Radio Neutrino Observatory Greenland

Calibration & Ice modelling

GHENT
UNIVERSITY

RNO-G
Radio Neutrino Observatory - Greenland

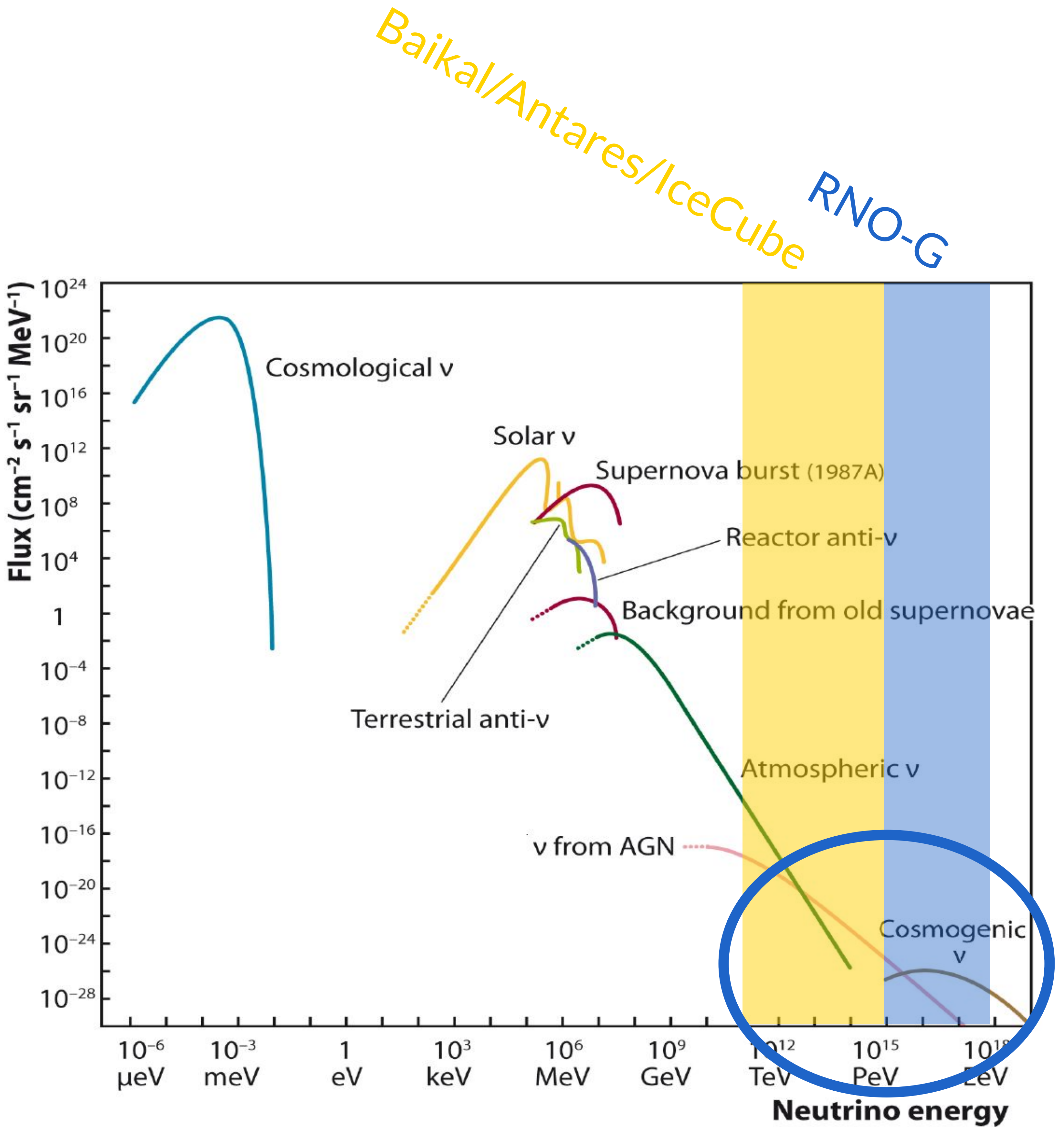
Radio Neutrino Observatory

GHENT UNIVERSITY

RNO-G
Radio Neutrino Observatory - Greenland

A whole range of neutrino energies

Look at very high energies!

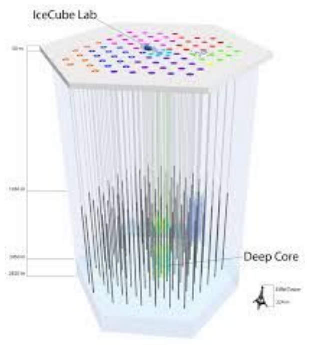


Detecting UHE neutrinos is a challenge

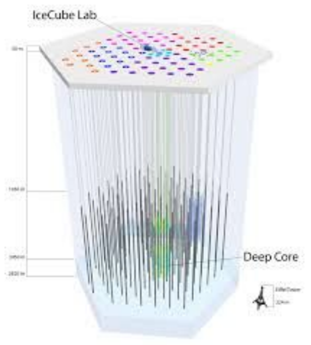
Interact rarely

Extreem low flux

⇒ 10 neutrinos:

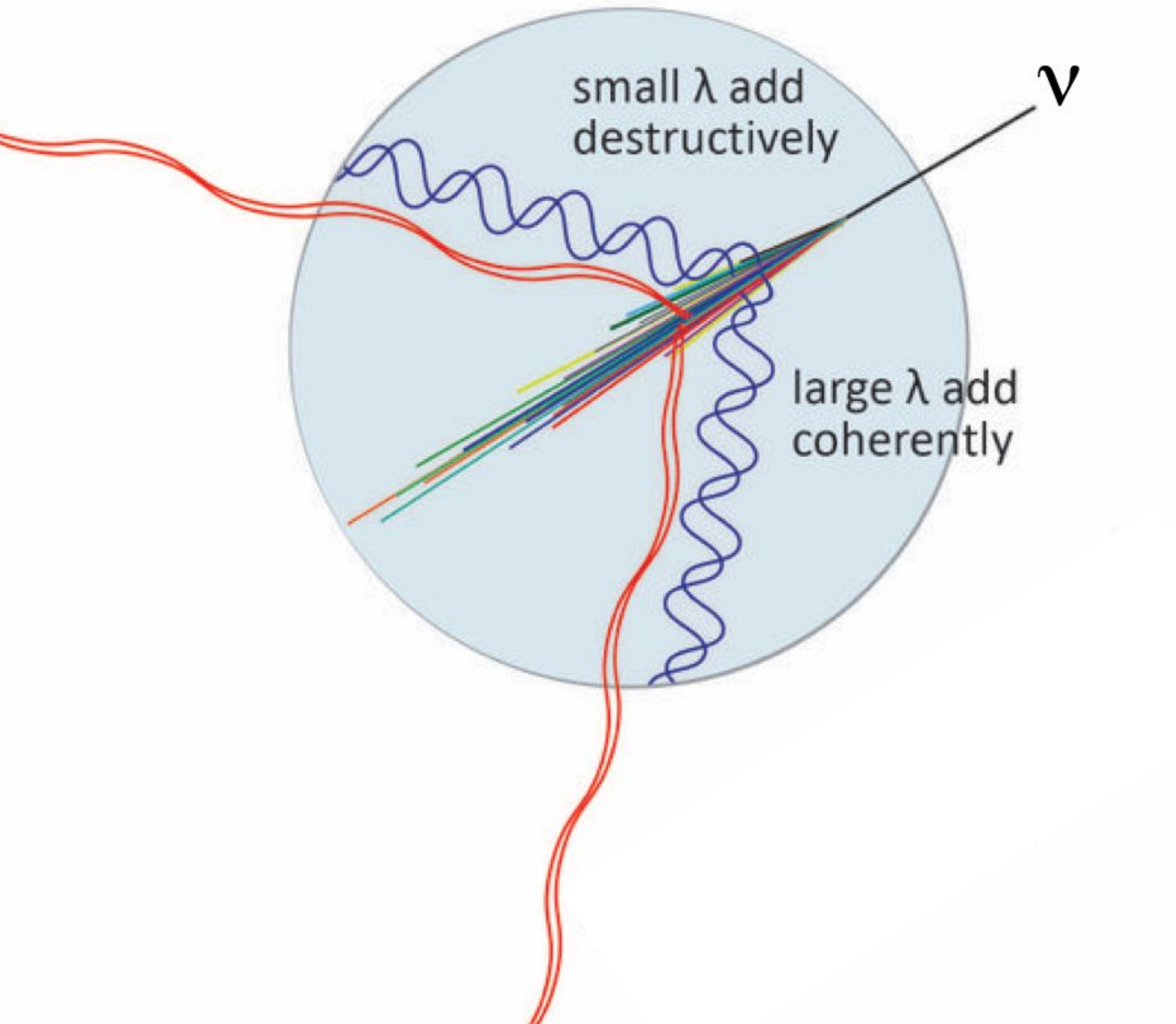


OR



X 100

The **Askaryan** Effect



⇒ λ << size: destructive interference

⇒ λ >> size: constructive interference

= **Askaryan Effect**

That's why we **use radio**!

Absorption lengths polar ice:

- $\lambda \sim 400$ nm (optical) $\rightarrow \sim 200$ m
- $\lambda \sim 1.00$ m (radio) $\rightarrow \sim 1200$ m

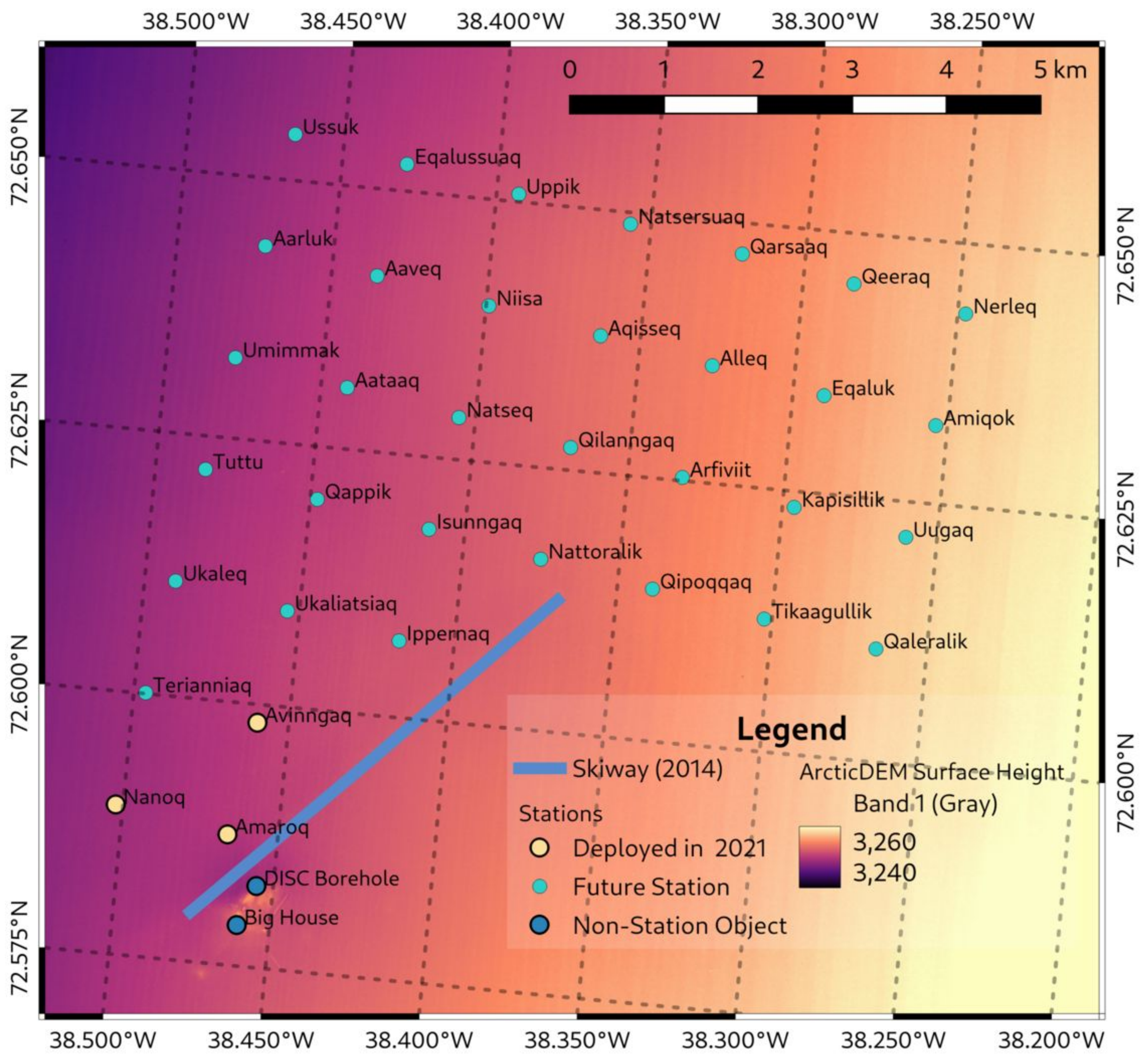
Energy > 1 PeV $\rightarrow$ lower flux $\rightarrow$ need of large detection volume

Span a larger volume with same amount of radio detectors then with optical detectors

The RNO-G array

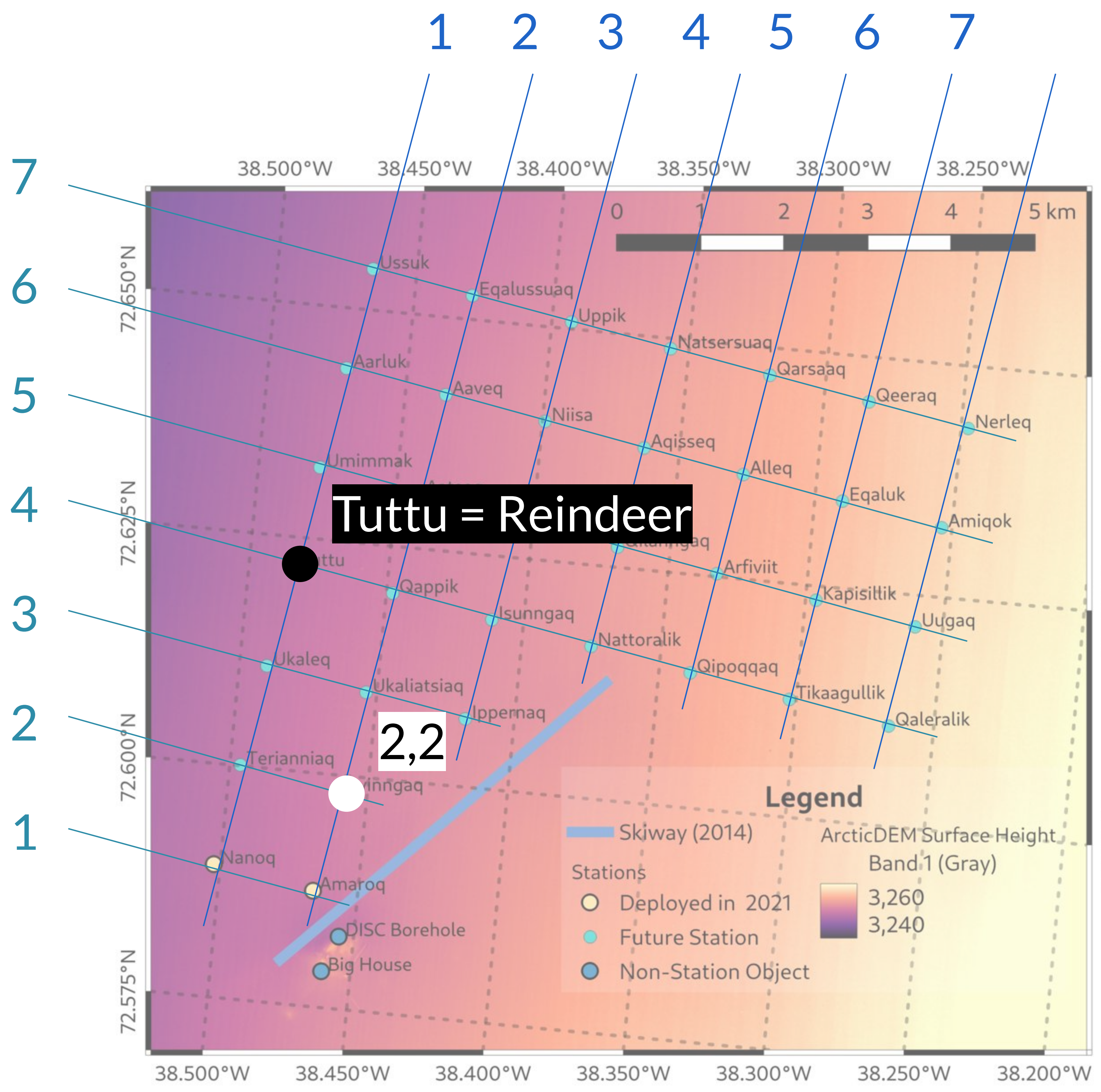
35 autonomous stations:

- LTE comms to Summit Station
- ~10% of data via satellite
- solar/wind powered



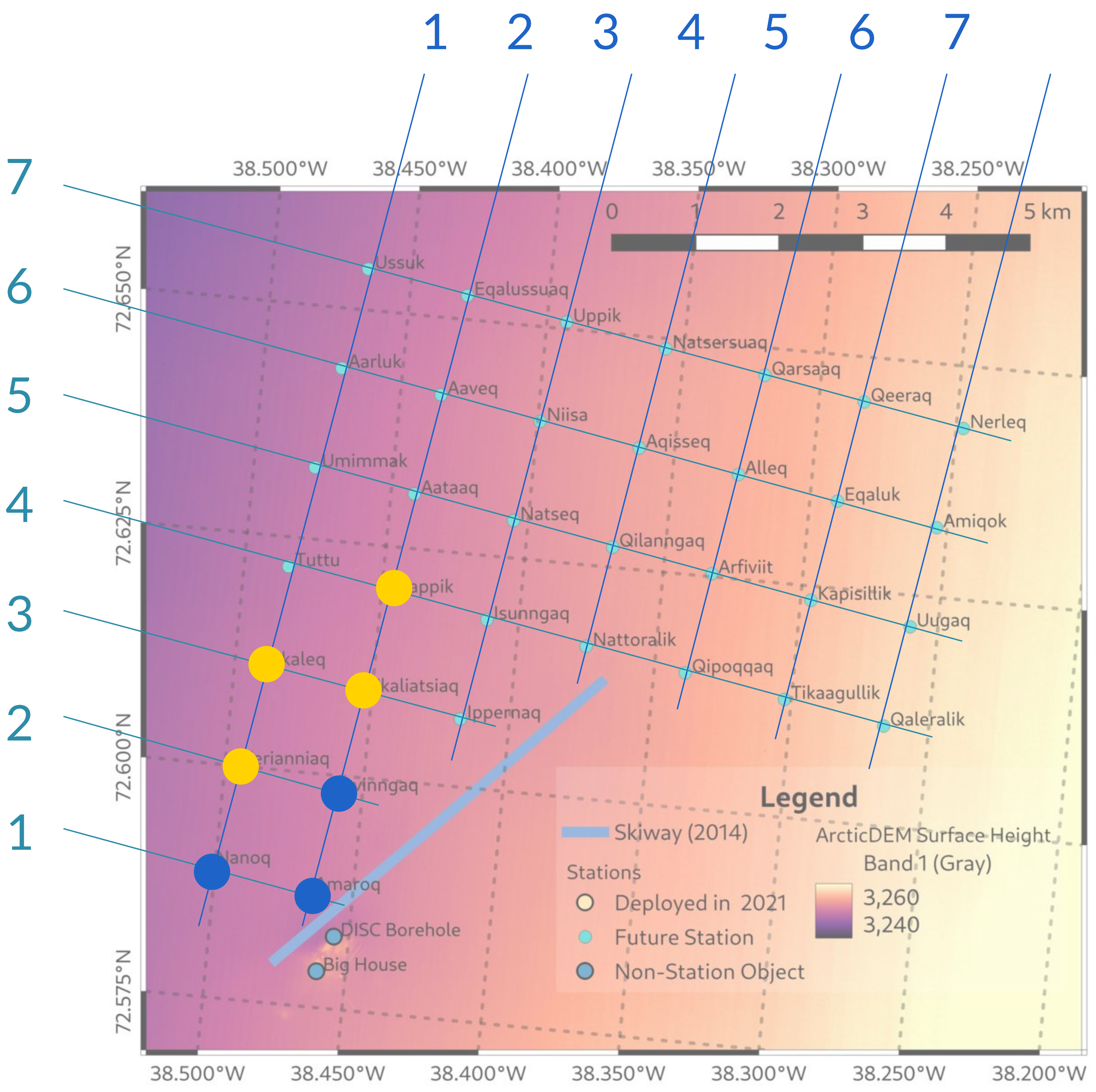
The RNO-G array

Station numbering on a grid



The RNO-G array

We build 3 stations in 2021 …
and 4 more past month



Station design

RNO-G [2010.12279]

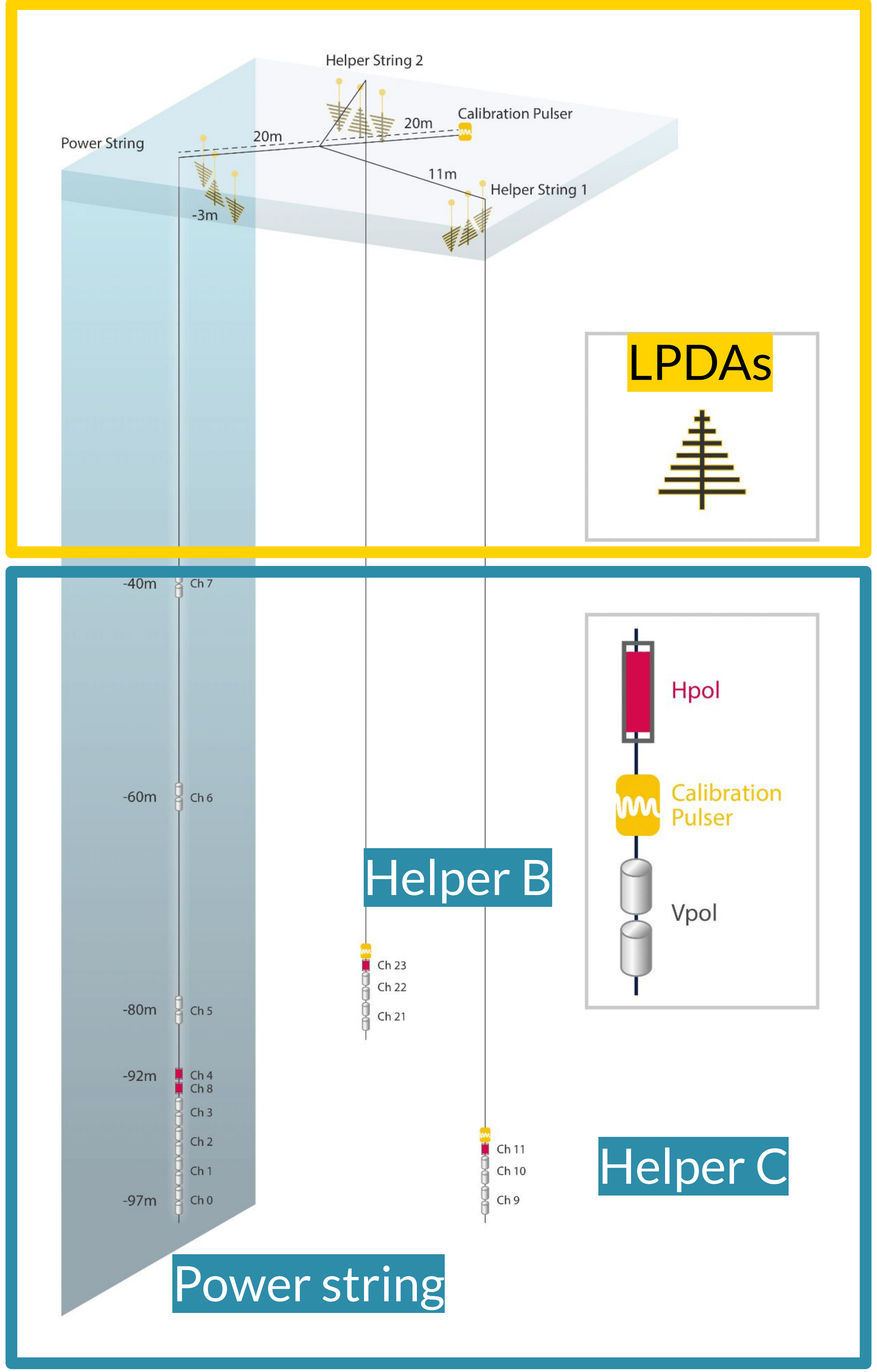
Surface component:

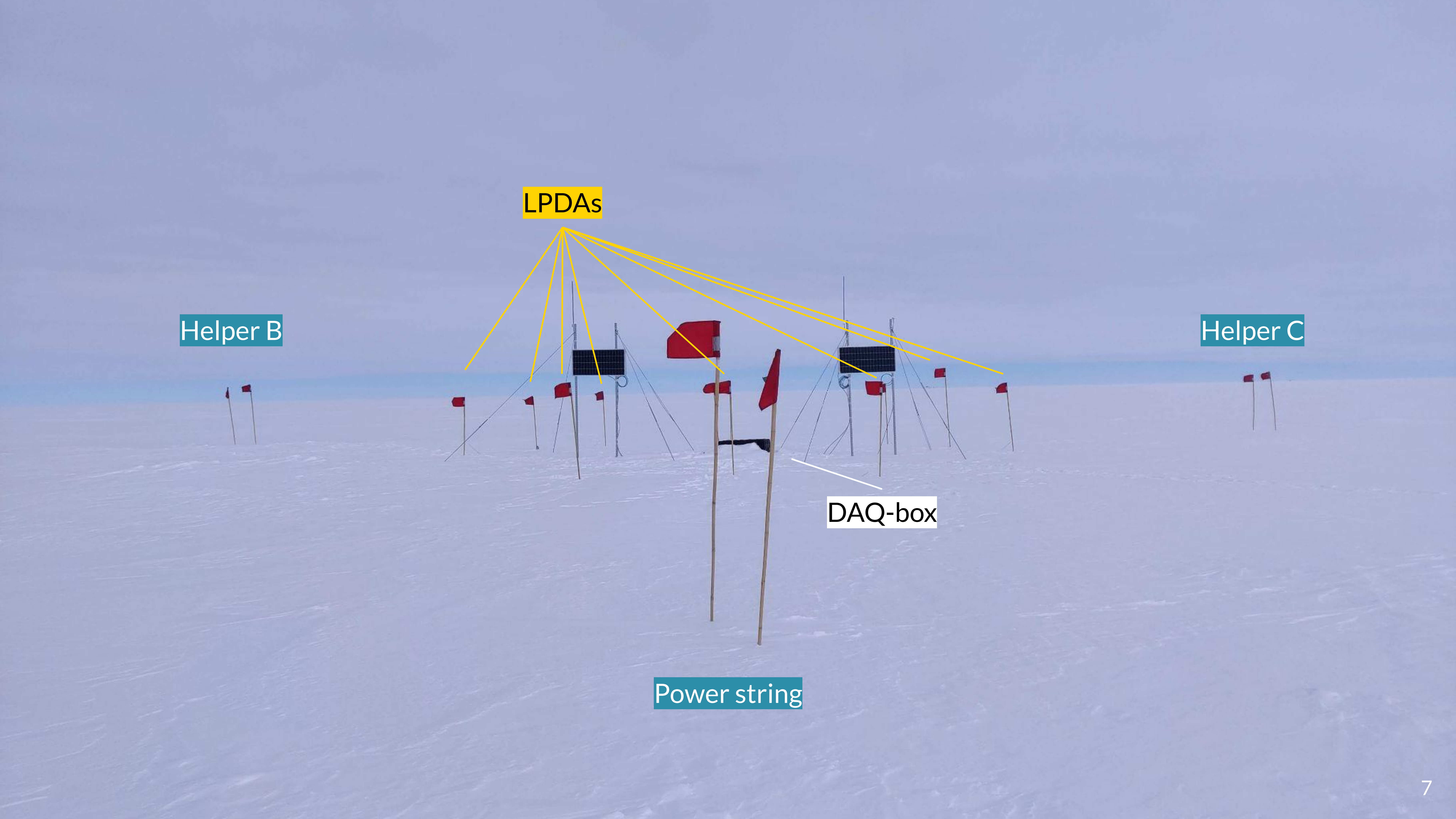
Cosmic rays, veto, **ν** detection,
more channels for reconstruction

Deep component:

Effective volume neutrinos

Designed to be **scalable**
→ Informs array design **IceCube-Gen2**




LPDAs
Helper B
Helper C
DAQ-box
Power string


Johns Manville
POOL SHOCK
PLASTIC BOTTLES

The importance of ice & the need for numerical ray tracing

GHENT UNIVERSITY

RNO-G
Radio Neutrino Observatory - Greenland

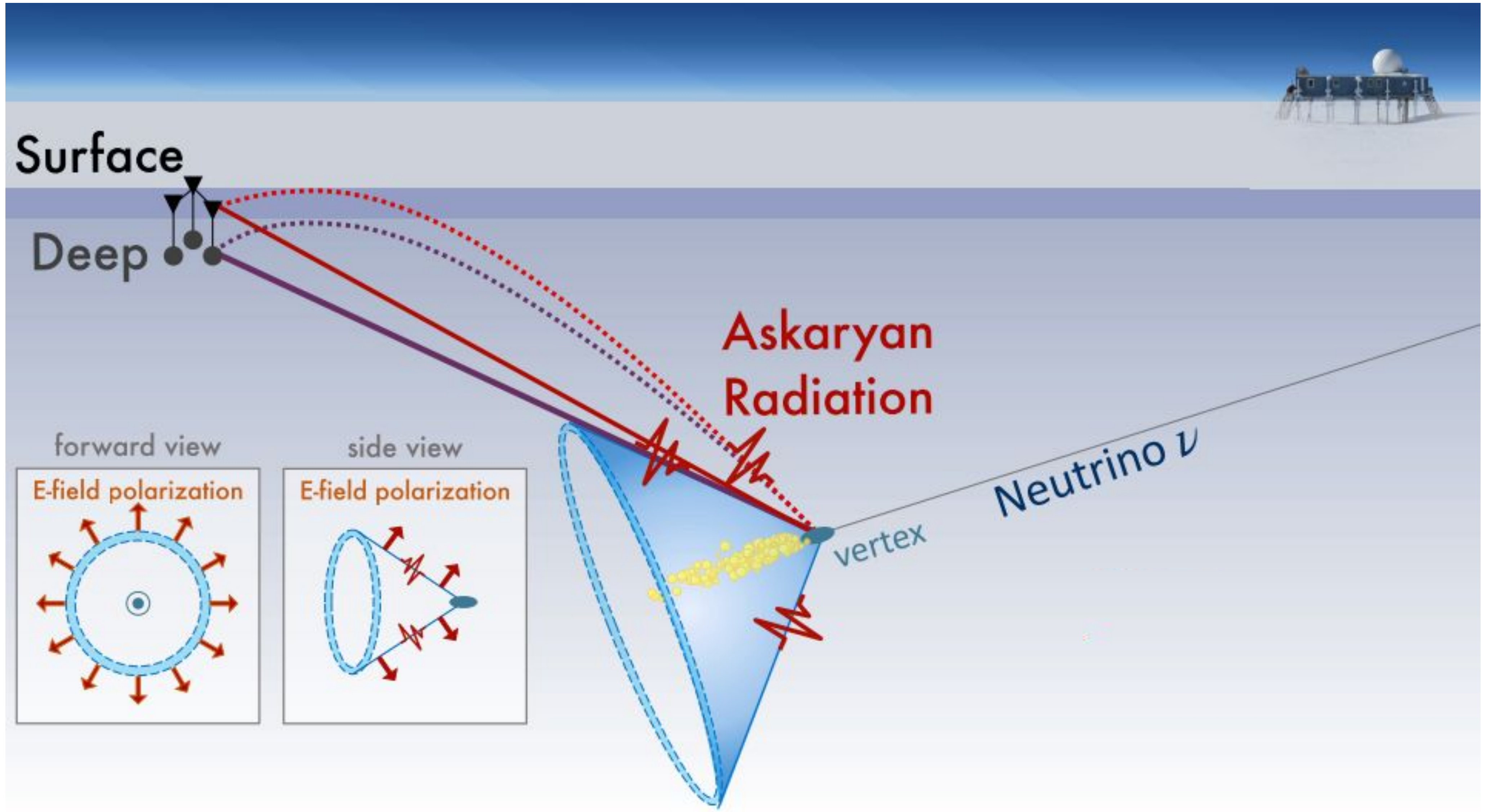
Reconstruction relies on ice & antenna position

Reconstruction uses paths of radio rays

⬇

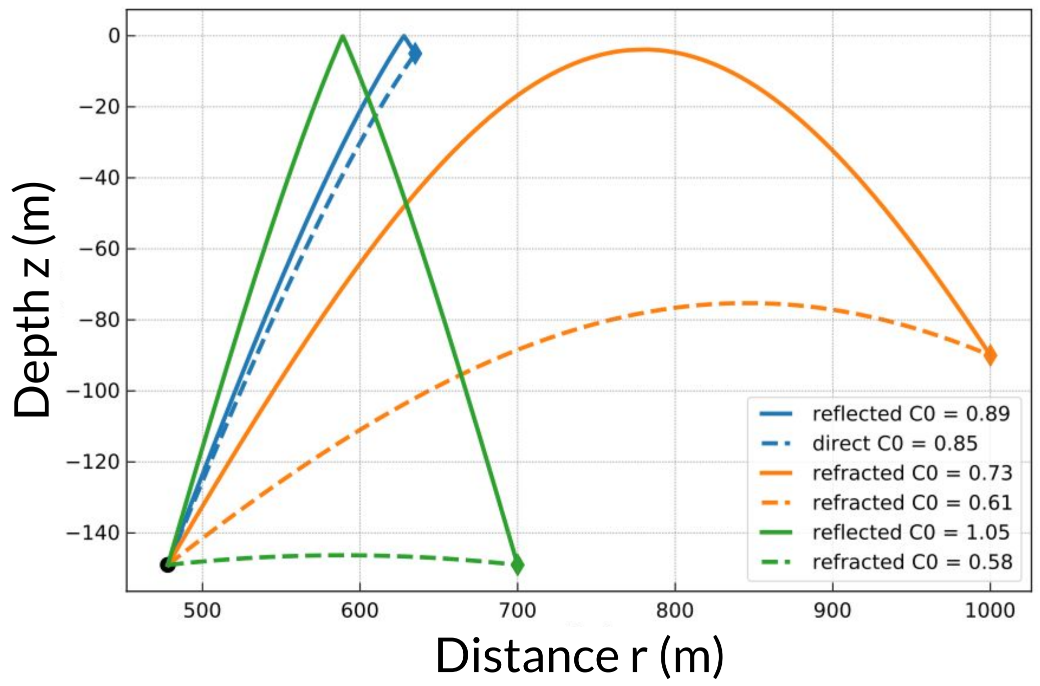
Ray paths influences by:

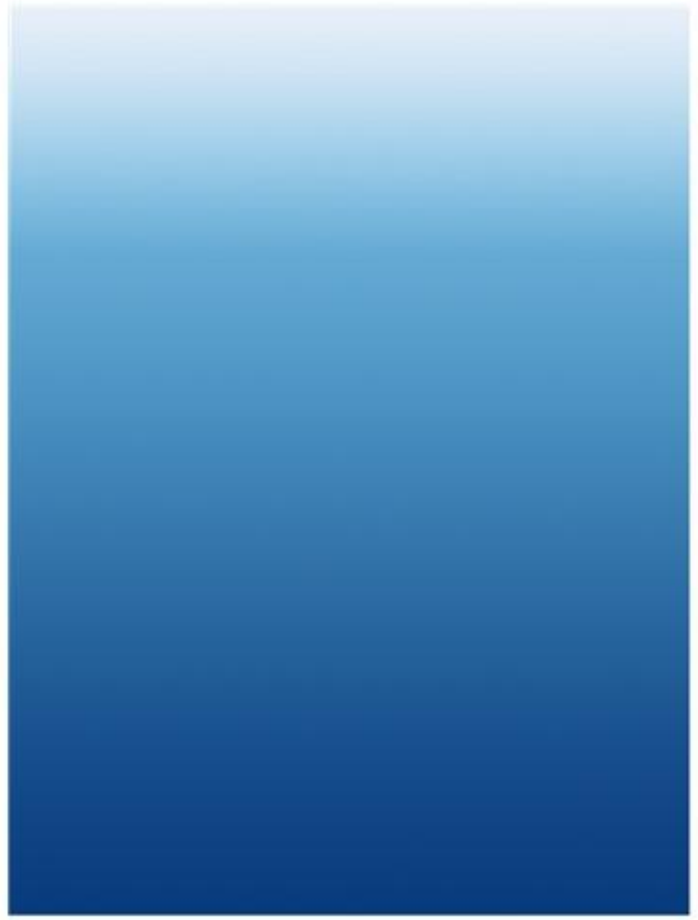
- Refractive index ice
- Position of antenna



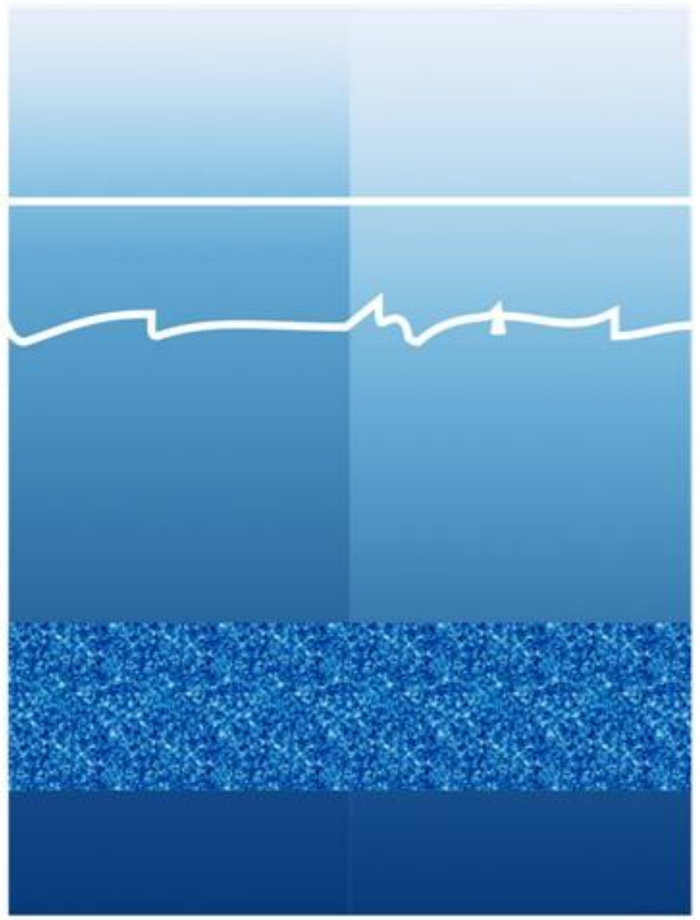
Glacier ice can be very **complex in reality**

Analytical tracer solves **only exponential** ice models





Single exponential

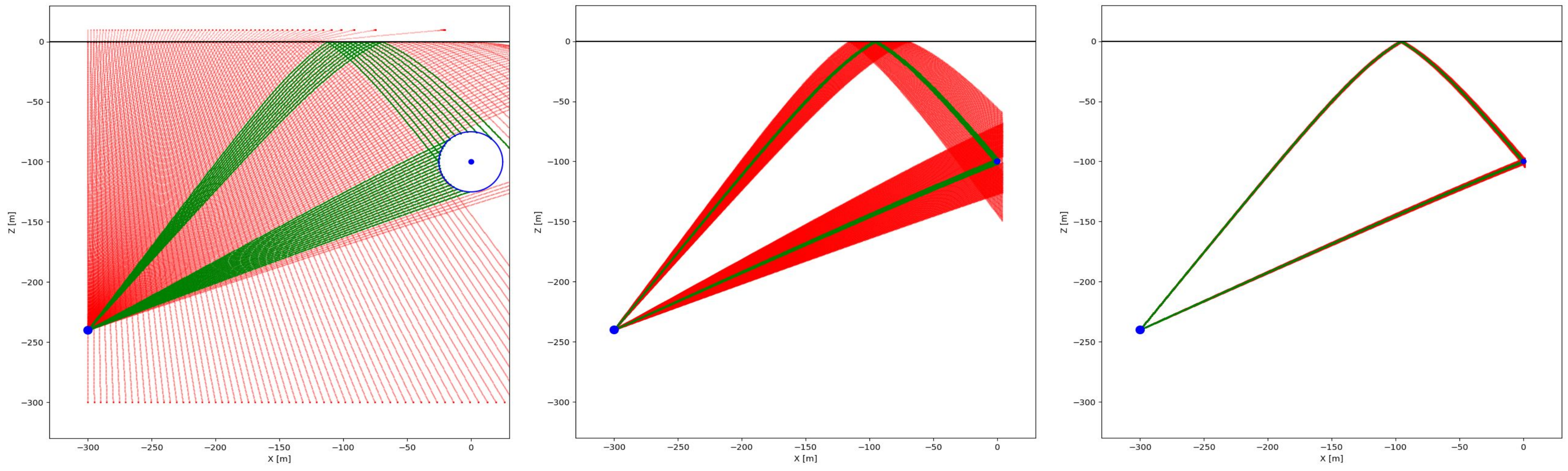


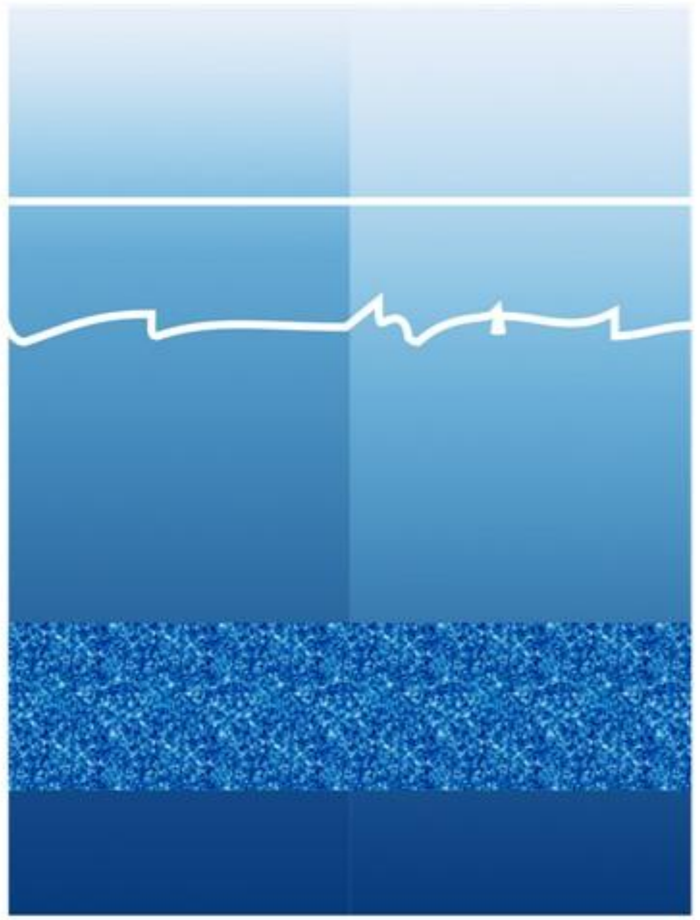
Complex ice features

NuRadioMC [1906.01670]

Glacier ice can be very **complex in reality**

RadioPropa traces ray path by **iterative scanning** using paraxial approximation of **Eikonal equations**



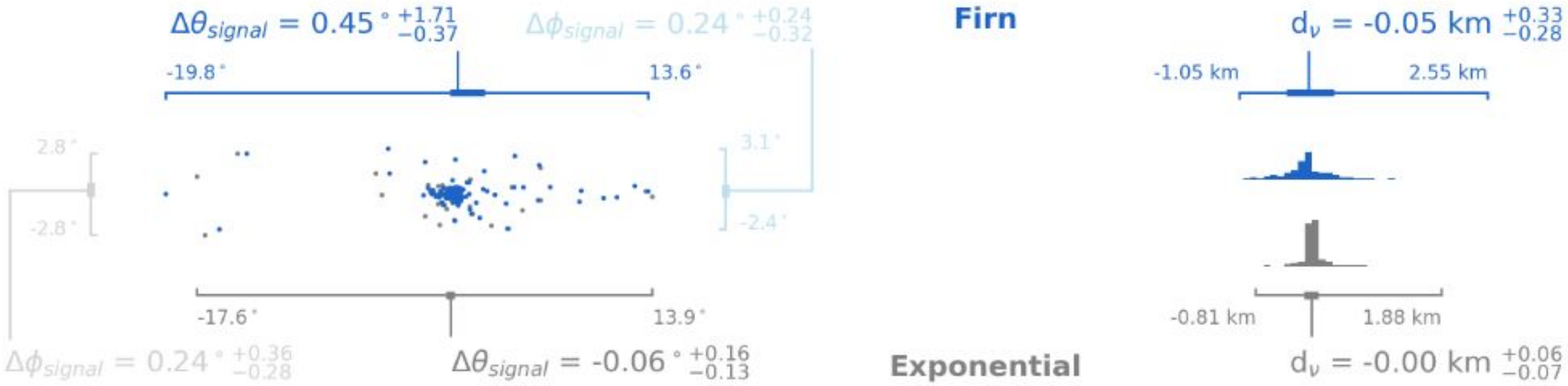


Complex ice features

RadioPropa [1810.01780] & Contribution ICRC 2021

Firn model has effect on reconstruction

Contribution ICRC 2021



Pulser reconstruction & station calibration

GHENT UNIVERSITY

RNO-G
Radio Neutrino Observatory - Greenland

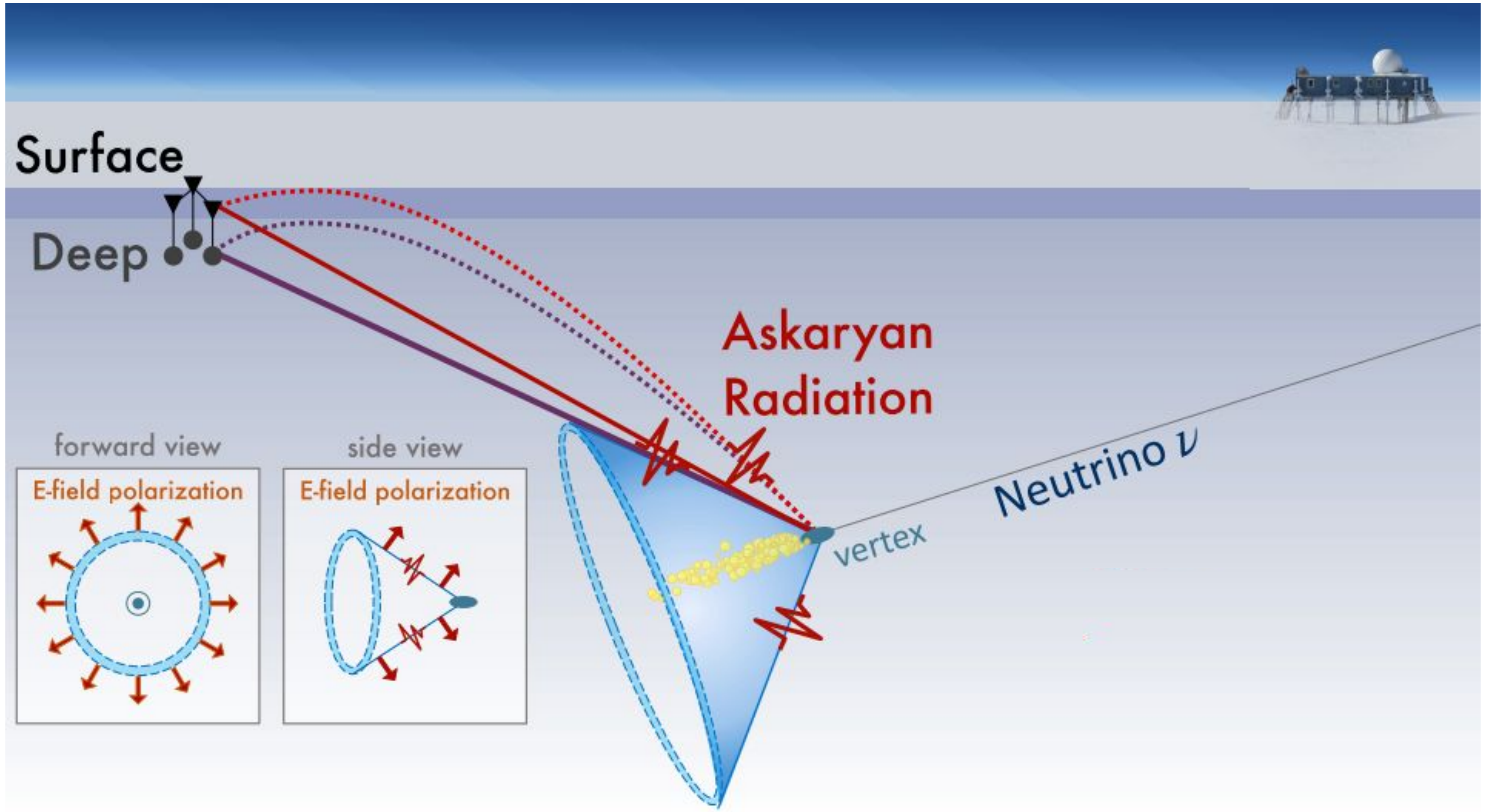
Reconstruction relies on ice & antenna position

Reconstruction uses paths of radio rays

⬇

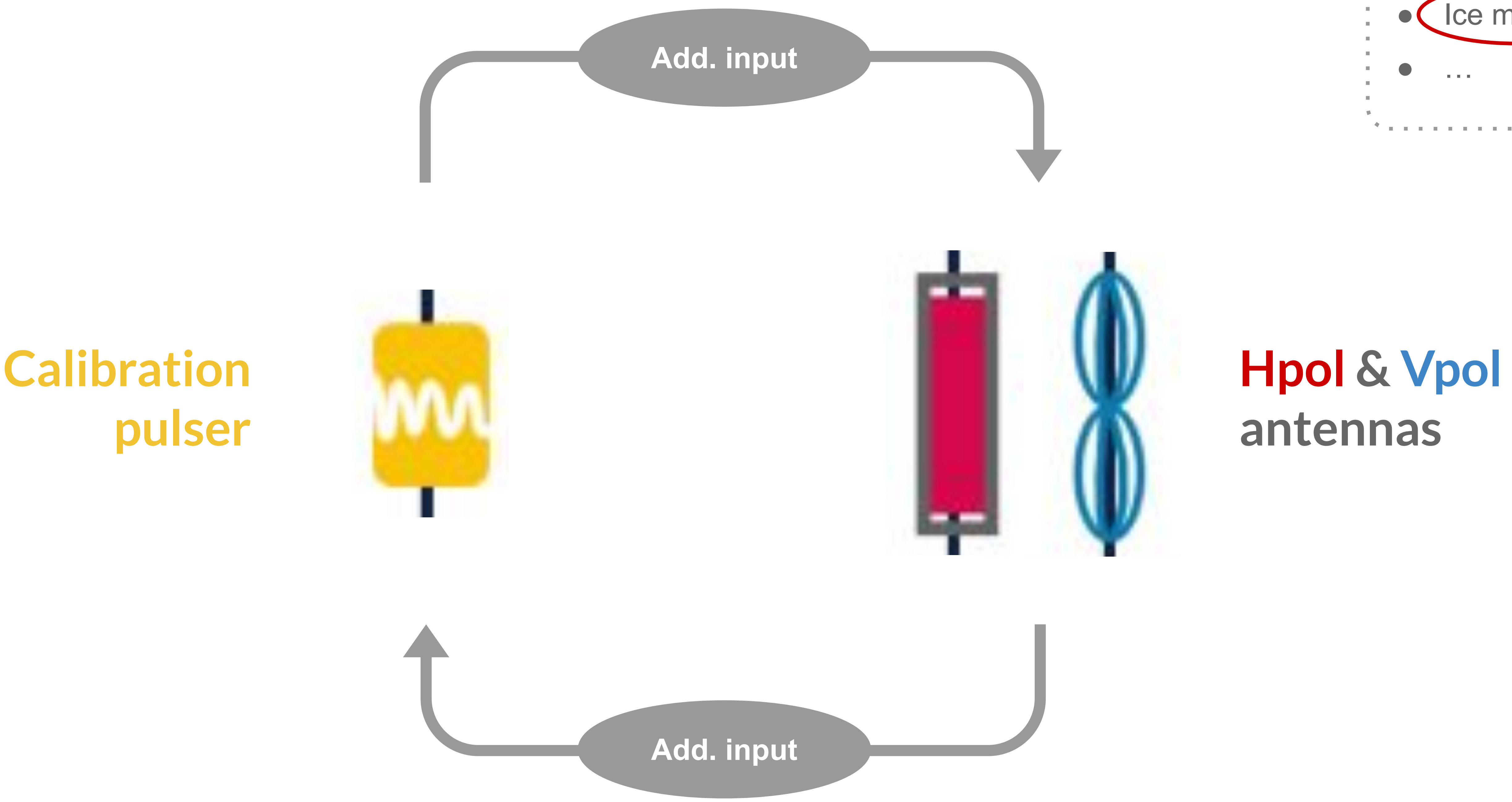
Ray paths influences by:

- Refractive index ice
- Position of antenna

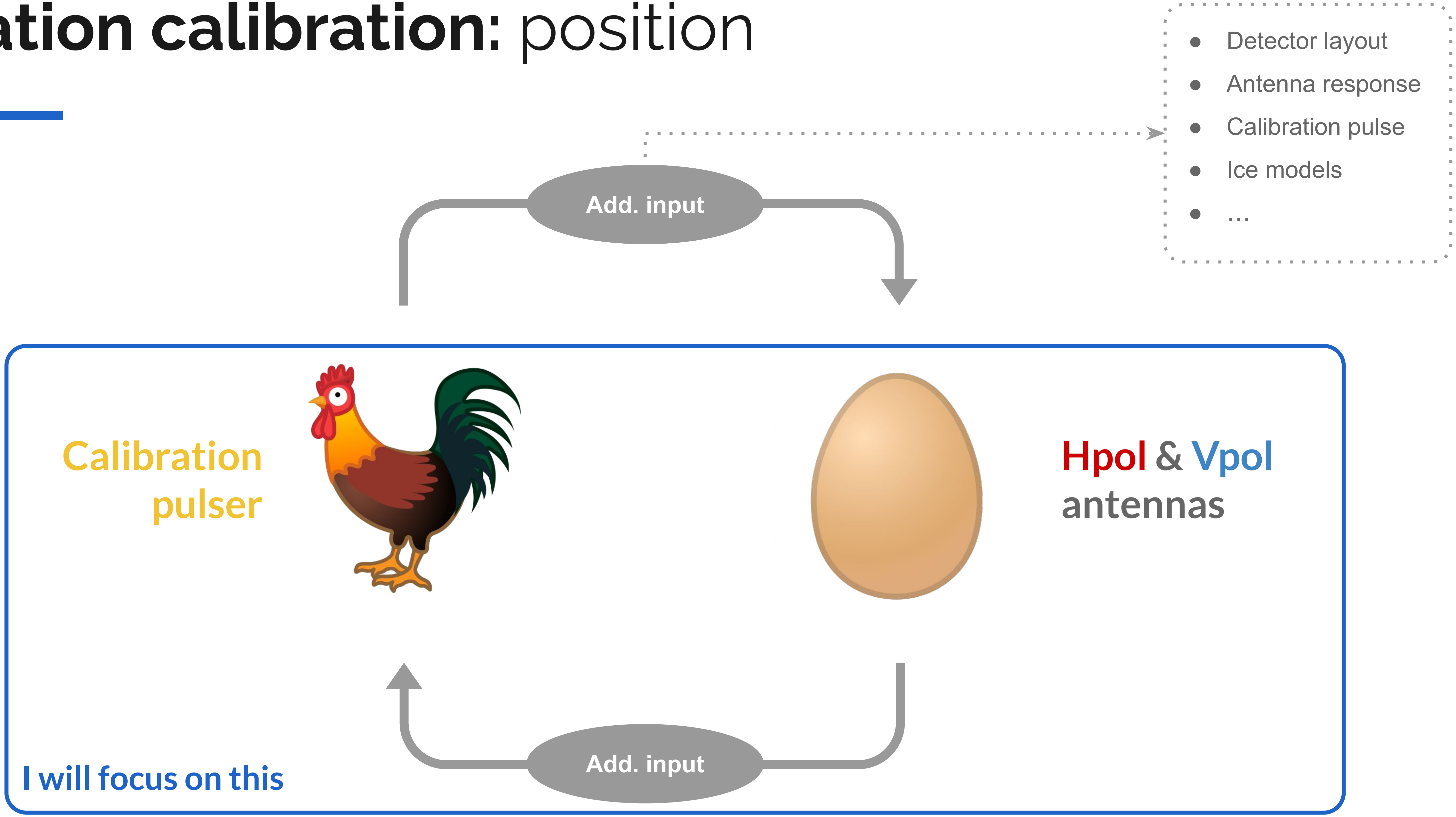


Station calibration: position

- Detector layout
- Antenna response
- Calibration pulse
- Ice models
- …



Station calibration: position



Pulser reconstruction

Ray tracing takes to long for fitting procedure

↓

Assume direct path ≈ spherical waves

↓

Relative timing channel pairs

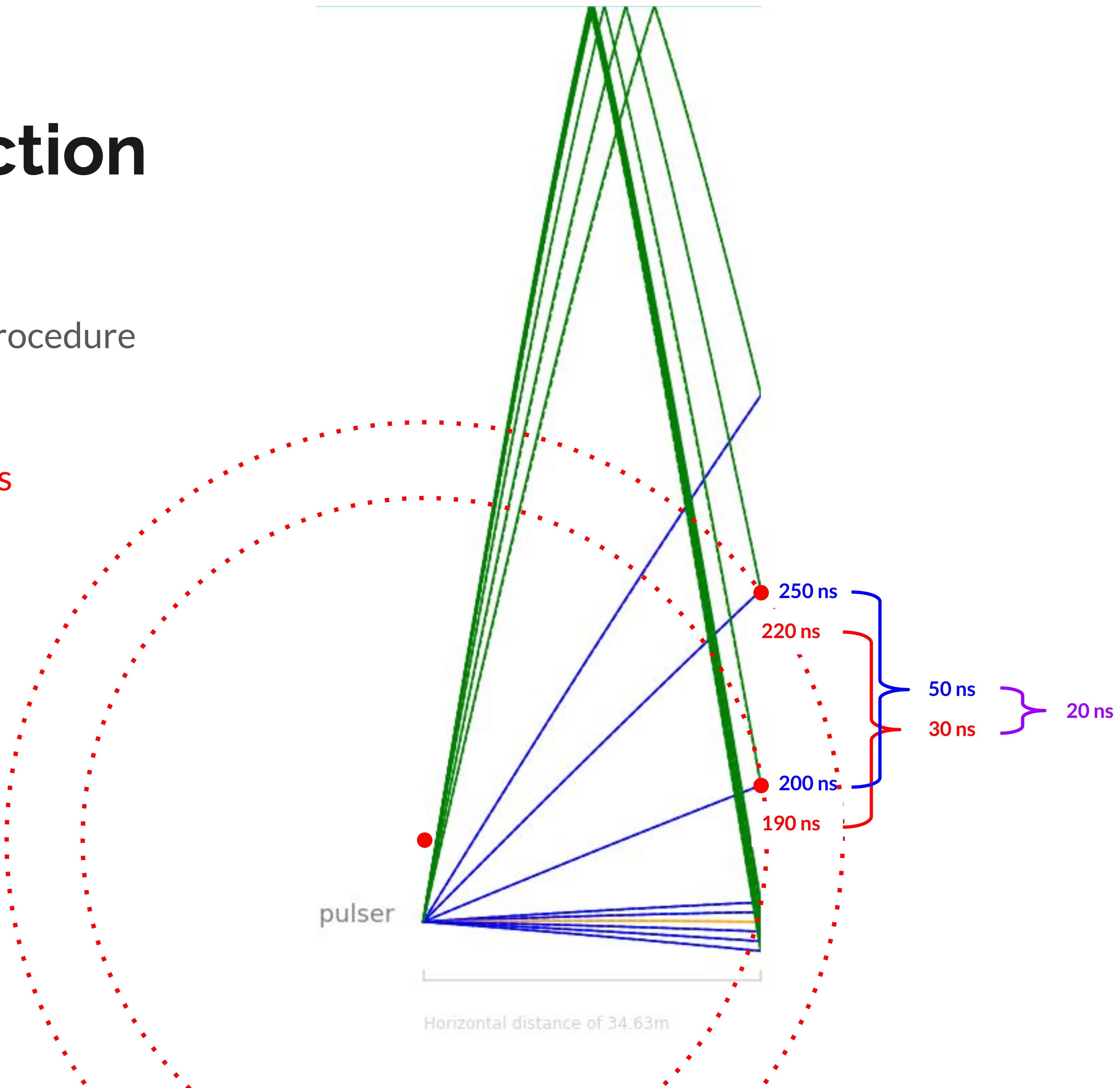
(signal correlation & spherical sim)

↓

Difference between rel. timings

↓

Minimize this difference



Pulser reconstruction

Ray tracing takes to long for fitting procedure

↓

Assume direct path ≈ spherical waves

↓

Relative timing channel pairs

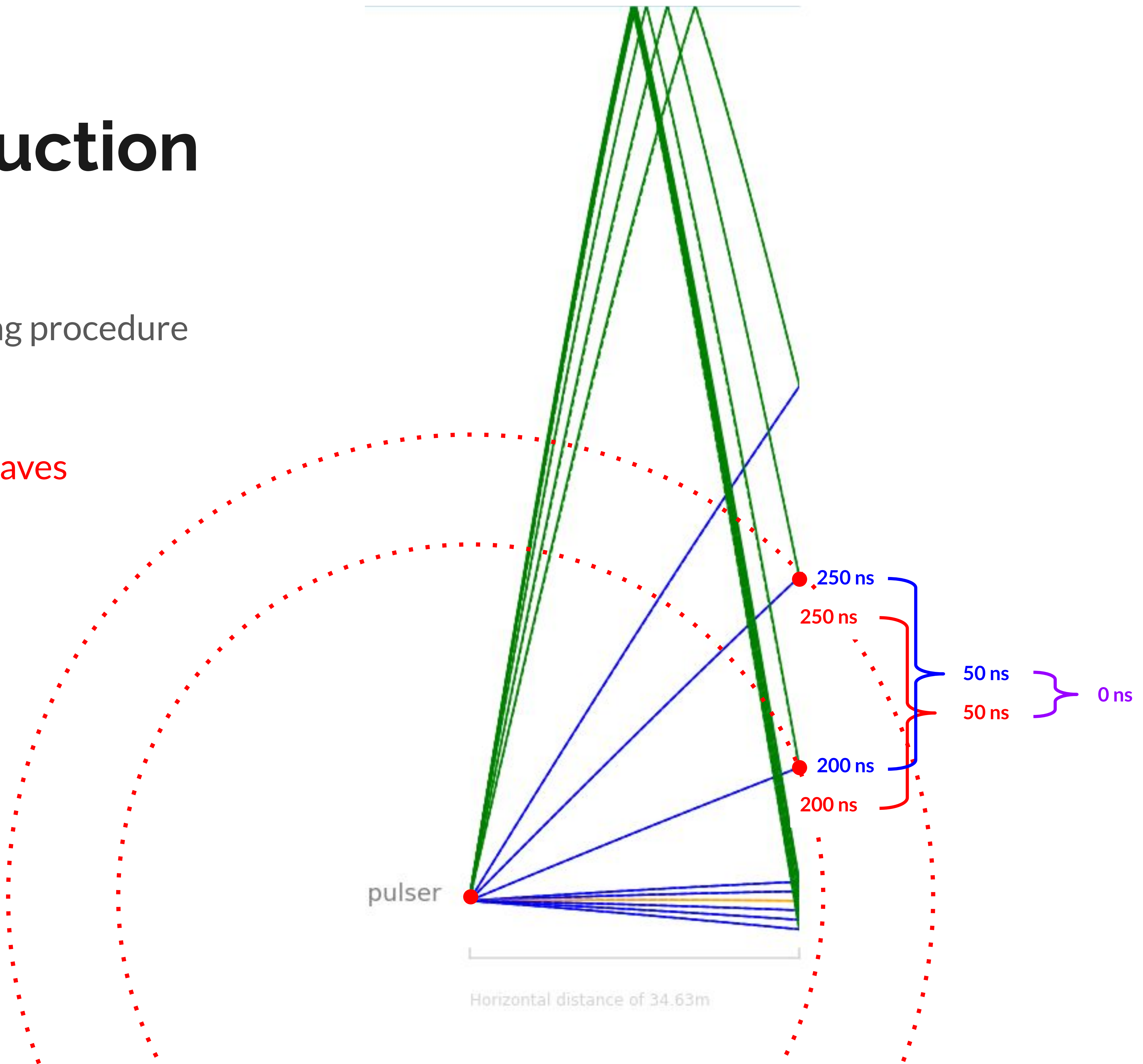
(signal correlation & spherical sim)

↓

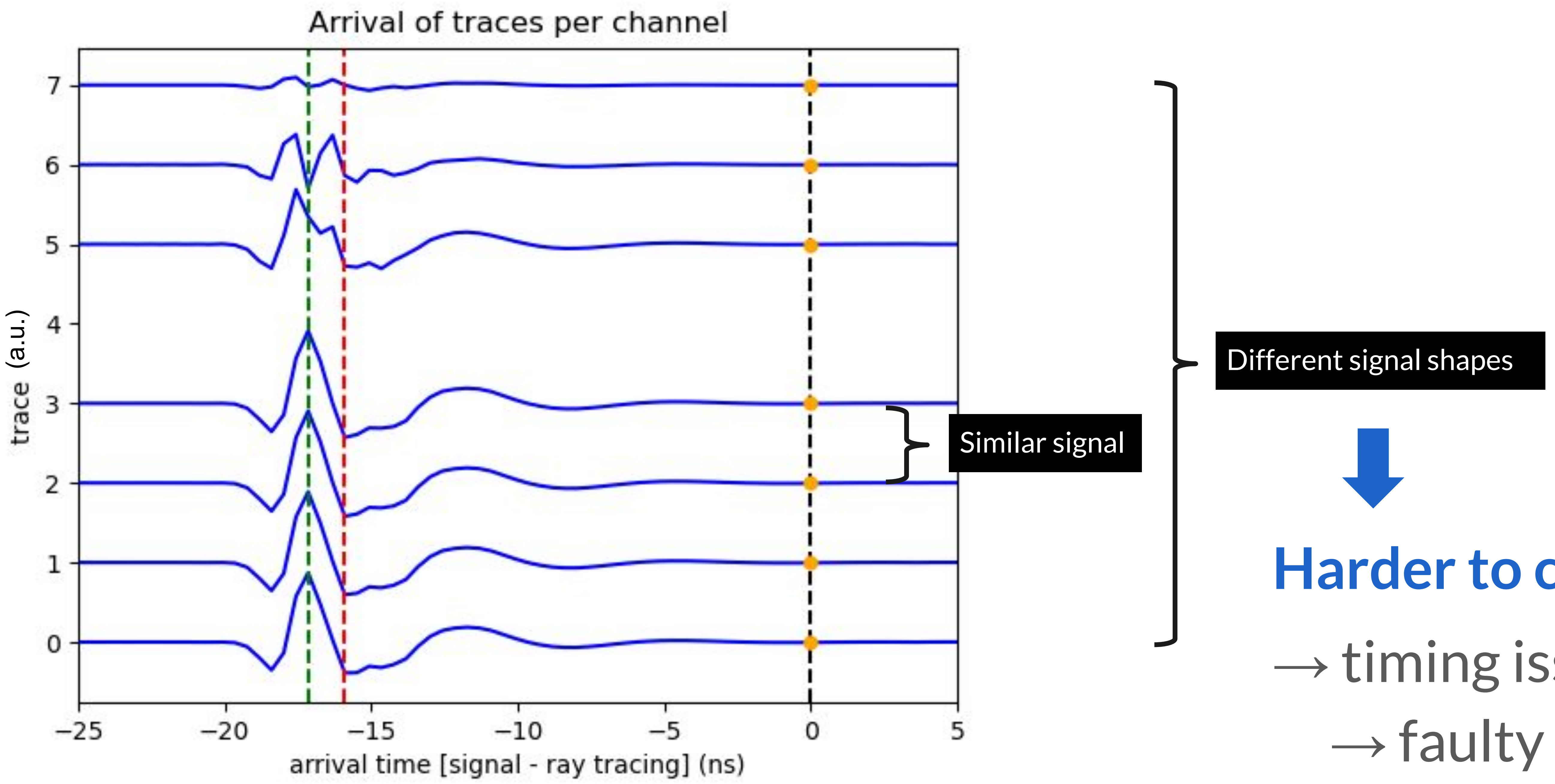
Difference between rel. timings

↓

Minimize this difference



Relative timing by **signal cross correlation** (sim)



Harder to correlate

→ timing issues

→ faulty reconstruction

Calibration: an **iterative** procedure

Reconstruct pulser & antennas using relative timing & assuming:

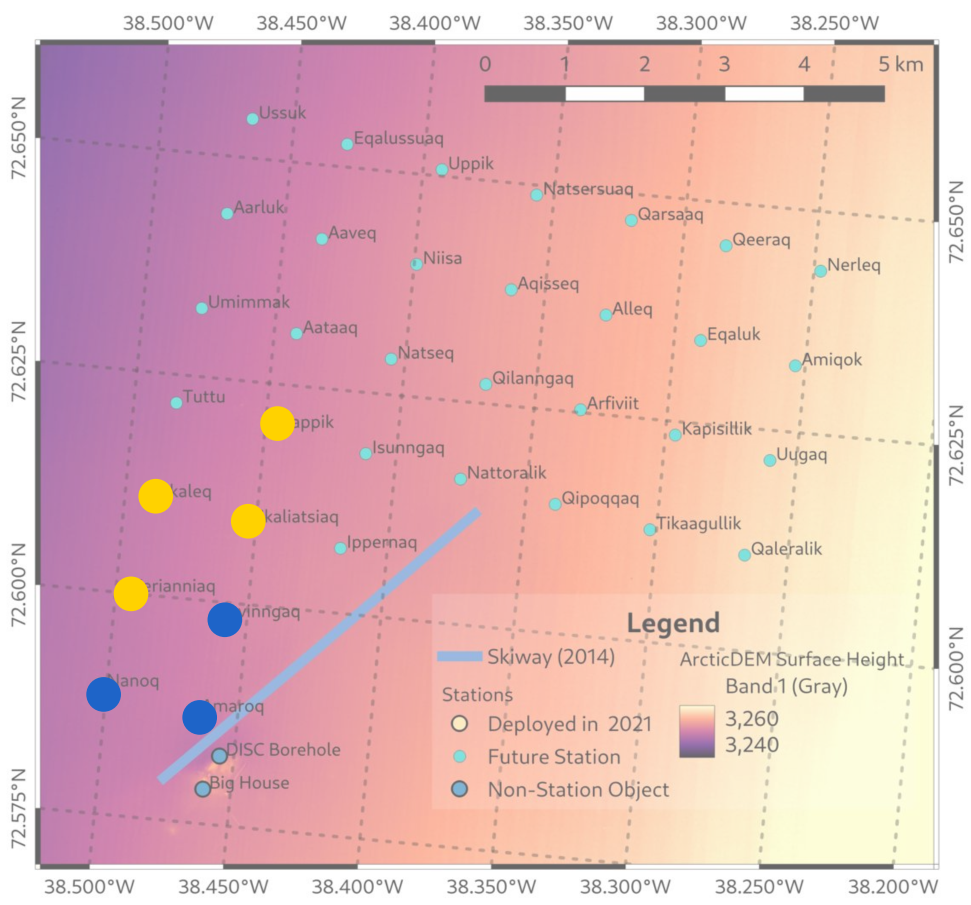
- Certain ice model
- Detector & antenna characteristics (cable delays, respons ...)
- Initial antenna position & constraints
- ...

Use reconstructed antenna position to:

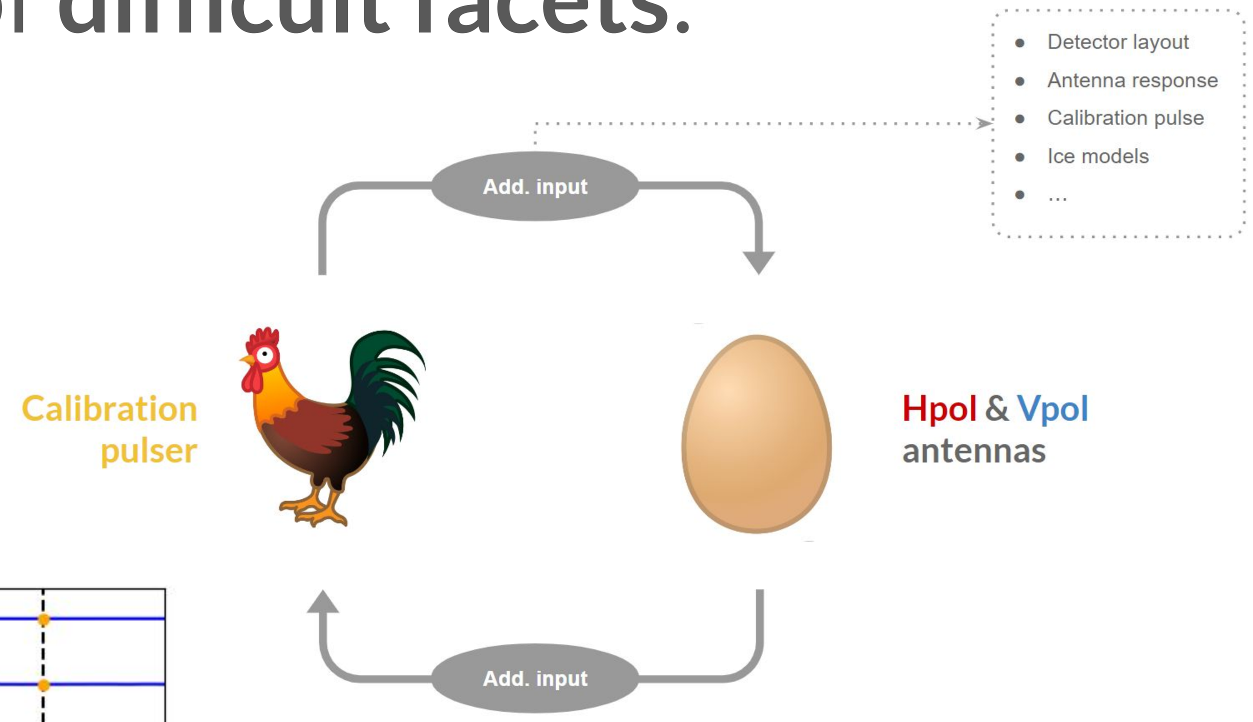
- Refine ice model
- Detector & antenna characteristics

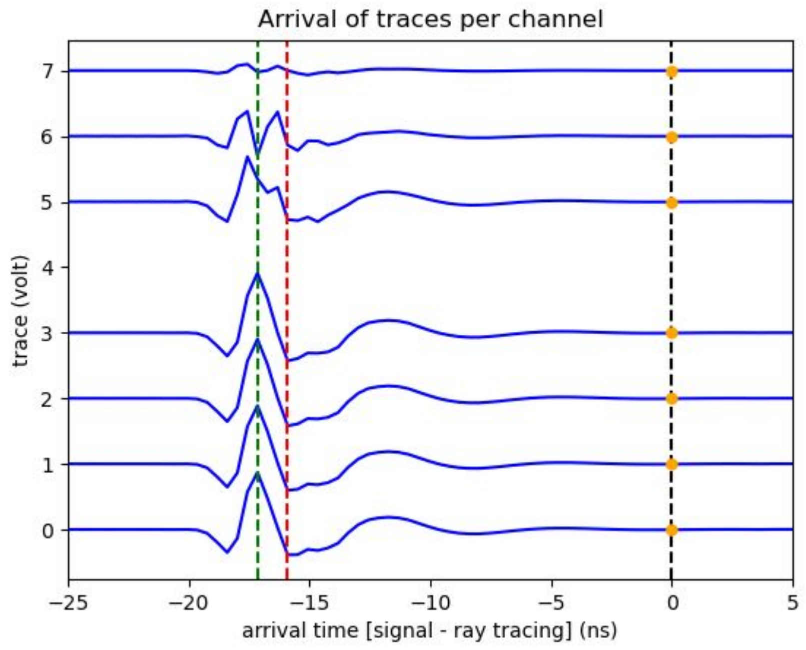
Summary

RNO-G is growing:



Position calibration started
→ lots of **difficult facets:**





12


Thank You!

FACULTY OF SCIENCES

Bob Oeyen

PhD student Physics & Astronomy
Experimental Particle Physics - Ghent University

Bob.Oeyen@UGent.be

GHENT UNIVERSITY

RNO-G
Radio Neutrino Observatory - Greenland