

Radar echo signals in the RET-CR experiment

NBI Neutrino Summer School

Isha Loudon, on behalf of the Radar Echo Telescope
collaboration

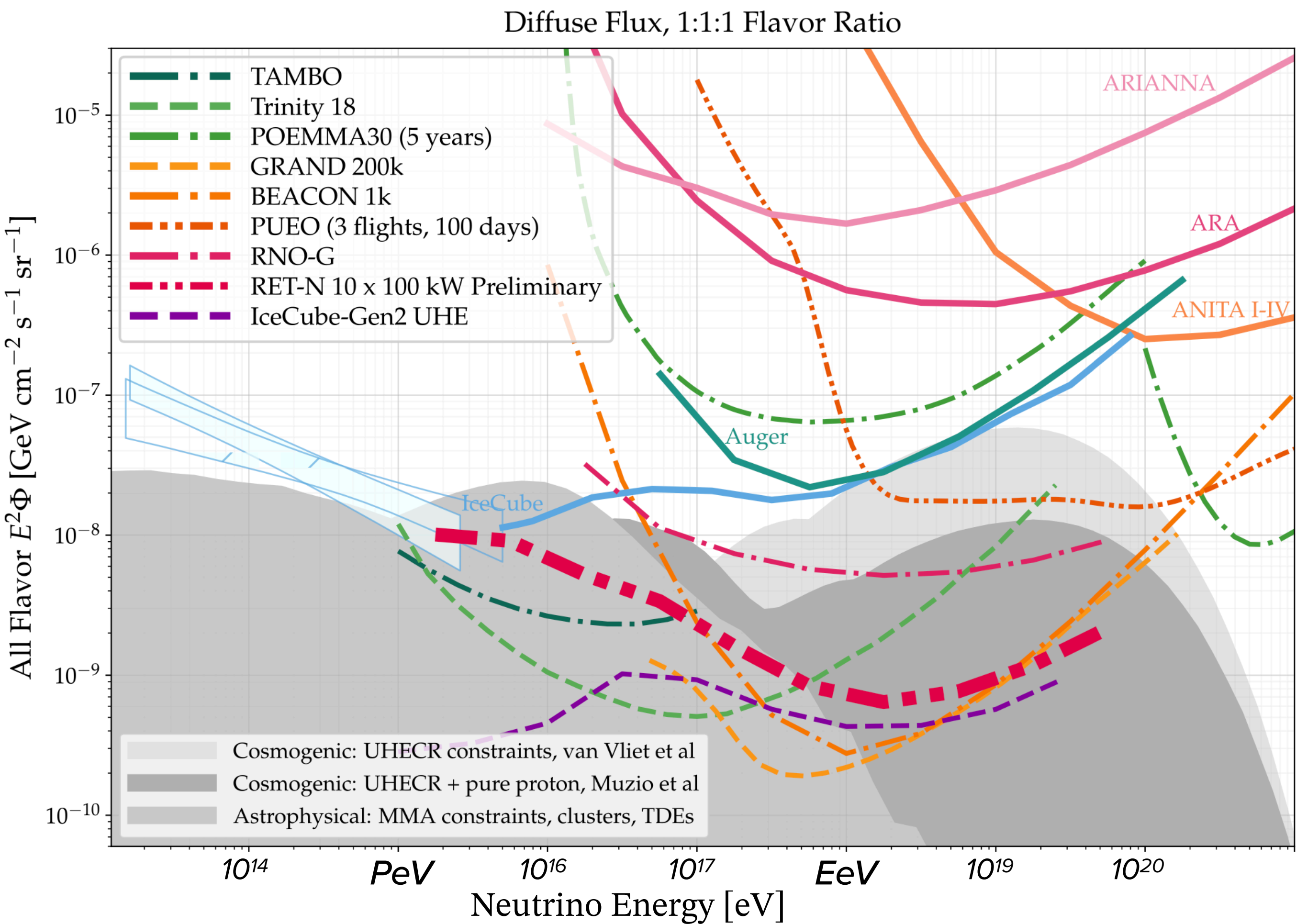
10/07/25

Picture credit: D. Frikken

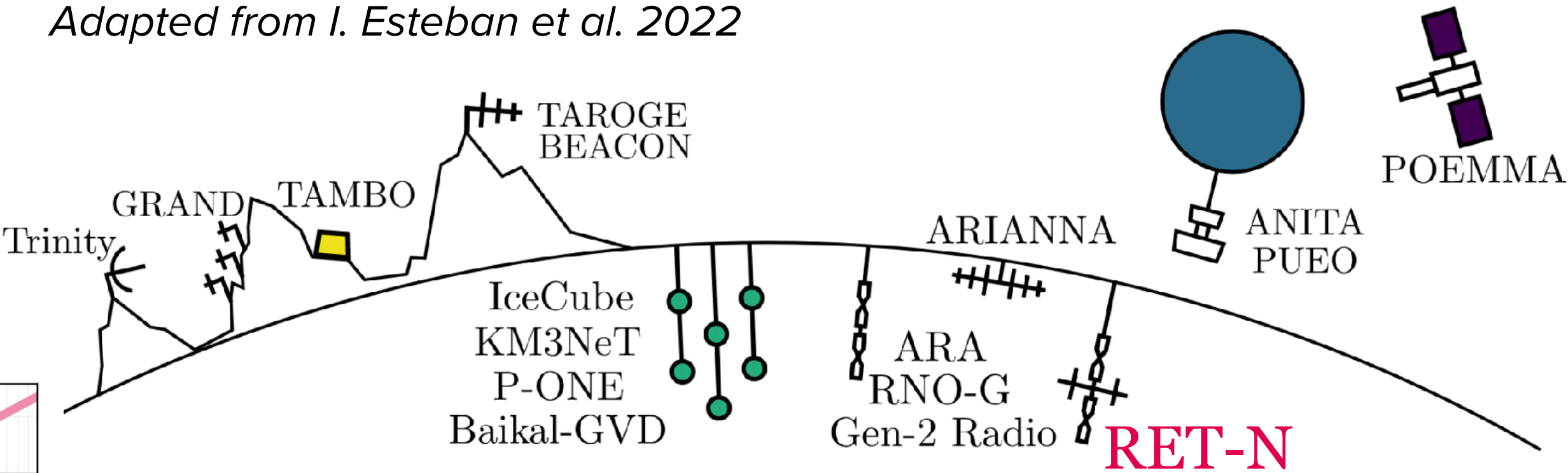


RET-N Neutrino Telescope

→ Aiming to detect **UHE** cosmic neutrinos



Adapted from I. Esteban et al. 2022



- Looking to bridge neutrino flux sensitivity between **PeV - EeV** energies
- Scalable concept, can act as a complementary detection mechanism at higher energies

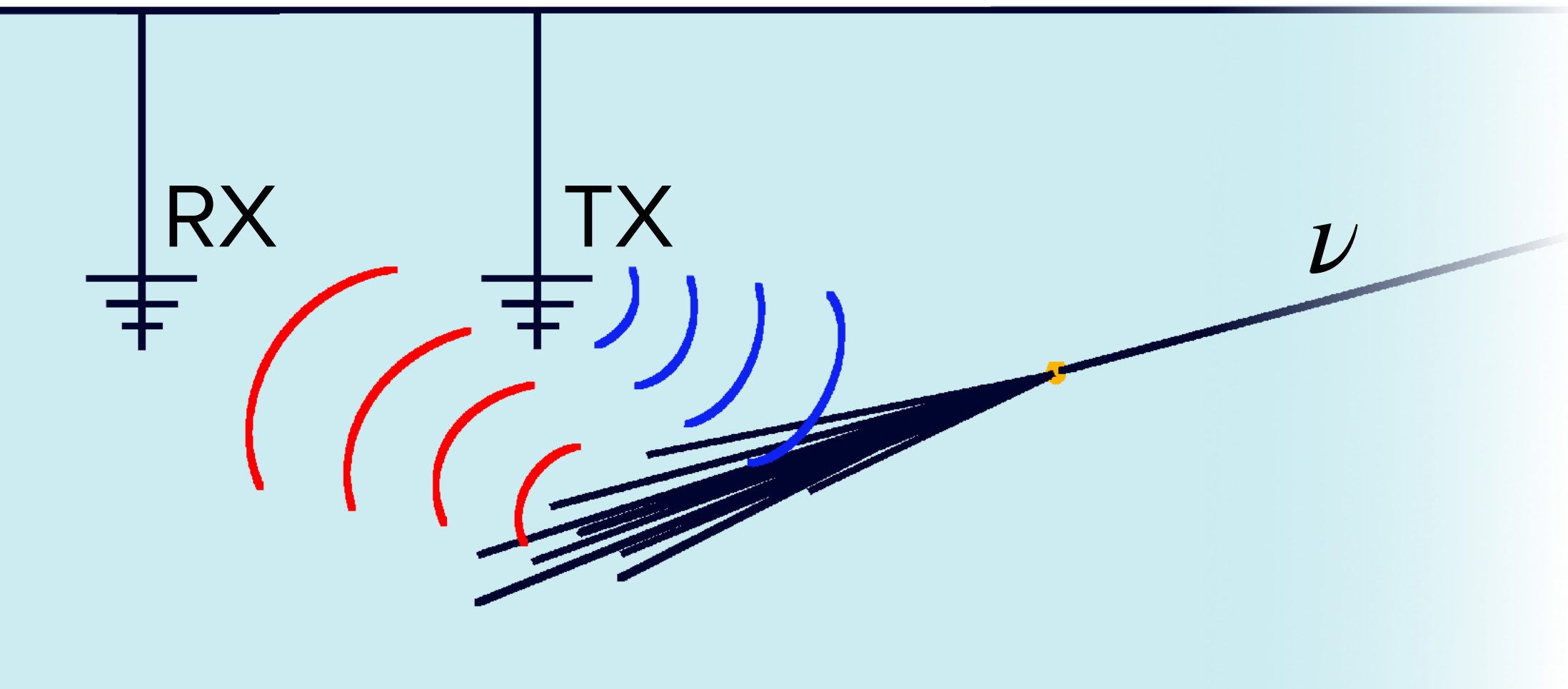
RADAR ECHO TELESCOPE

Adapted from M. Ackermann et al. 2022

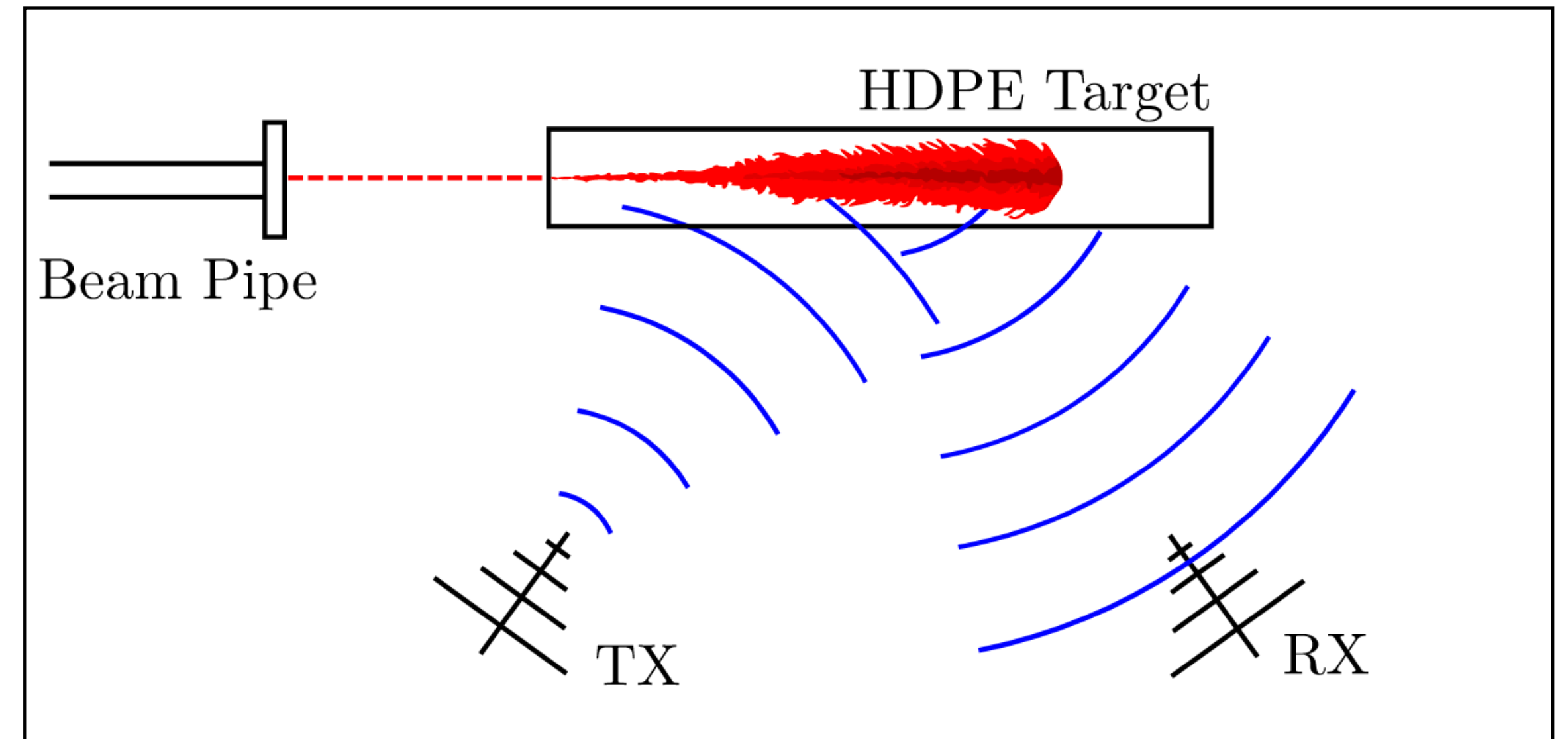
Radar Echo Technique

Using **in-ice radar** to detect neutrino-induced cascades

- Incoming neutrino interacts in ice, produces particle cascade
- Leaves behind **trail of ionisation**, which can reflect incident radio



S. Prohira et al. 2020



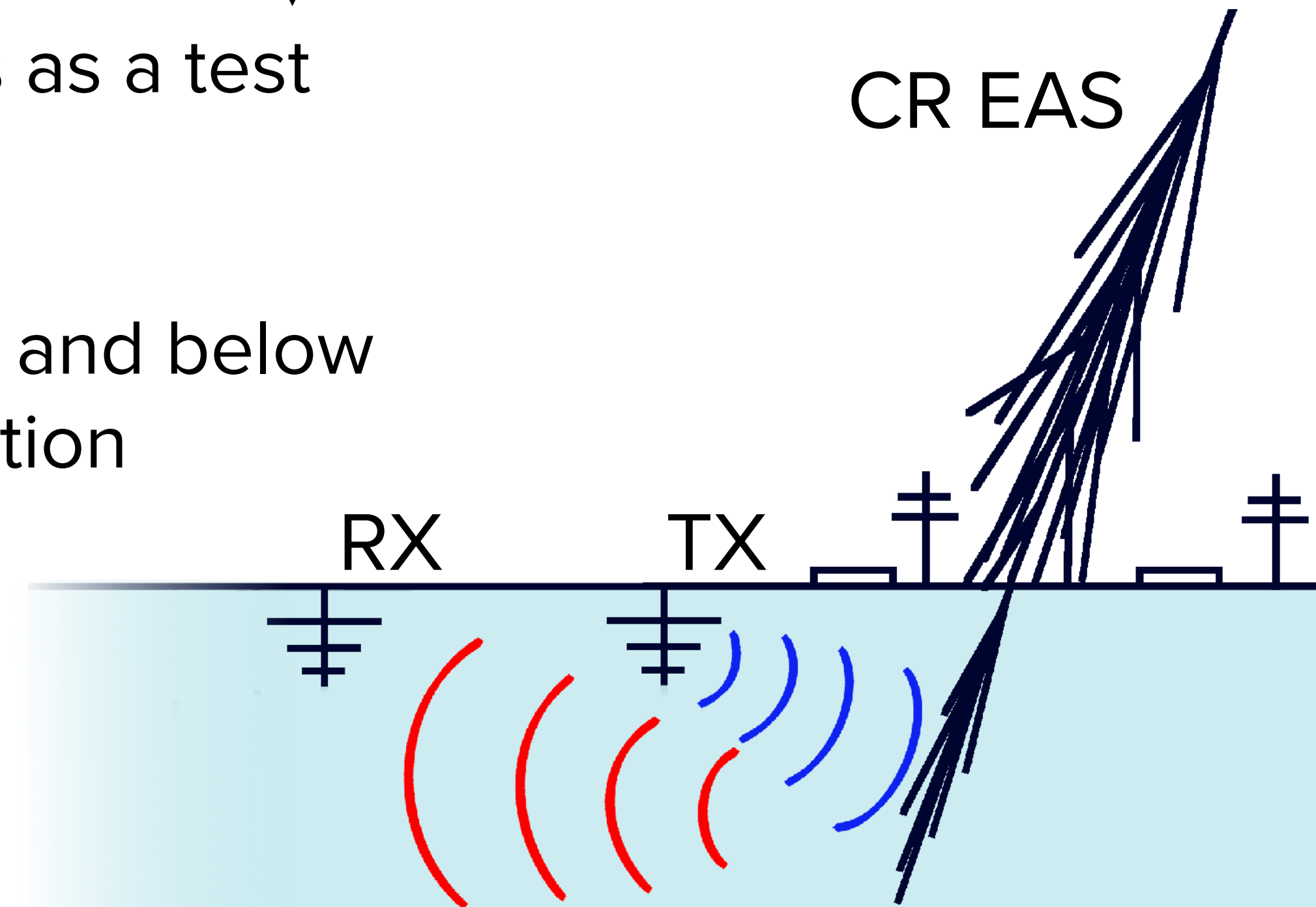
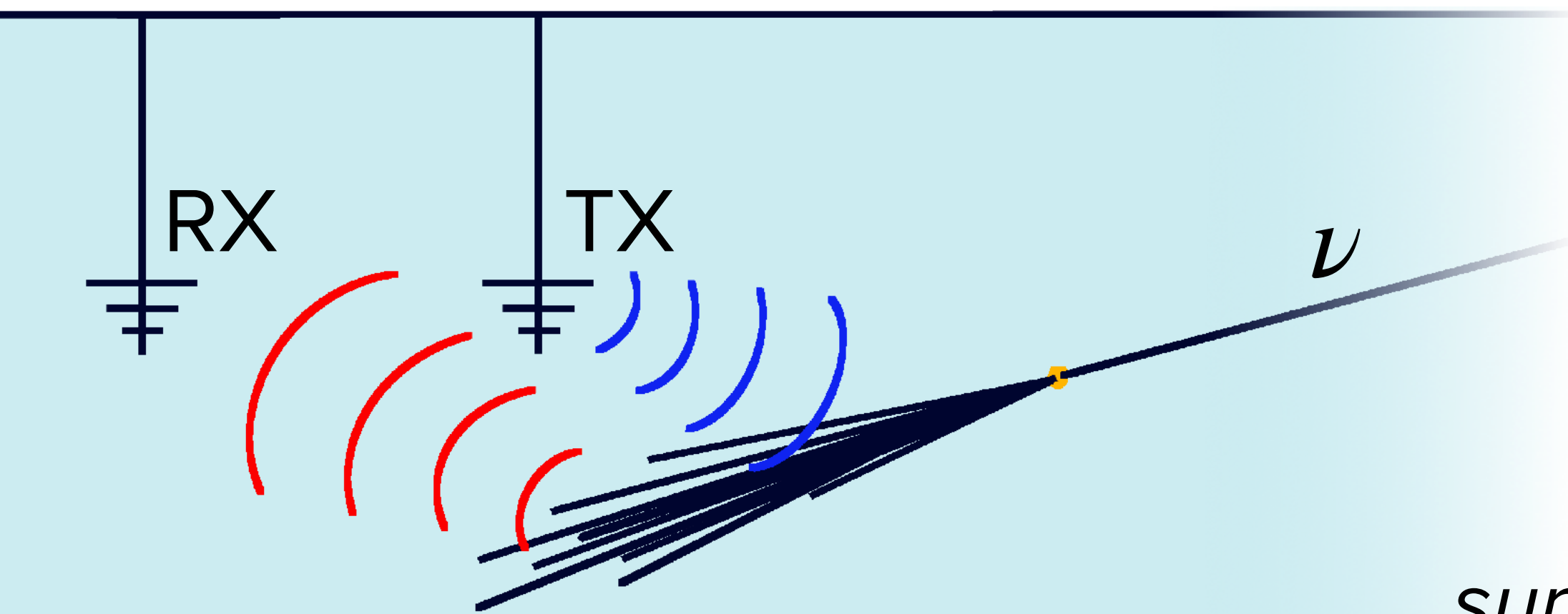
- Method has been demonstrated in SLAC laboratory experiments
- Next step: RET-CR

The RET-CR Experiment

Pathfinder experiment for RET-N, detecting **HE Cosmic Ray (CR) air showers**

RET-CR

- Use secondary in-ice cascades as a test beam
- Detect air showers both above and below ice for independent reconstruction



⇒ *The successful detection of in-ice CR cascades will support targeting UHE neutrinos with the radar technique*

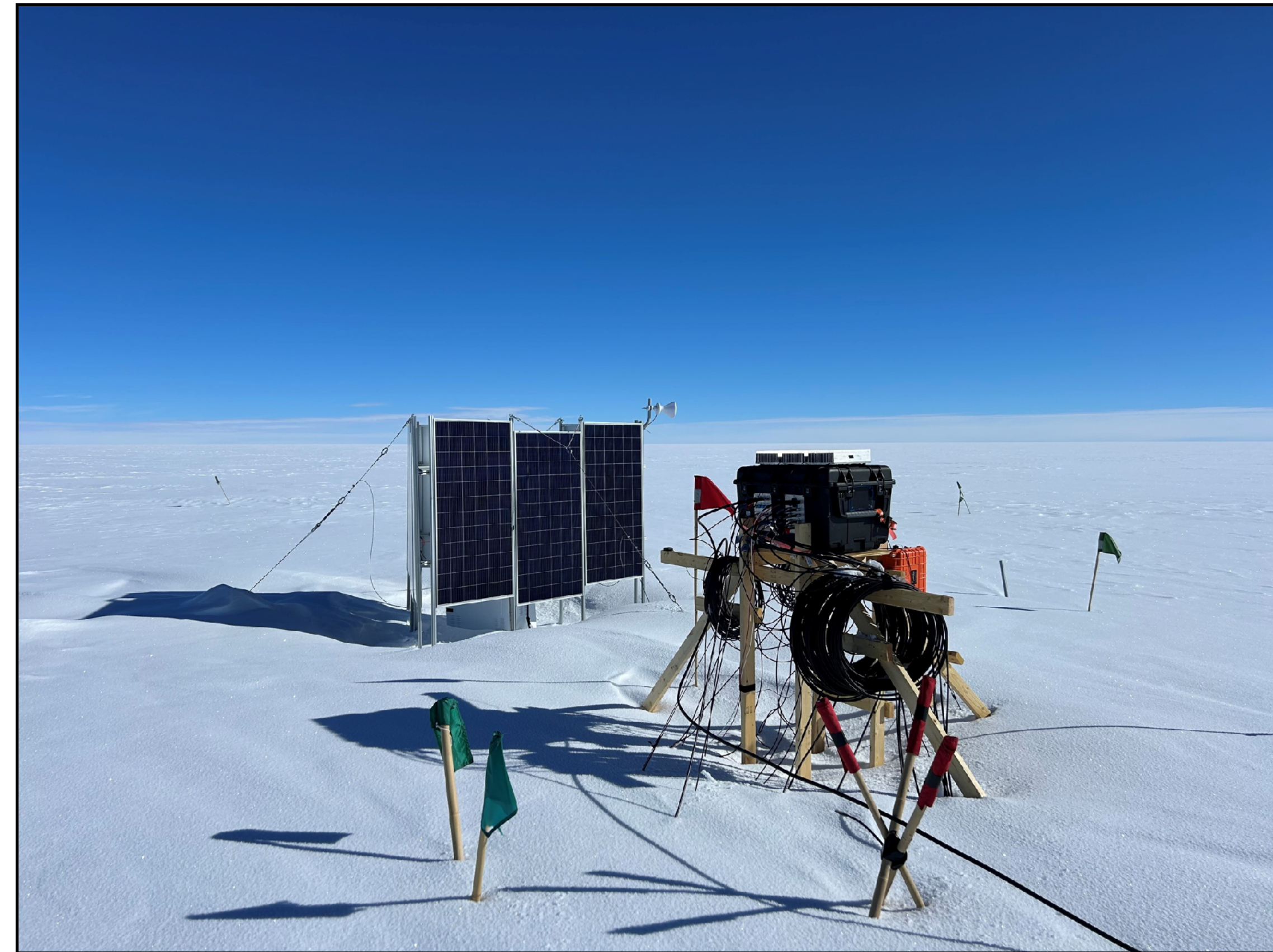
The RET-CR Experiment

RET-CR deployed near Summit Station, Greenland in 2023/2024 $\Rightarrow$ data analysis ongoing!

Exploring RET-CR signal properties

Simulating radar signals from in-ice cascades in an RET-CR setup:

- Fully understand radar signals in RET-CR
- Aid development of future reconstruction methods using the radar signal

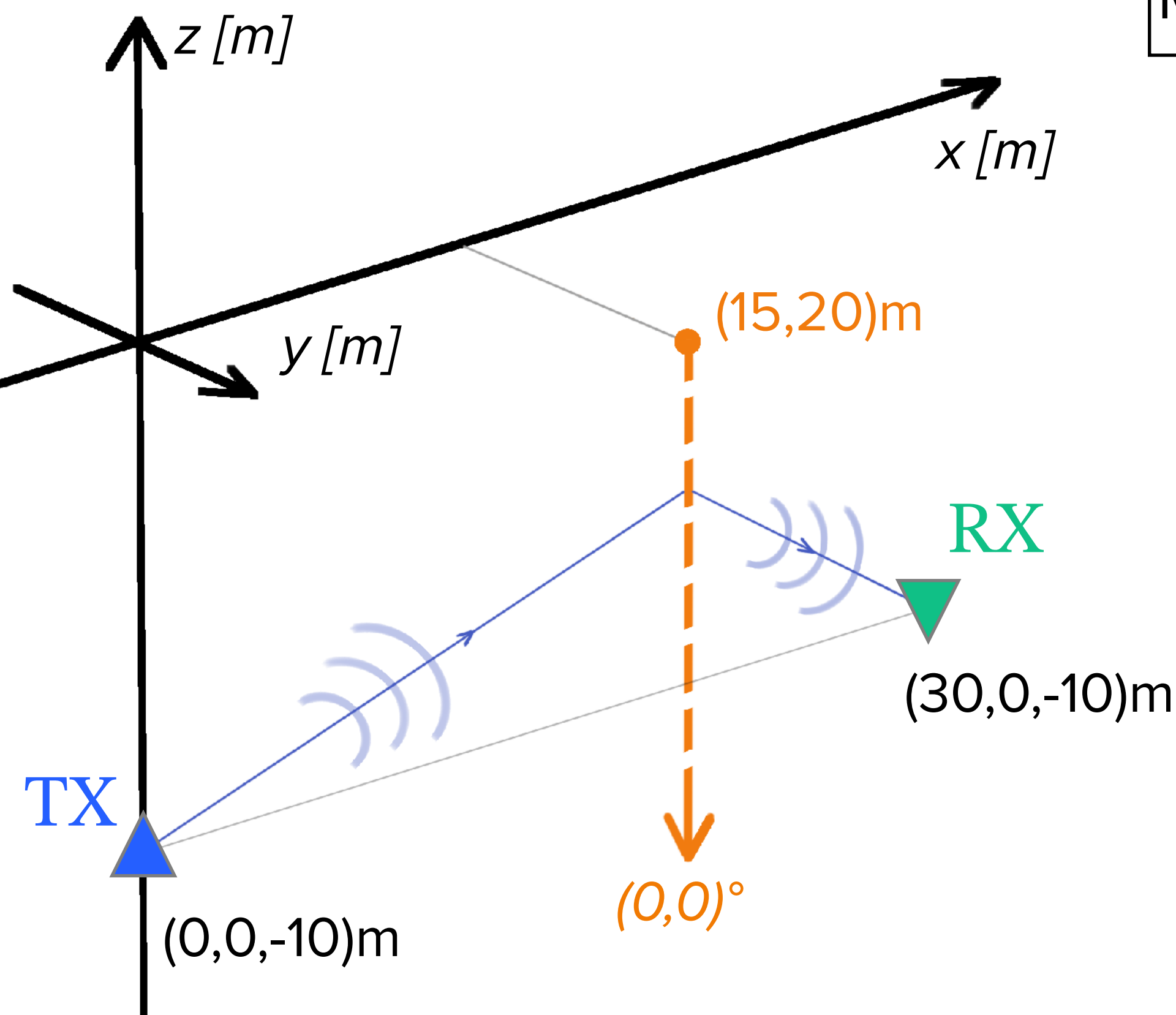


Picture credit: S. Prohira

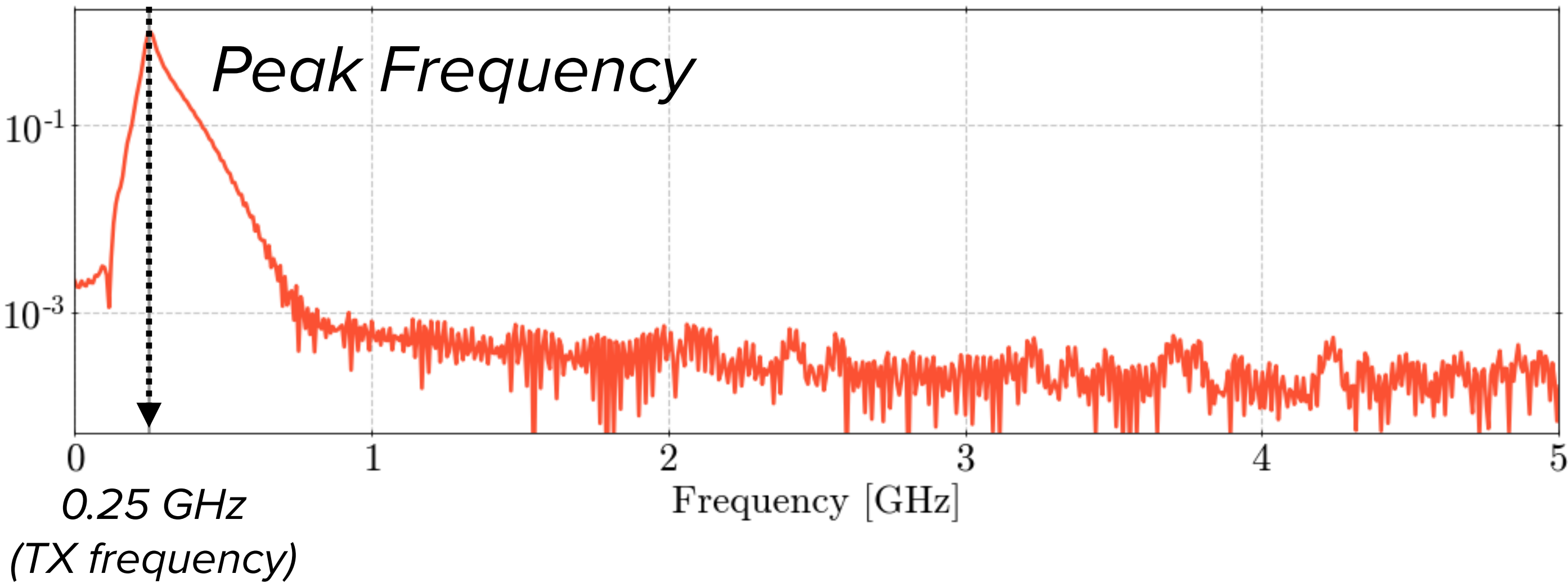
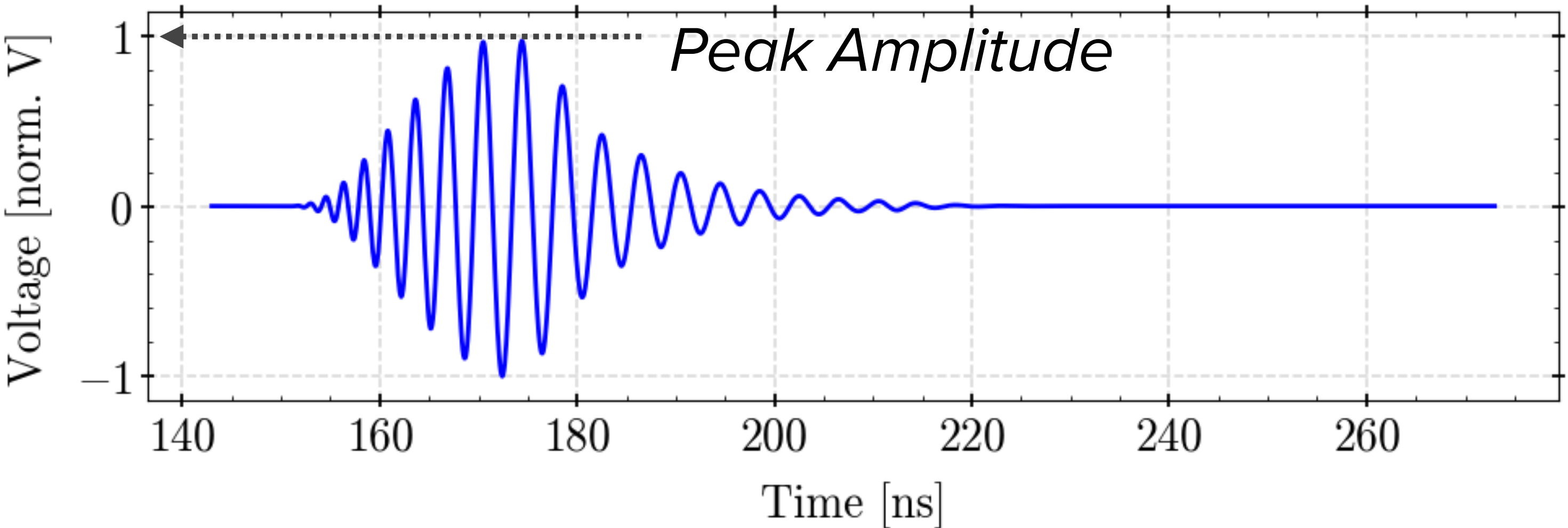
Signal Simulations

Radar signals simulated with MARES
⇒ E. Huesca Santiago et al. 2024
Macroscopic, semi-analytic code package

TX Frequency = 250 MHz
CS Energy = 20 PeV
Constant ice, $n = 1.78$

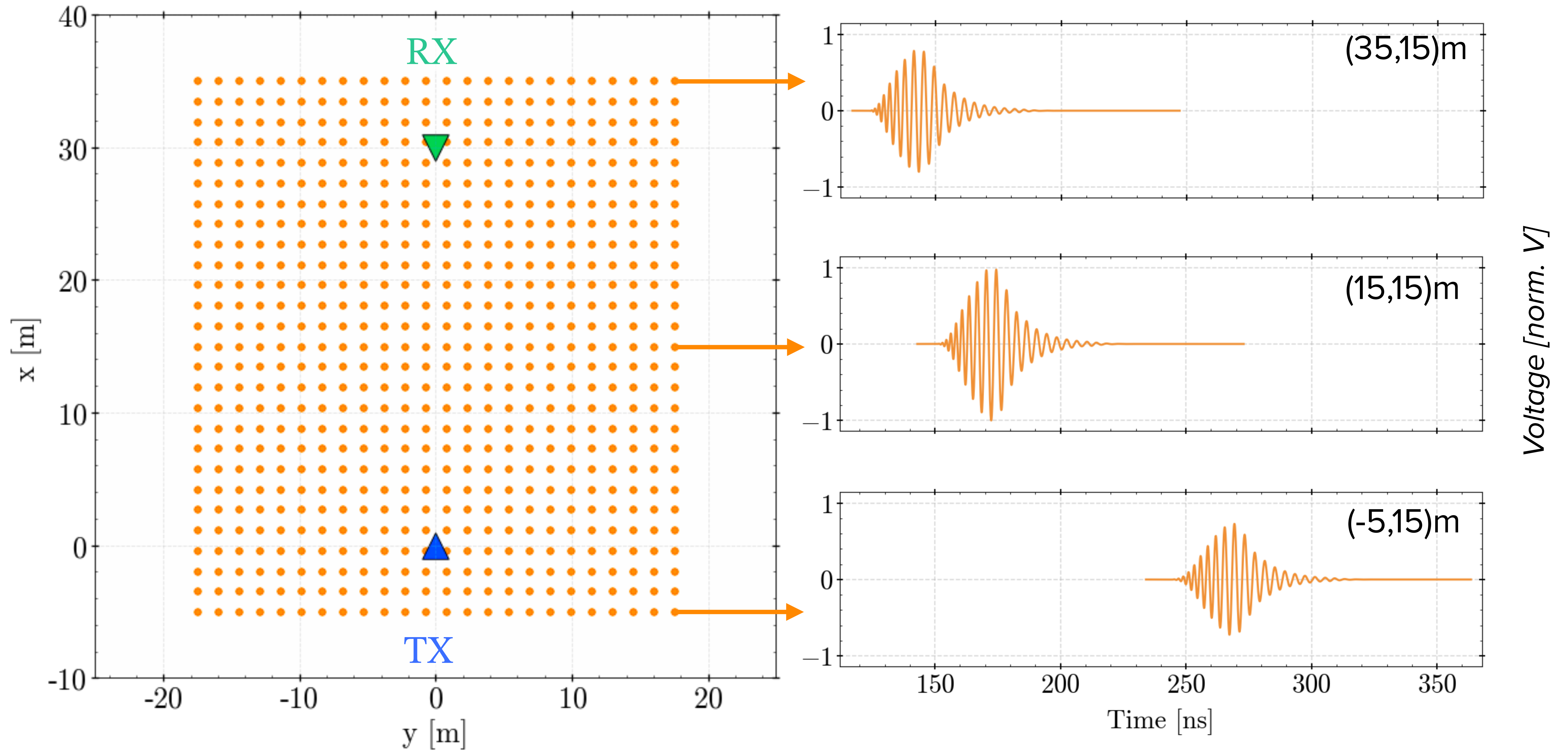


→ Focusing on effects of changing CS position and arrival direction on peak amplitude and frequency

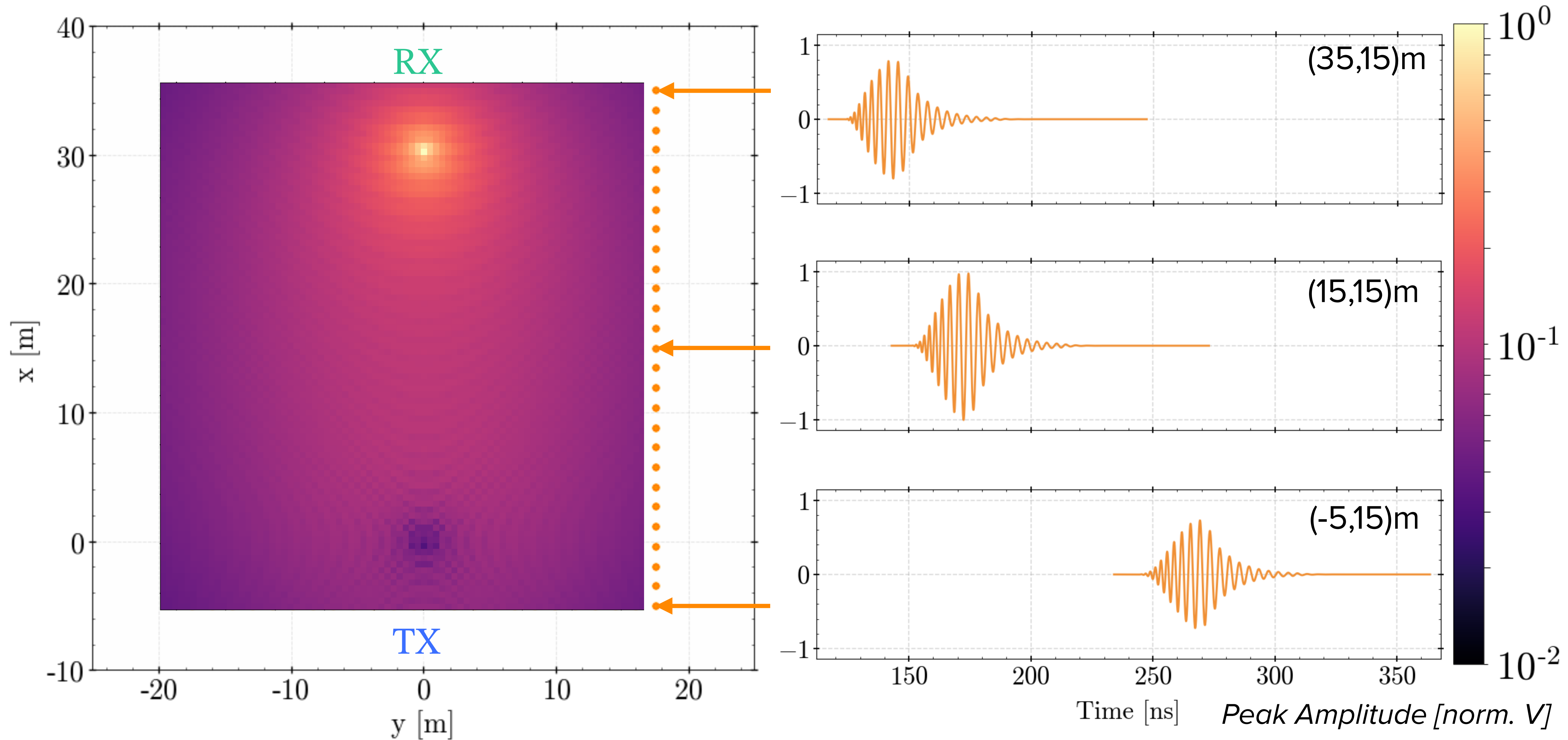


Position

For a fixed arrival direction = $(0,0)^\circ$

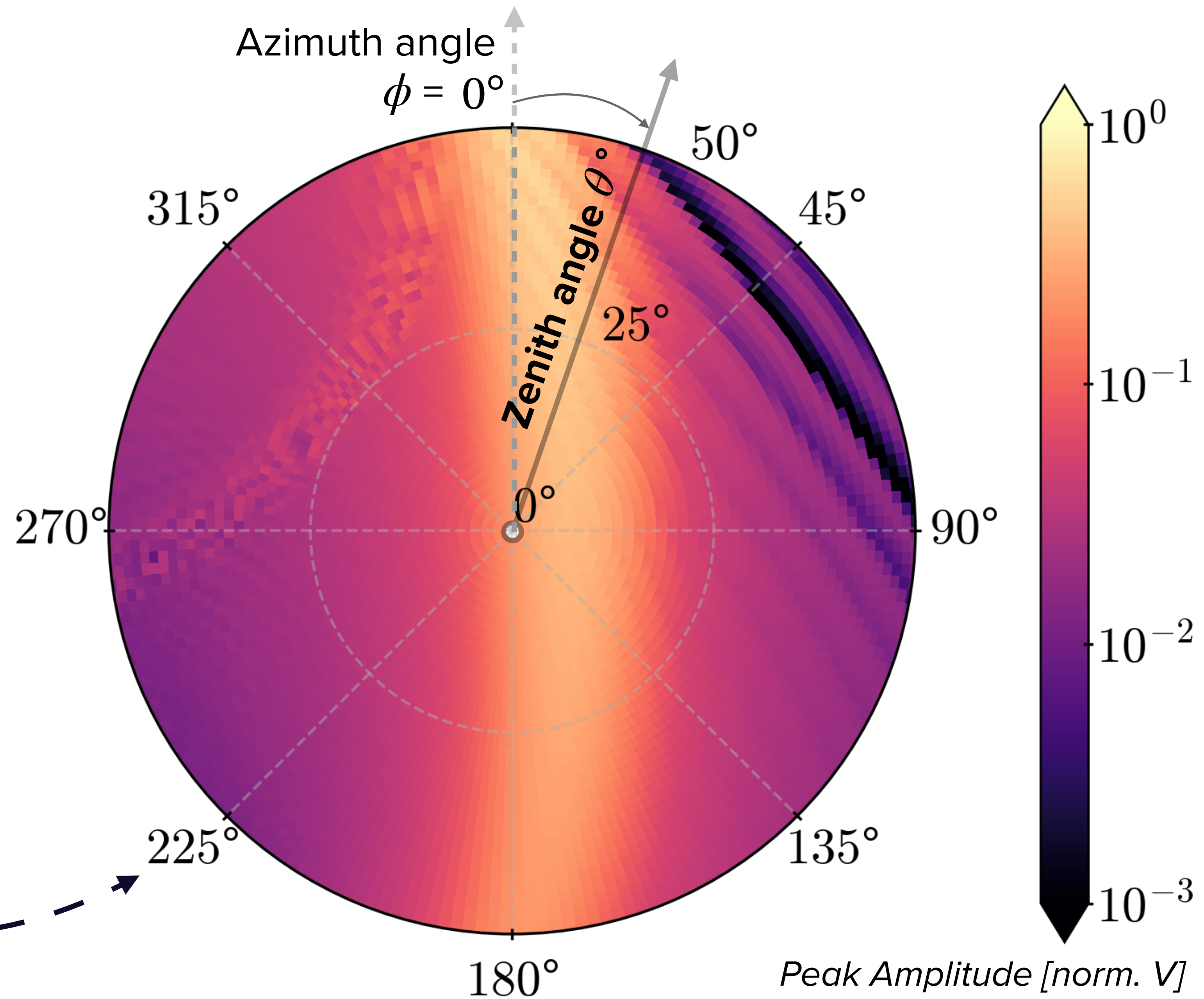
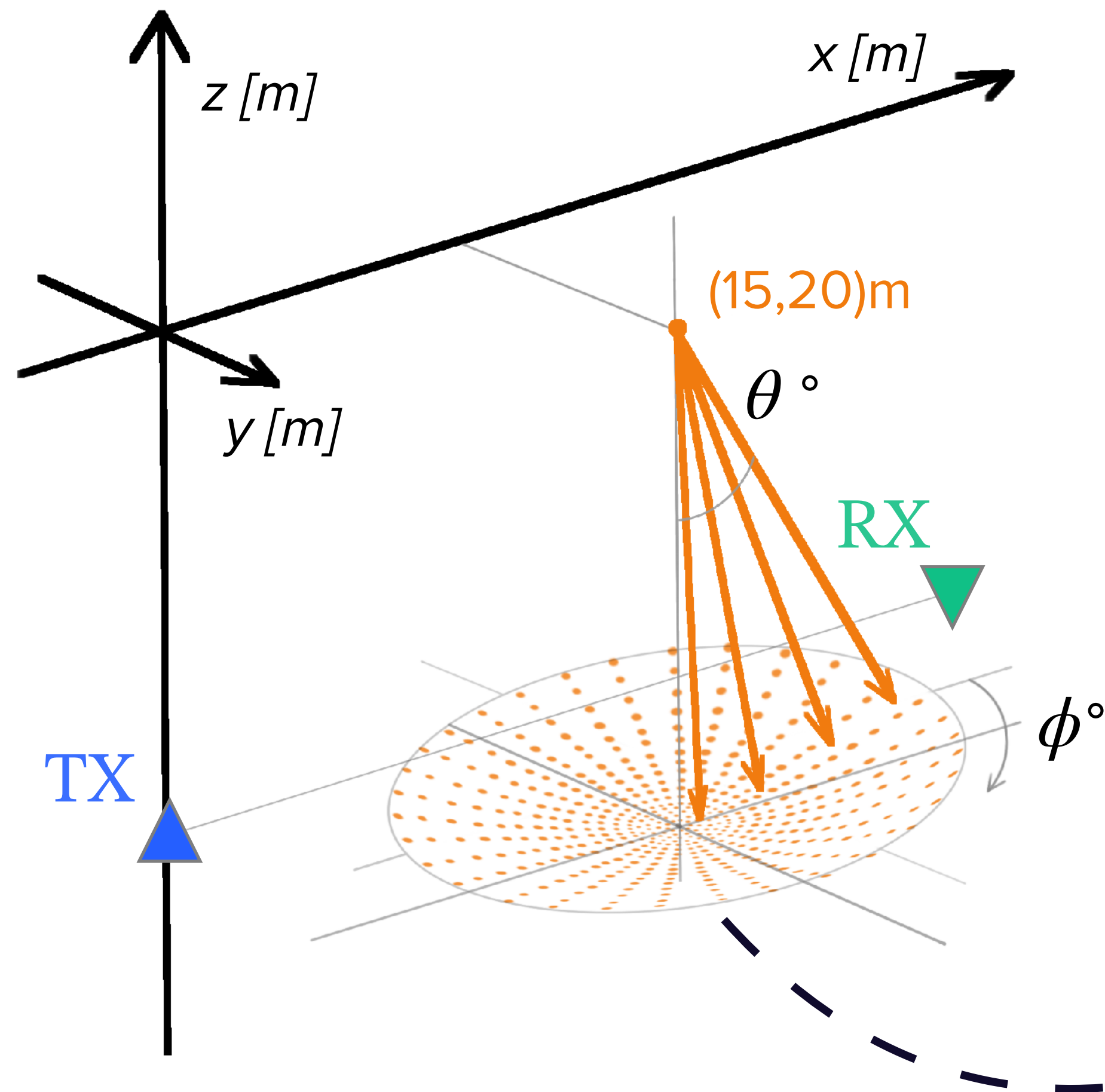


Position

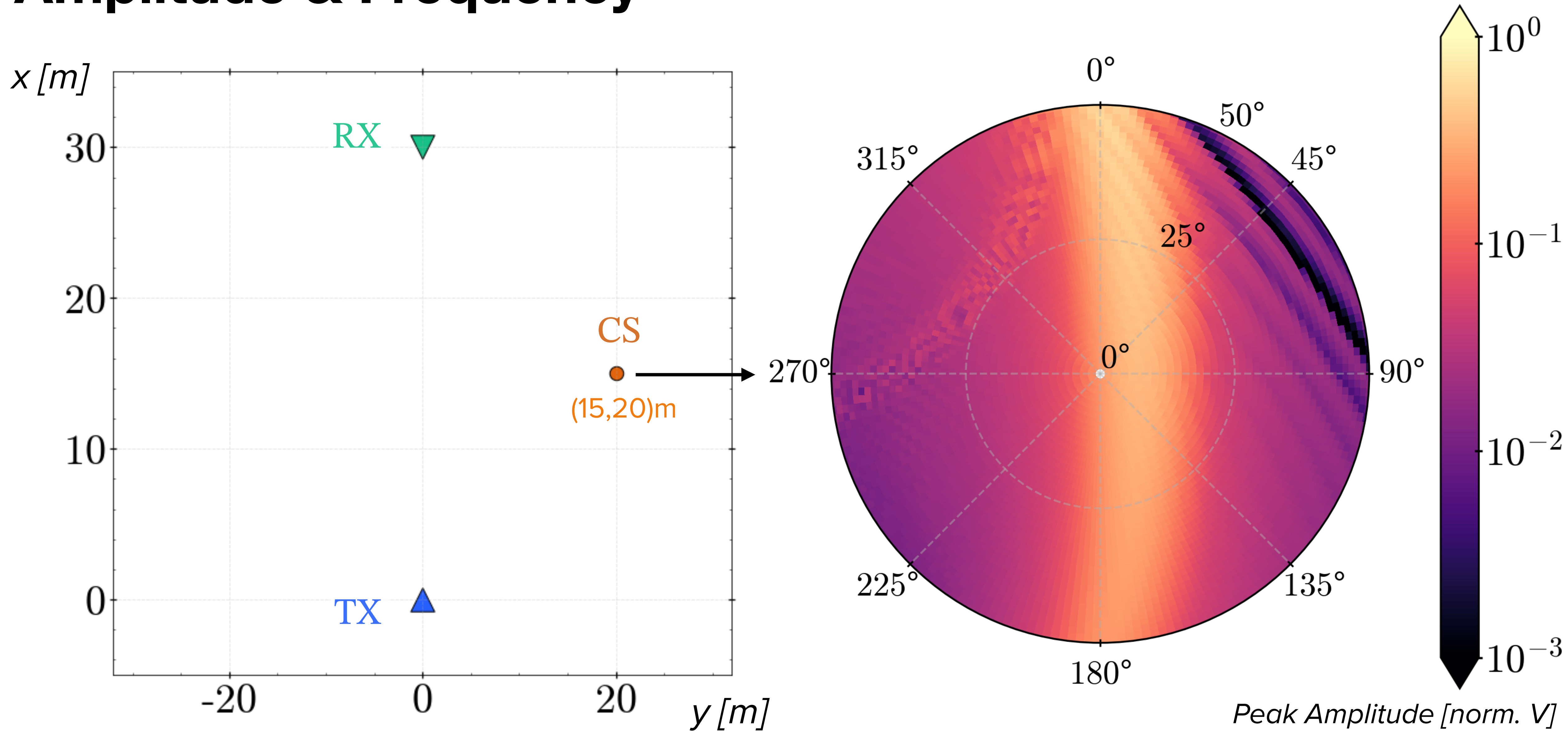


Arrival Direction

For a fixed position = (15,20)m

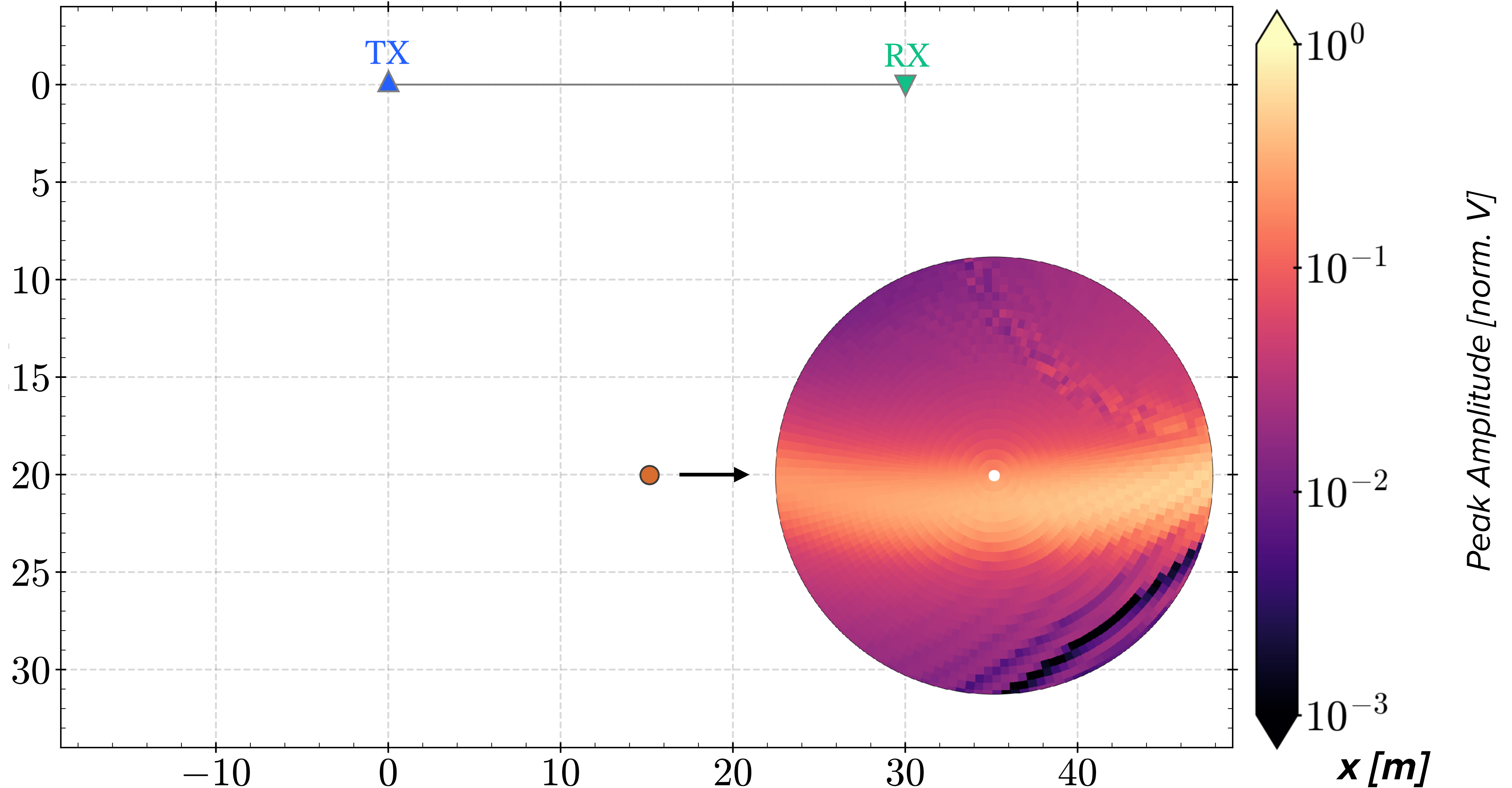


Amplitude & Frequency



Amplitude & Frequency

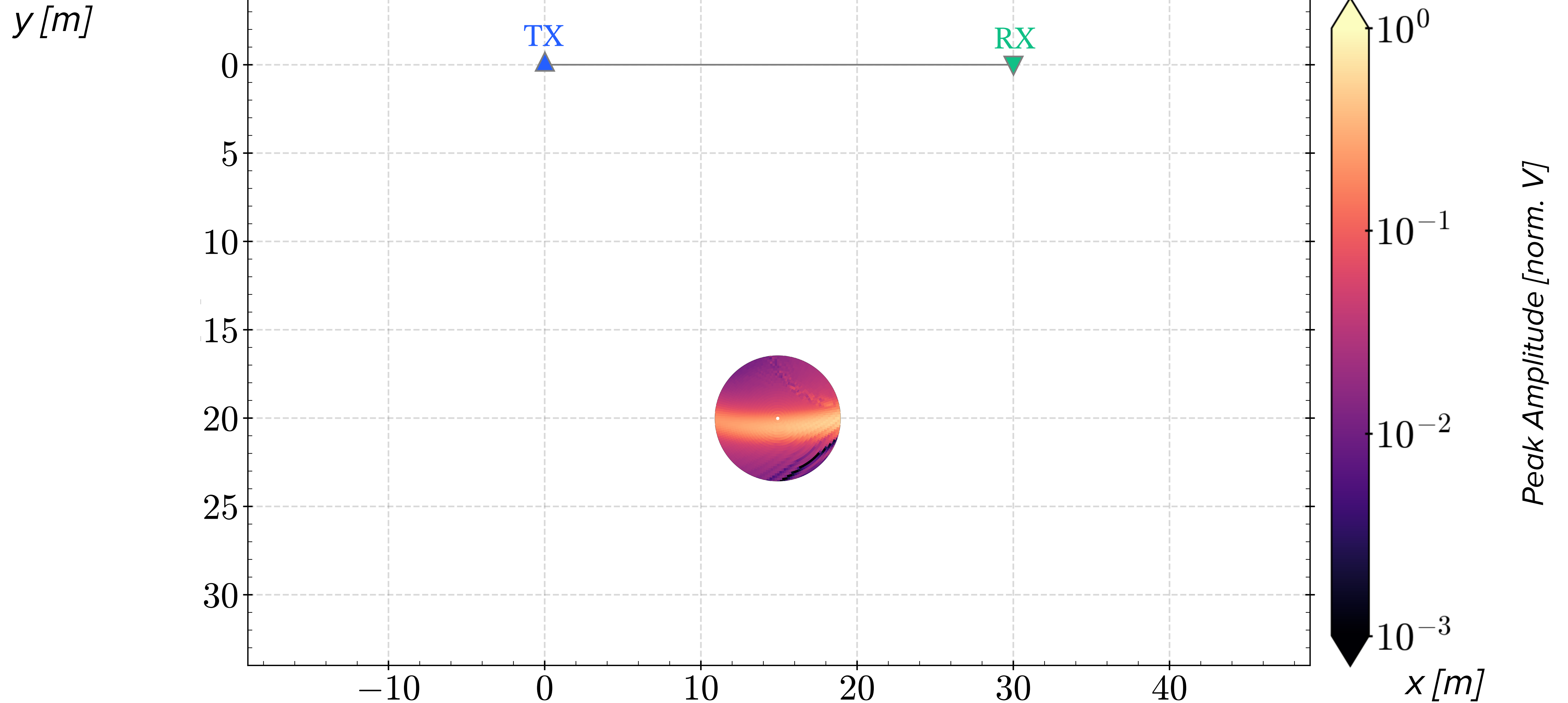
$y [m]$



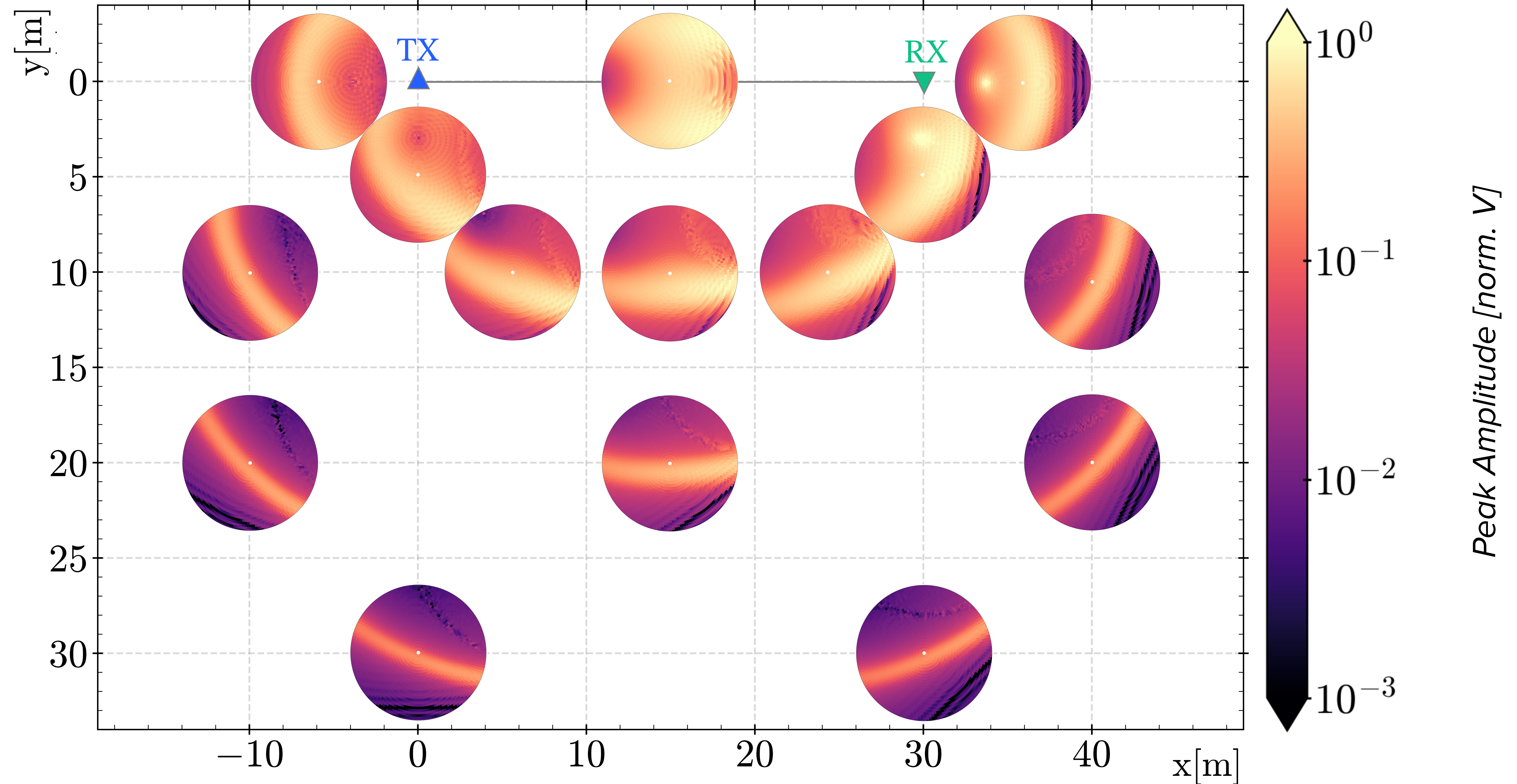
Peak Amplitude [norm. V]

$x [m]$

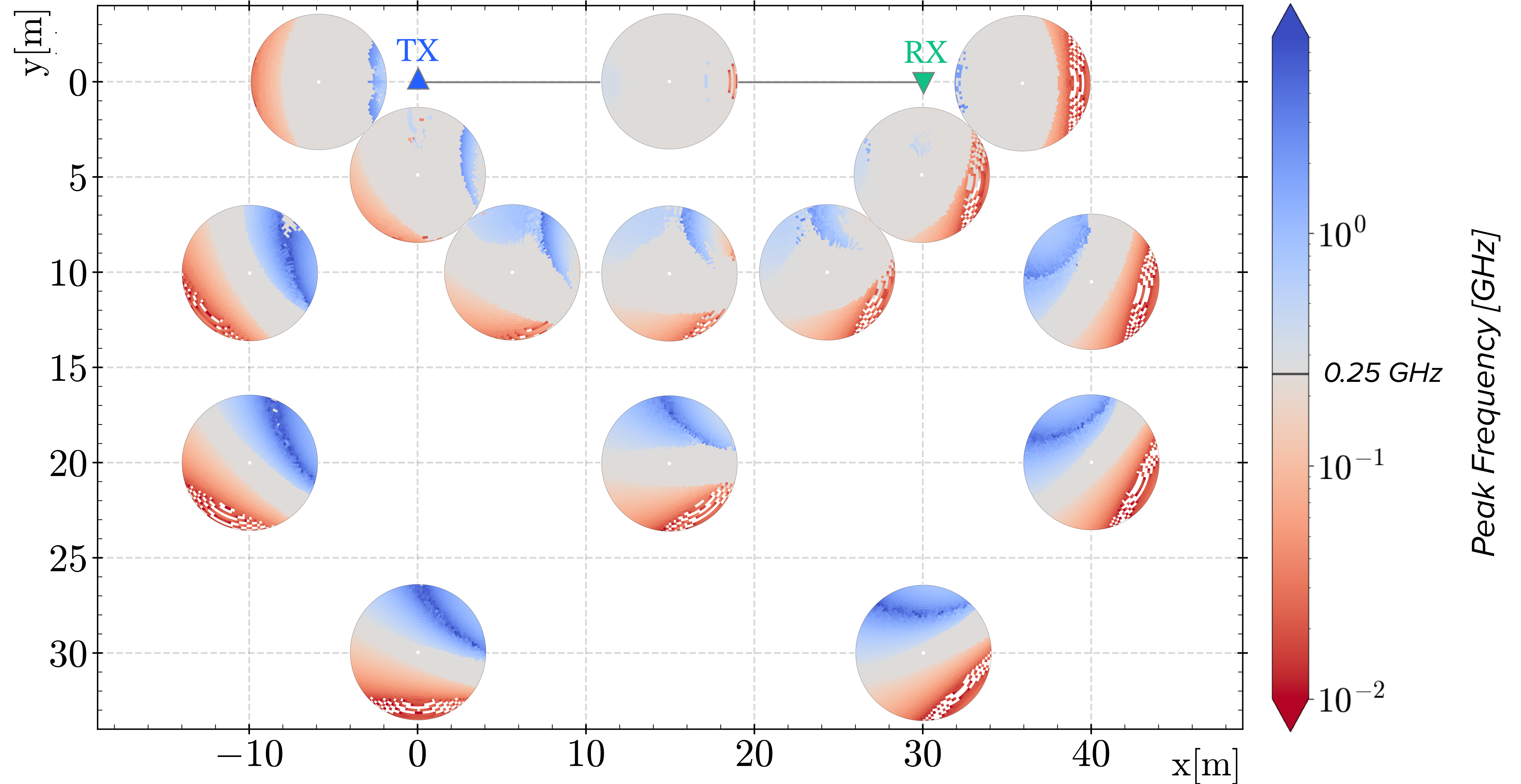
Amplitude & Frequency



Amplitude & Frequency

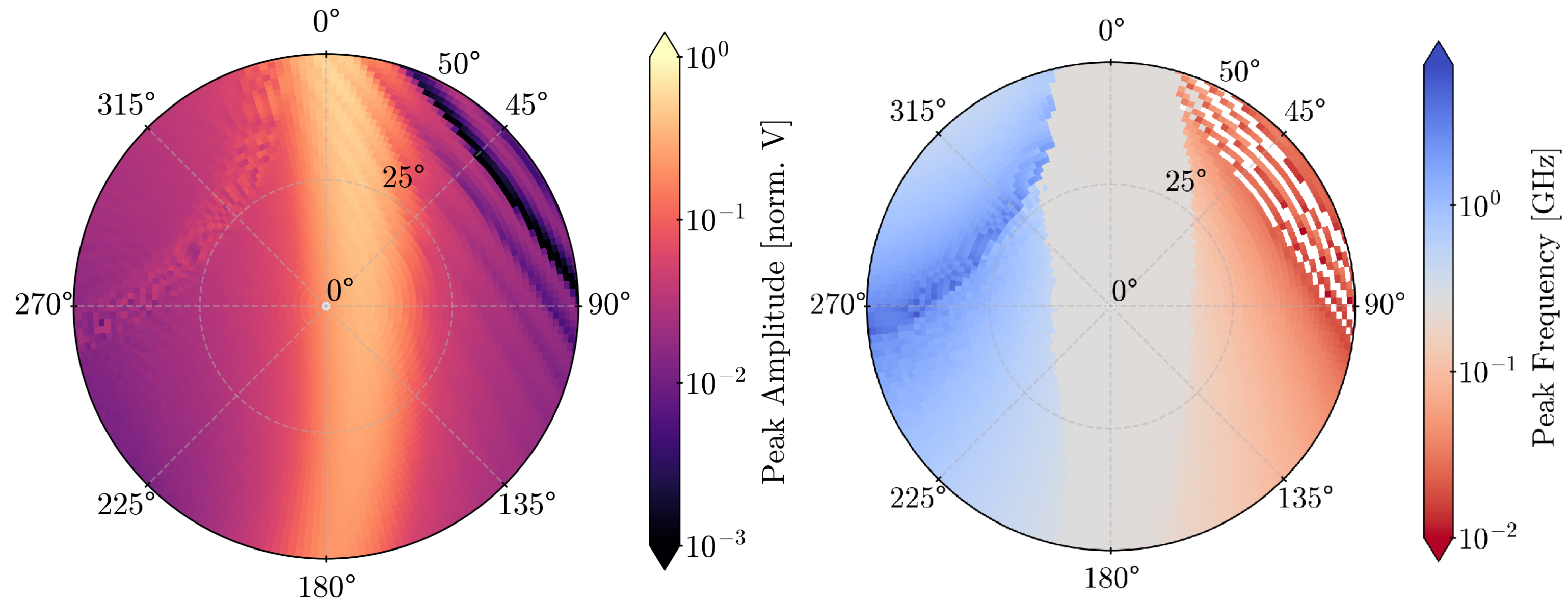


Amplitude & Frequency



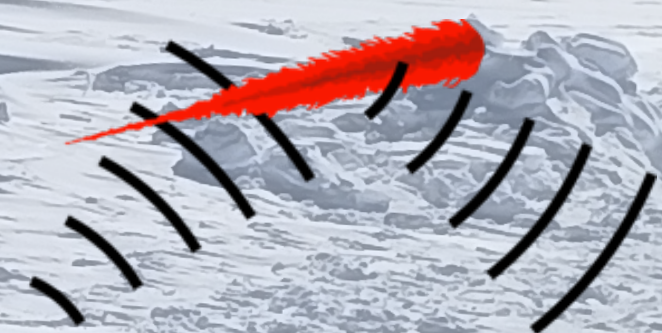
Summary

- RET aims to detect PeV - EeV neutrinos with in-ice radar
- RET-CR experiment serving as proof-of-concept of the radar method

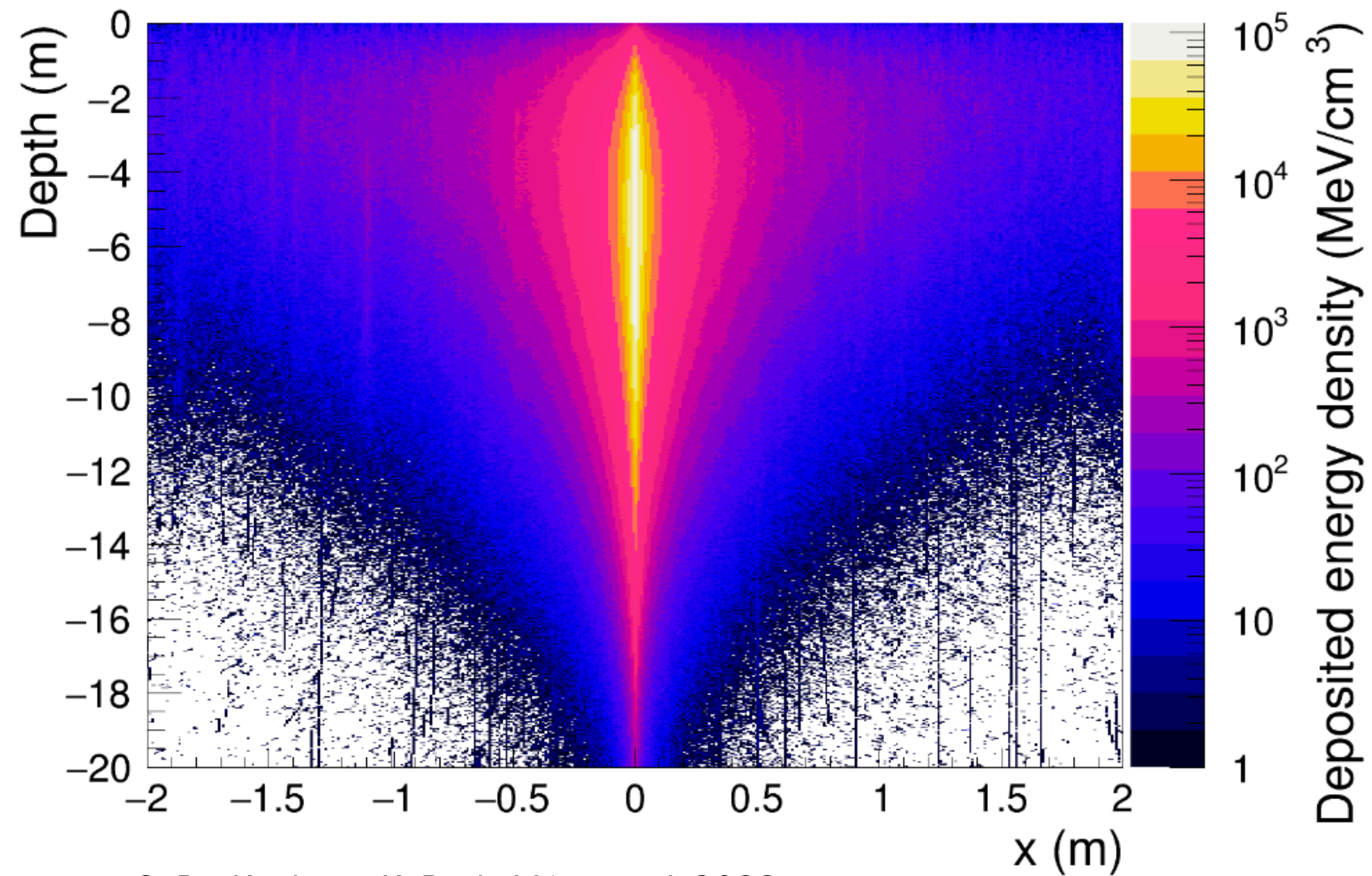


- Using simulations to explore properties of the radar echo signal, have found geometry-dependent features:
- Signal amplitudes controlled by phase coherence
- Signal frequency shifts linked to both Doppler shifts and Cherenkov effects

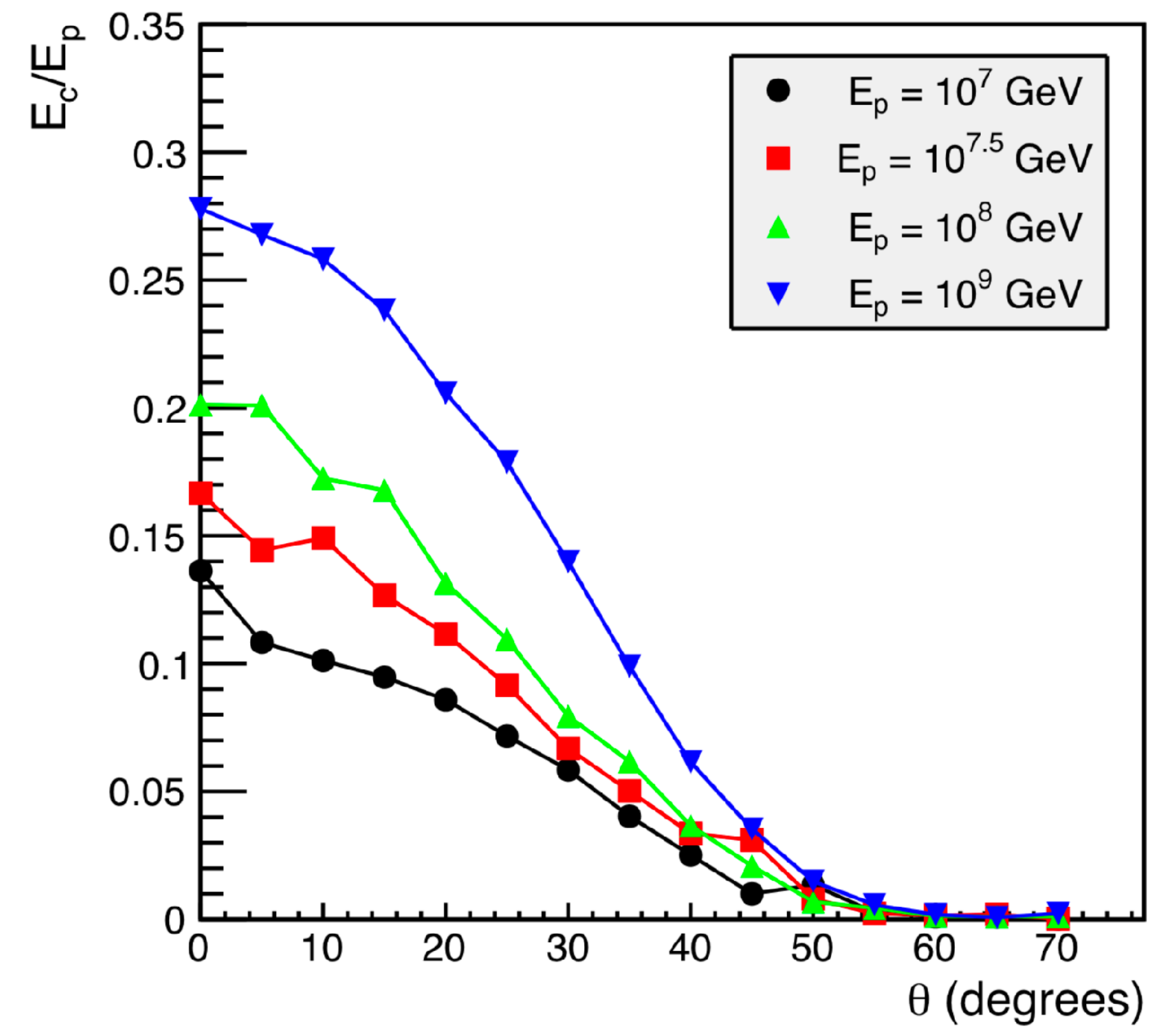
RADAR ECHO TELESCOPE



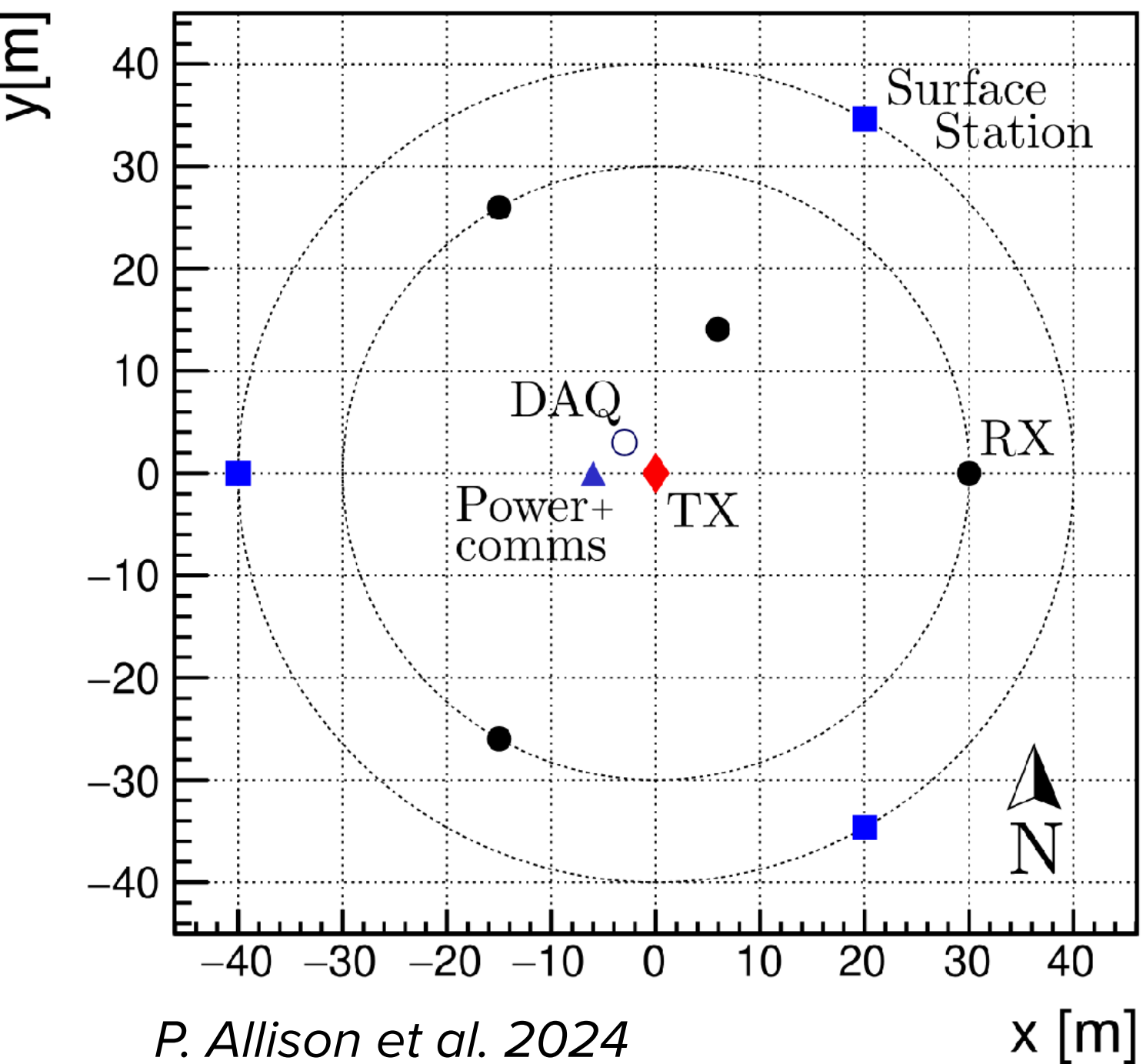
Picture credit: D. Frikken



S. De Kockere, K. D. de Vries et al. 2022

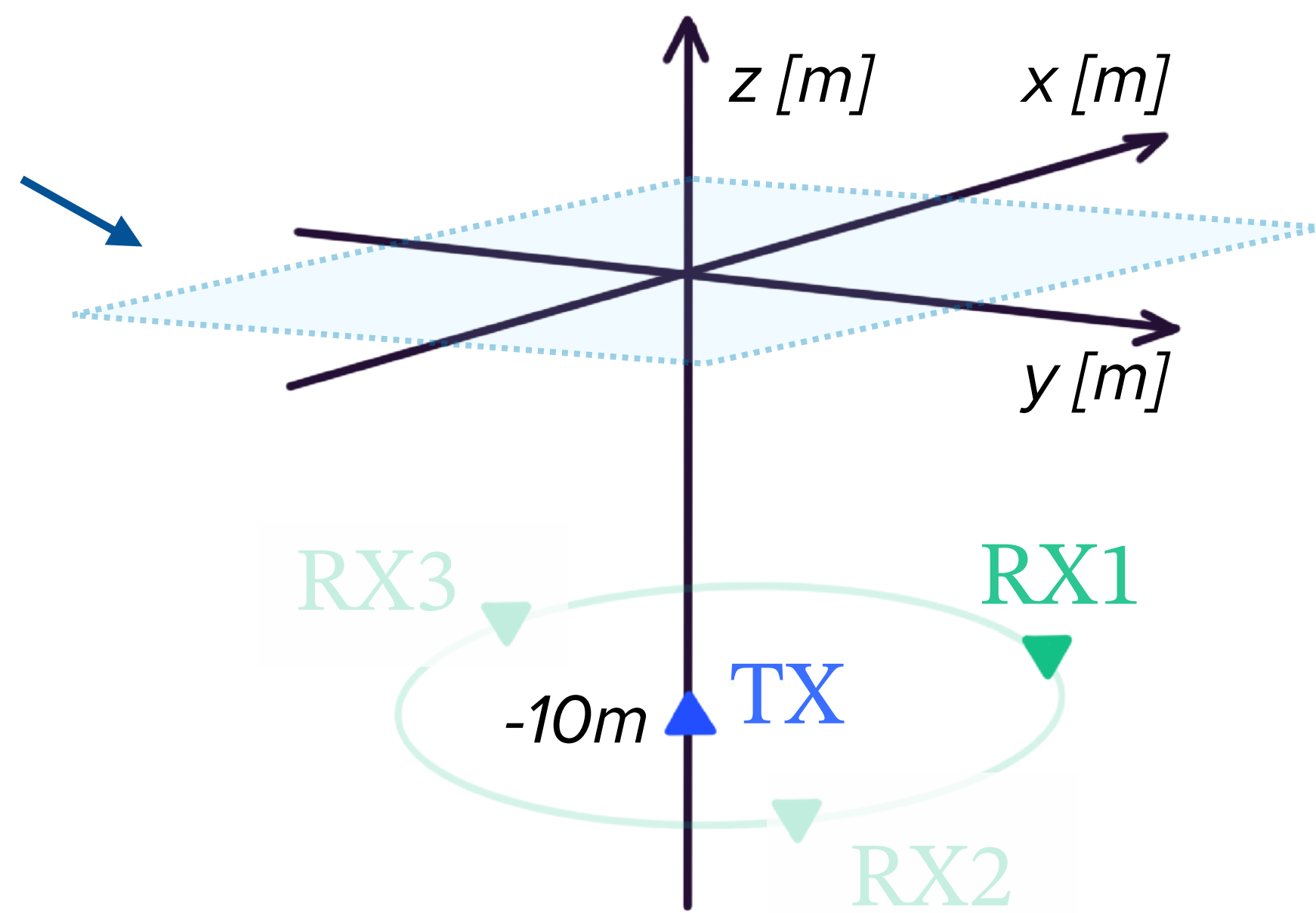
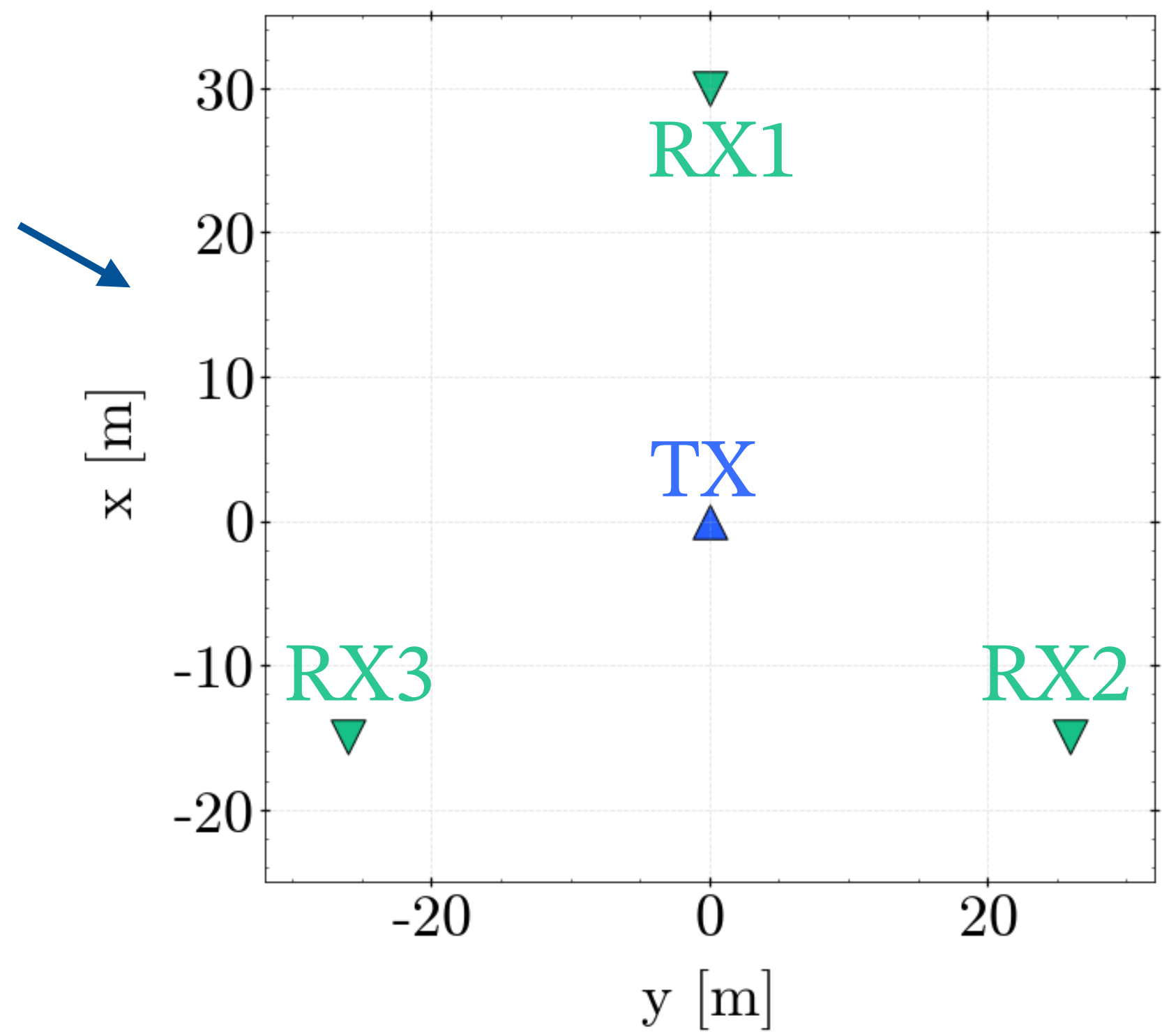


Antenna Setup



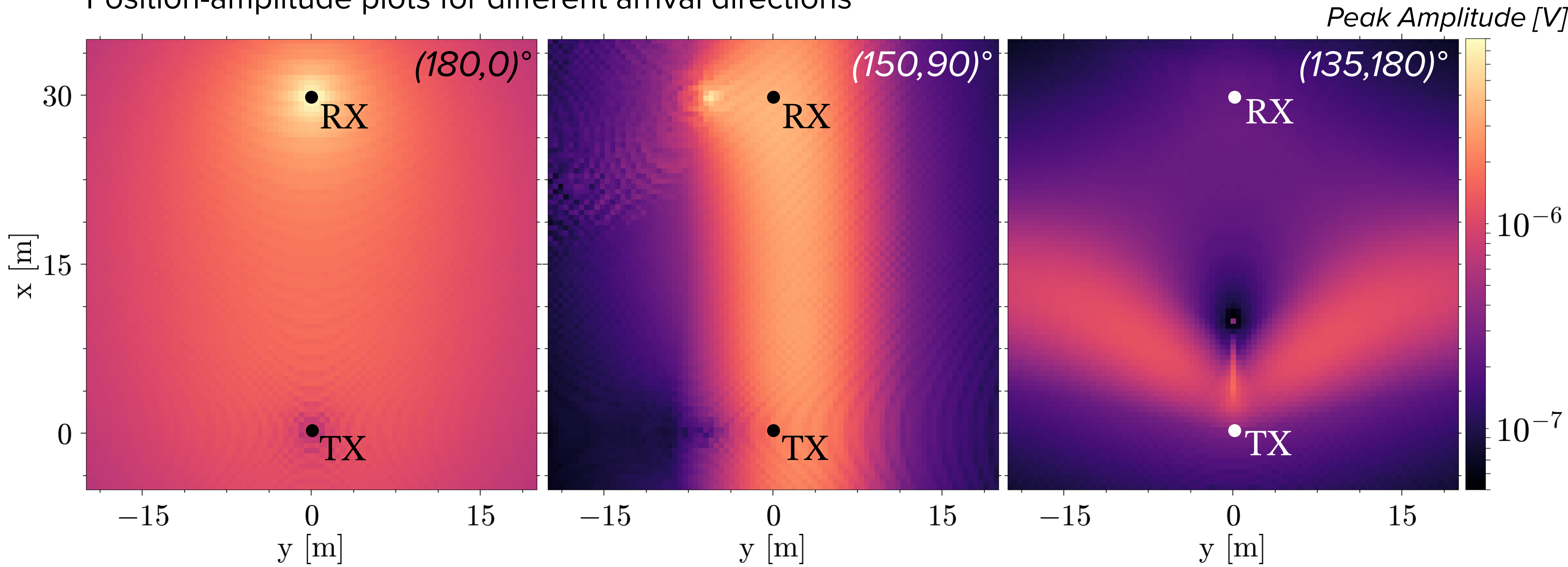
- Detector Parameters:*
- TX frequency = 250 MHz
 - Gain = 15 dBi
 - Power = 50 W
 - Zpol

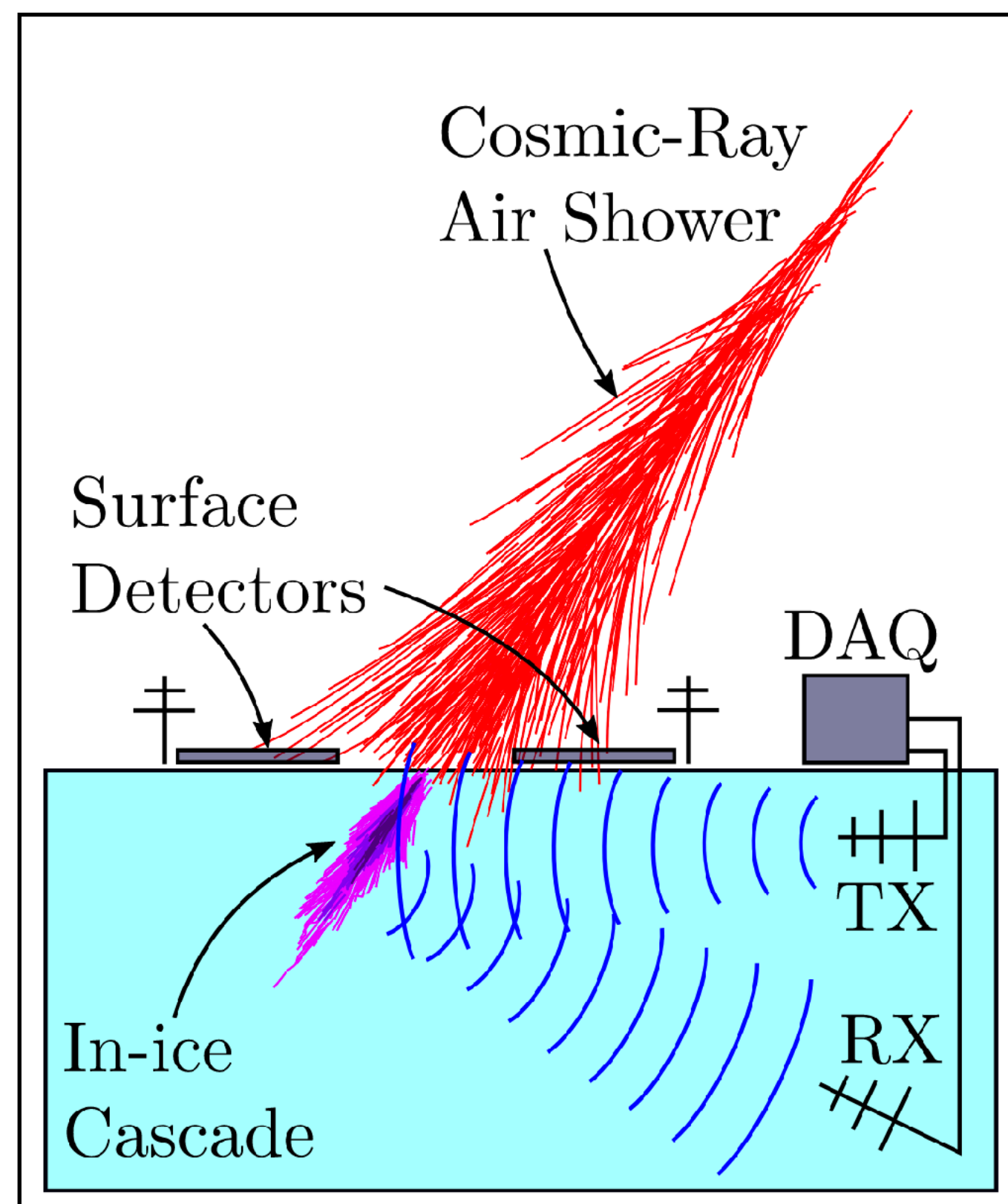
Using a detector setup within MARES resembling RET-CR as deployed in 2023



Position

Position-amplitude plots for different arrival directions

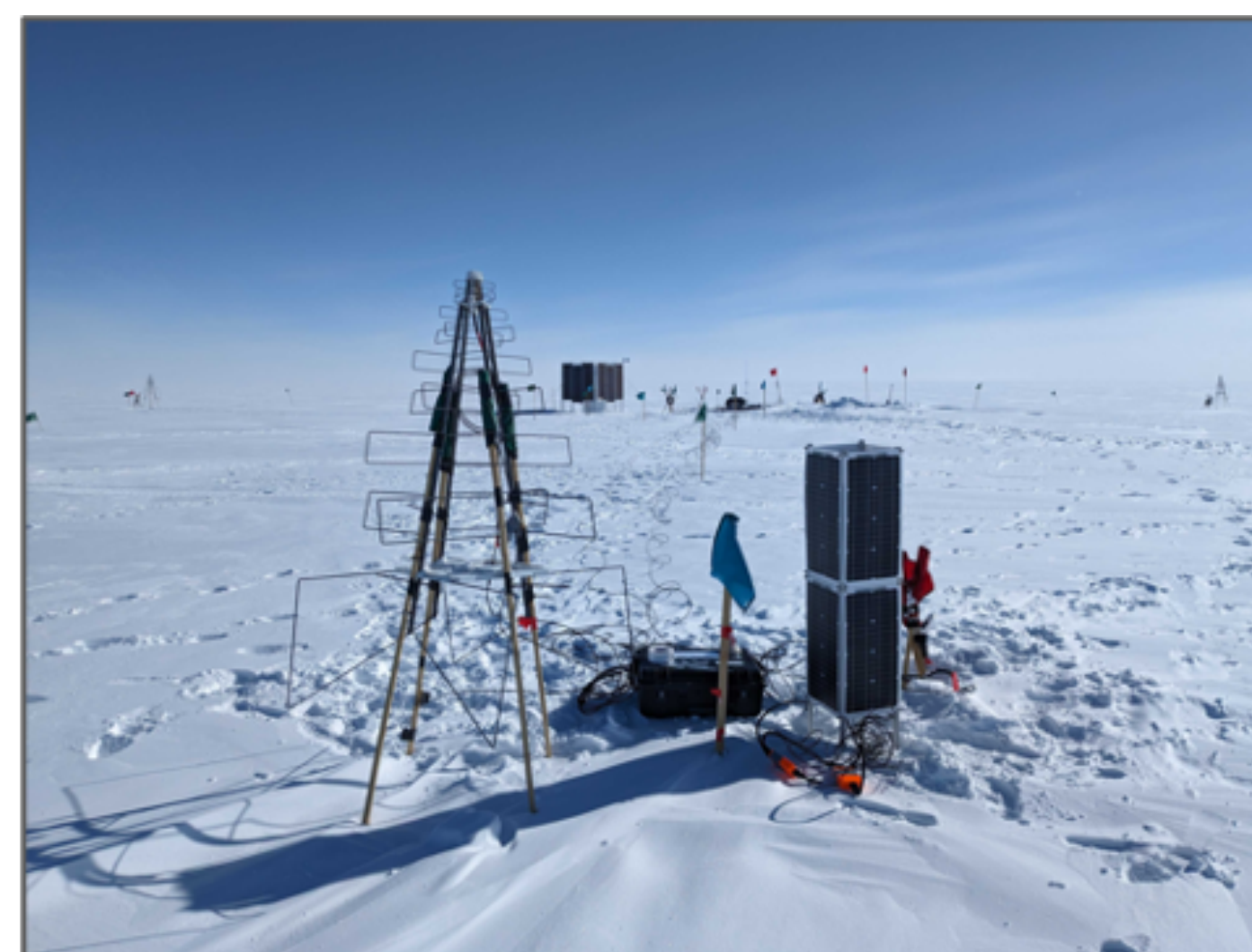




S. Prohira, K. D. de Vries, S. Toscano et al.
2021

Surface Stations:

- Radio antennas
 - Particle detectors
 - (+DAQ, solar panels...)
- Act as triggers for* →



Picture Credit: Simon De Kockere

In-Ice Component:

- Radar system:
Transmitter, receivers

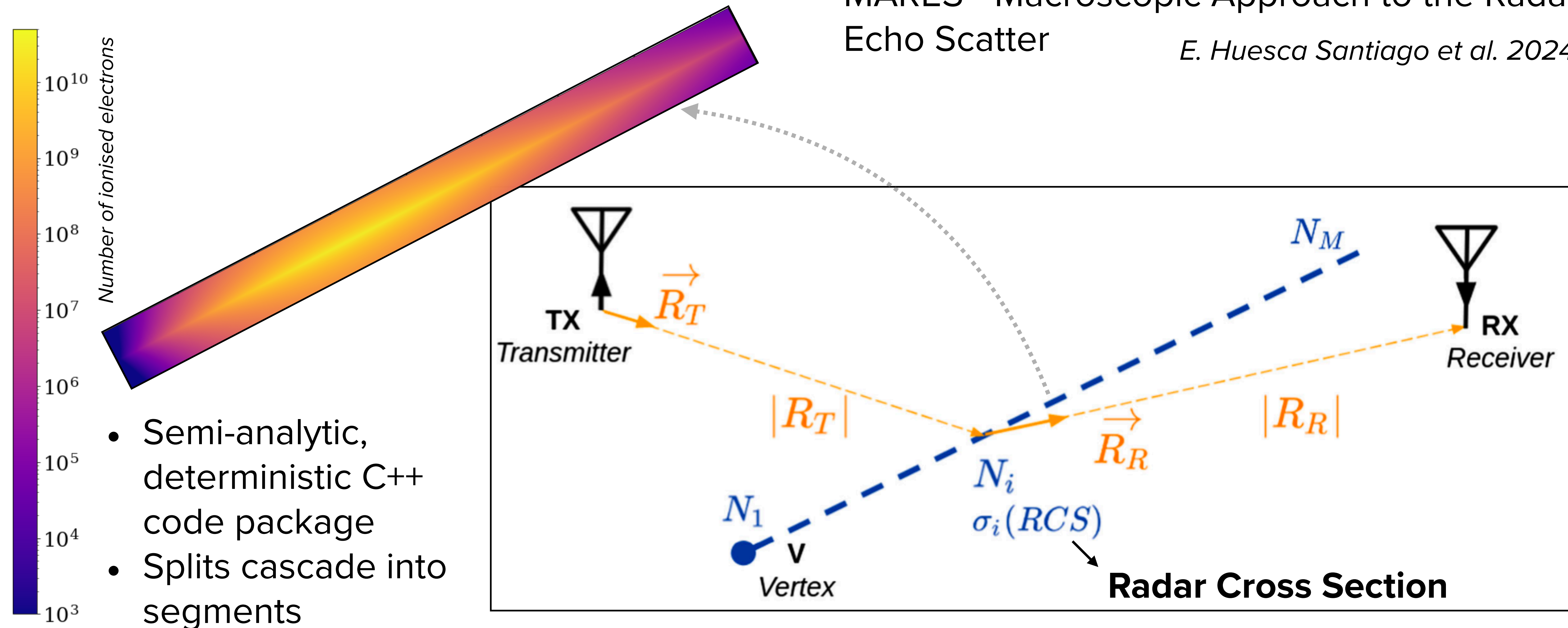


Picture Credit: Dylan Frikken

Independent reconstruction, validates radar method

MARES - Macroscopic Approach to the Radar Echo Scatter

E. Huesca Santiago et al. 2024



Final signal at receiver = sum of contributions of each segment