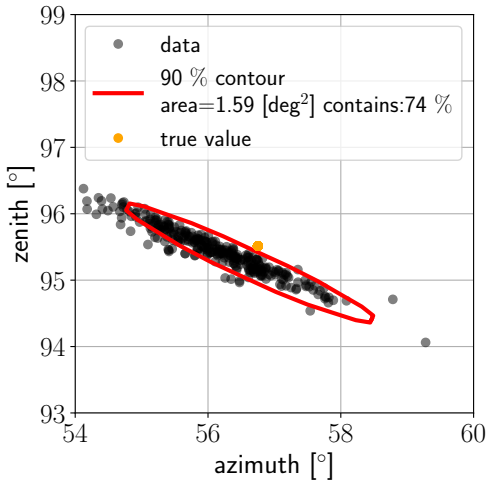
Sky Area for radio



Reconstructed Spread

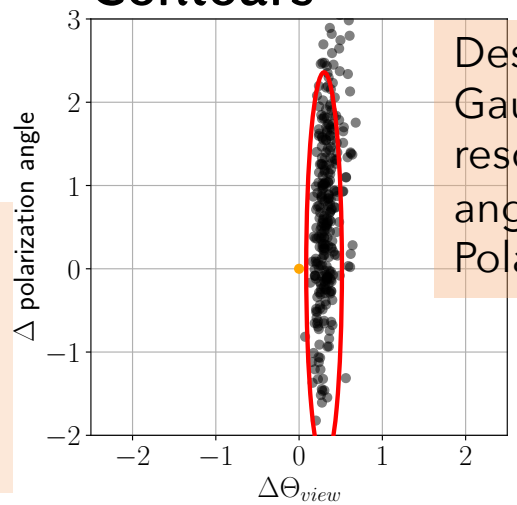


Uncertainty Contours



Switch to coordinate system of polarization and viewing angle

Uncertainty Contours



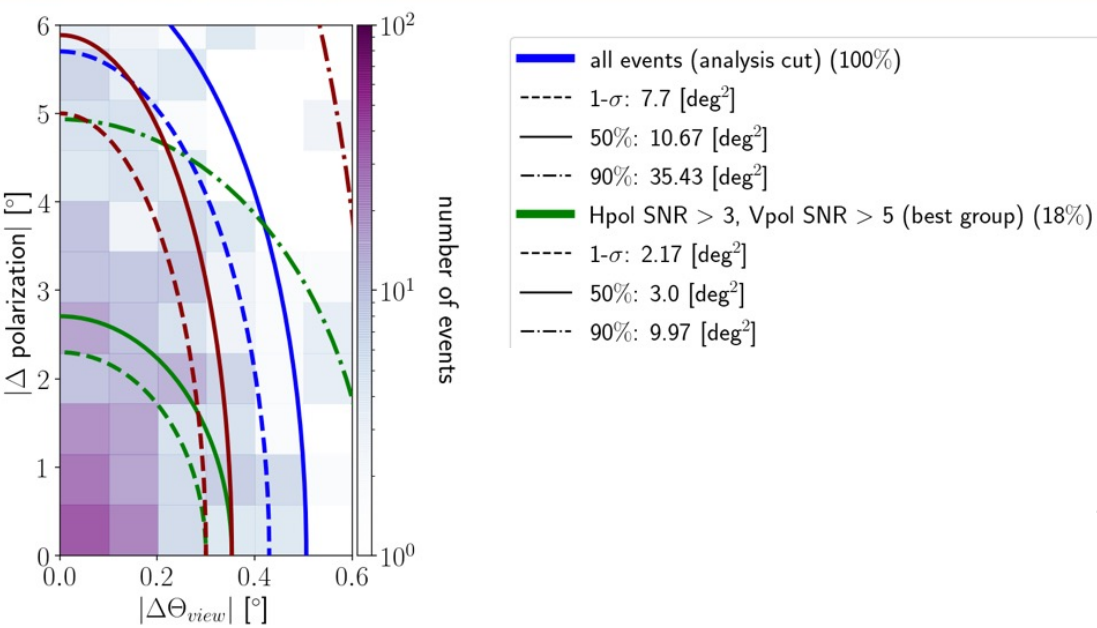
Describe as 2D Gaussian with resolution of viewing angle and Polarization

Angular Resolution Results

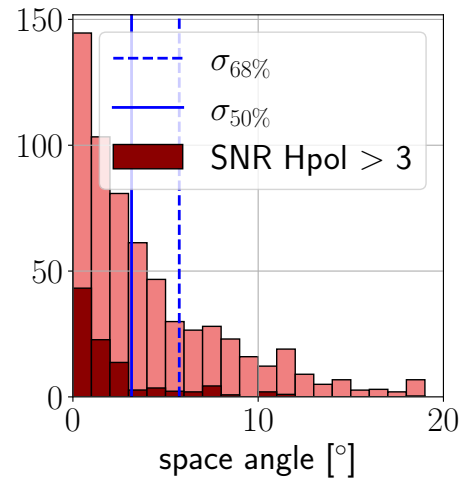
Uncertainty Contours

Event categories:

- **Viewing angle** dependent on **amplitude Vpol**
- **Polarization** dependent on **amplitude Hpol**



Space Angle



Space angle results for high quality event set:

Analysis cuts: $\sigma_{50\%} = 3.0°$

+ SNR Hpol > 3: $\sigma_{50\%} = 1.3°$

Summary

- RNO-G funded to 35 stations -> first experiment sensitive to UHE neutrino flux predictions
- Currently 7 deployed stations
- Besides neutrinos, also cosmic-ray detector -> talk tomorrow 17:15 Lilly Pyras
- Pathfinder for IceCube-gen2 radio

- Angular resolution limited by polarization reconstruction -> Hpols
- Uncertainty contours ellipse-like
  - Dependent on viewing angle and polarization resolution
  - 10 deg^2 90%-contours for high quality events