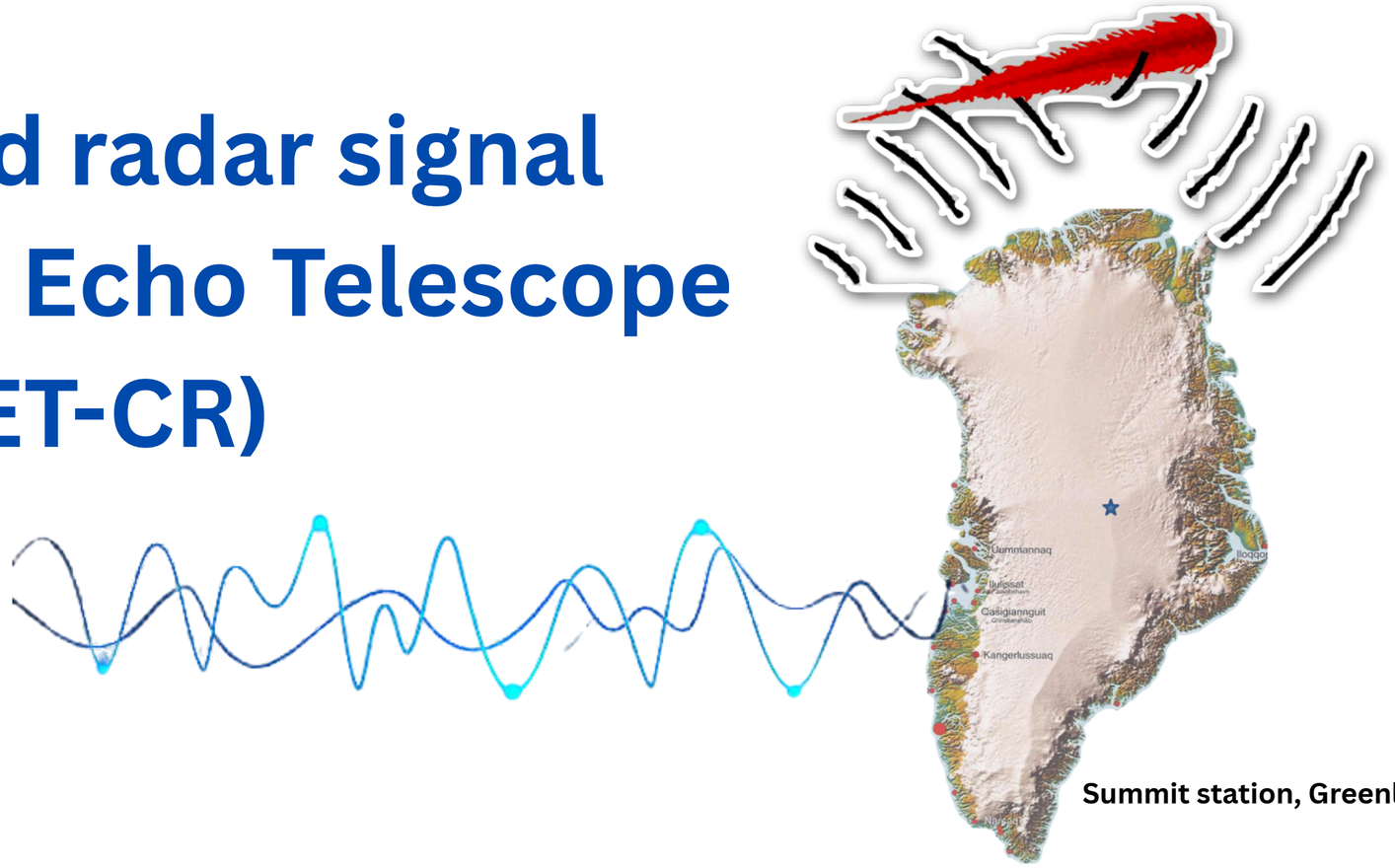
Combined radio and radar signal study for the Radar Echo Telescope for Cosmic Rays (RET-CR)



Summit station, Greenland

Radboud Universiteit Nijmegen

Krishna Nivedita G

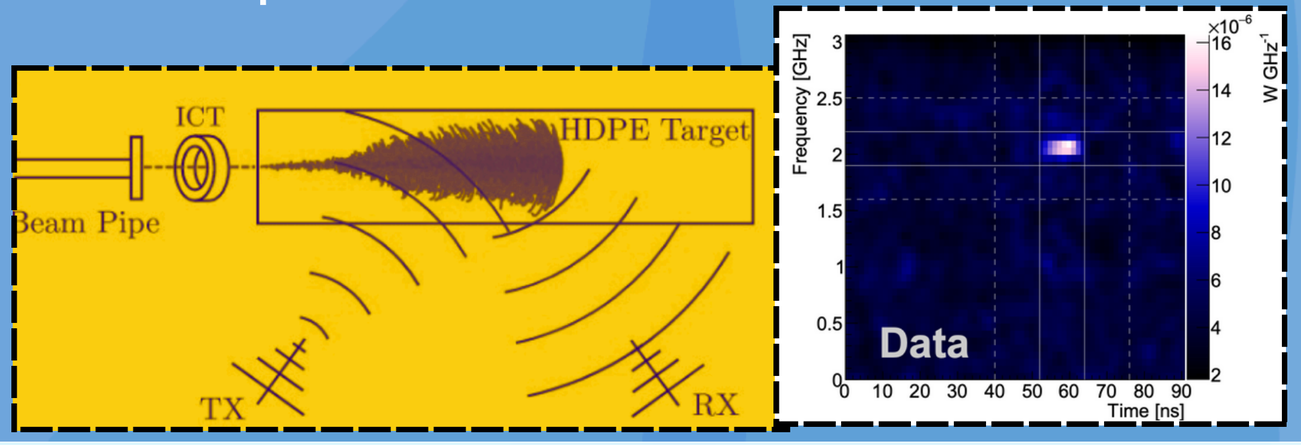
6th October, TeVPA, Valencia

The Radar Echo Telescope (RET)

SLAC Beam Test Experiment T576 (2020)[1]

First laboratory detection of particle cascade with a radar!

2020



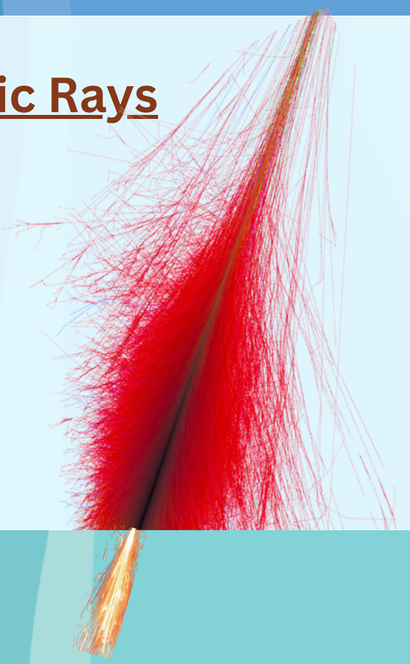
From laboratory to nature

2023-present

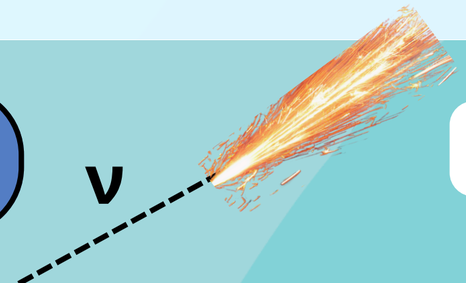
- Test the method in nature
- Very steeply falling flux of neutrinos
- Use Cosmic rays as a known source

The Radar Echo Telescope for Cosmic Rays (RET-CR) (2024 - present)

Pathfinder Experiment



Future

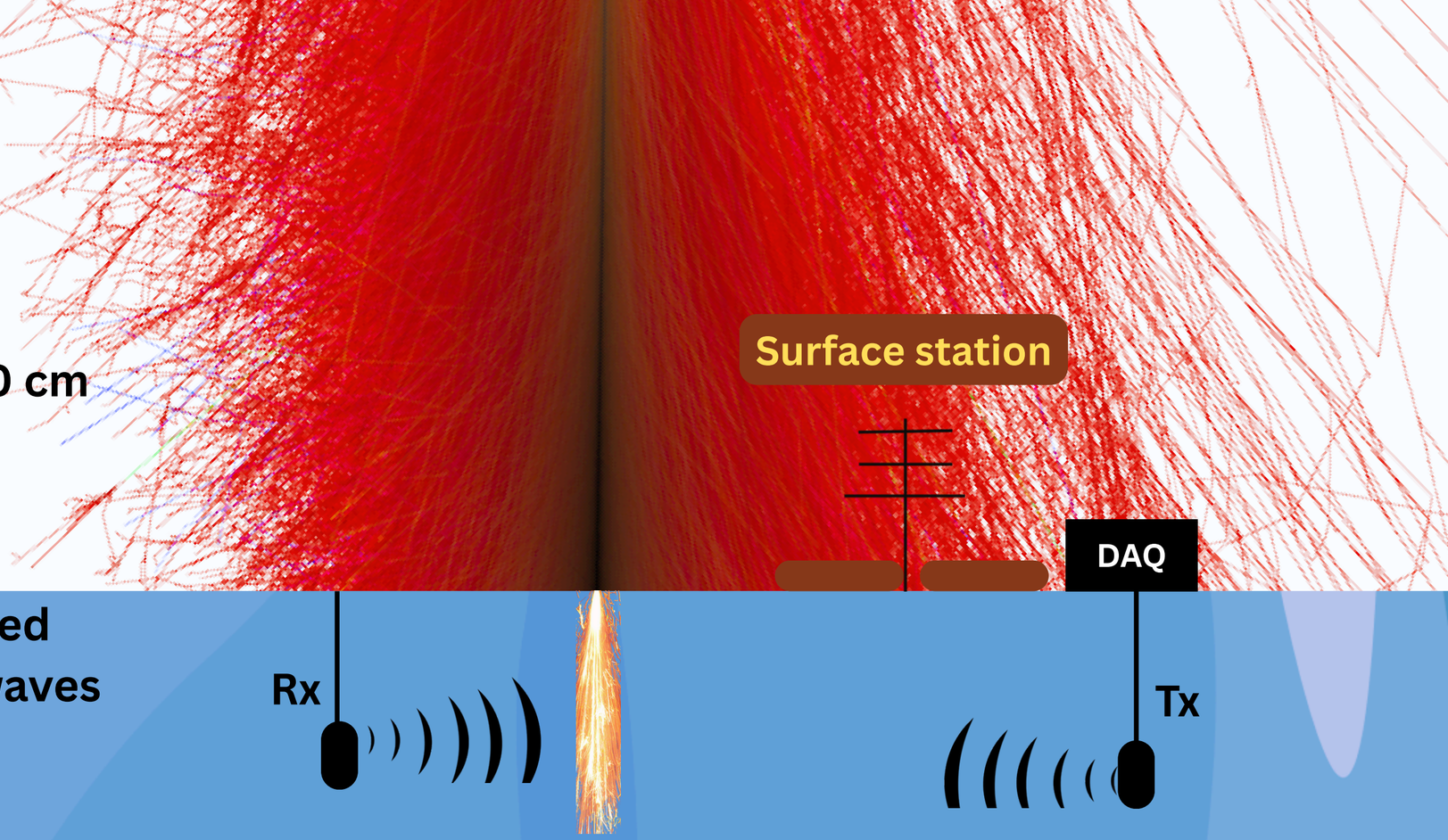


The Radar Echo Telescope for Neutrinos

[1] DOI: 10.1103/PhysRevLett.124.091101

The Radar Echo Telescope for Cosmic rays

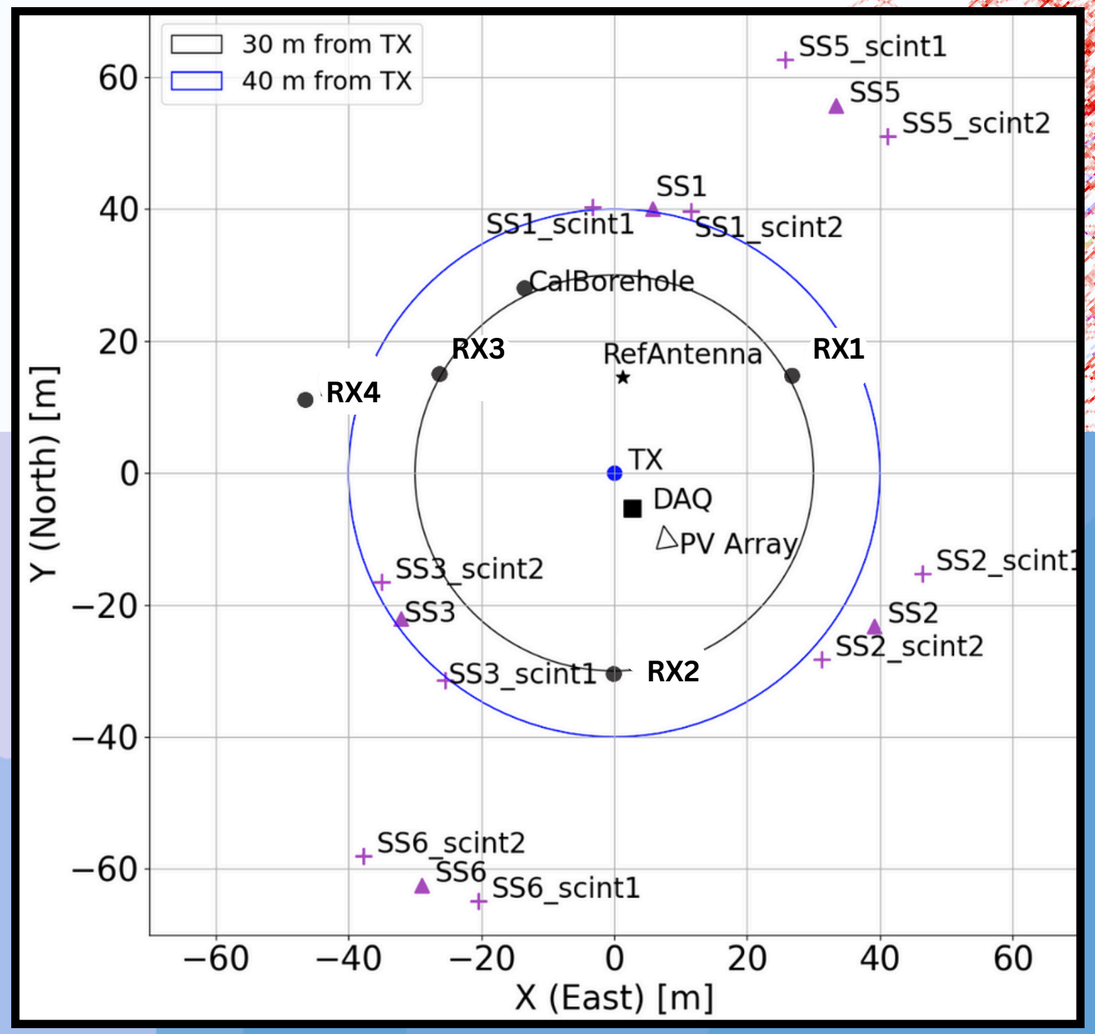
- Most of the cascade energy is contained within approximately 10 cm of the shower axis[1].
- Shower core propagates into the ground
- Dense secondary cascade generated
- Can theoretically reflect radio waves E(CR) > 10PeV

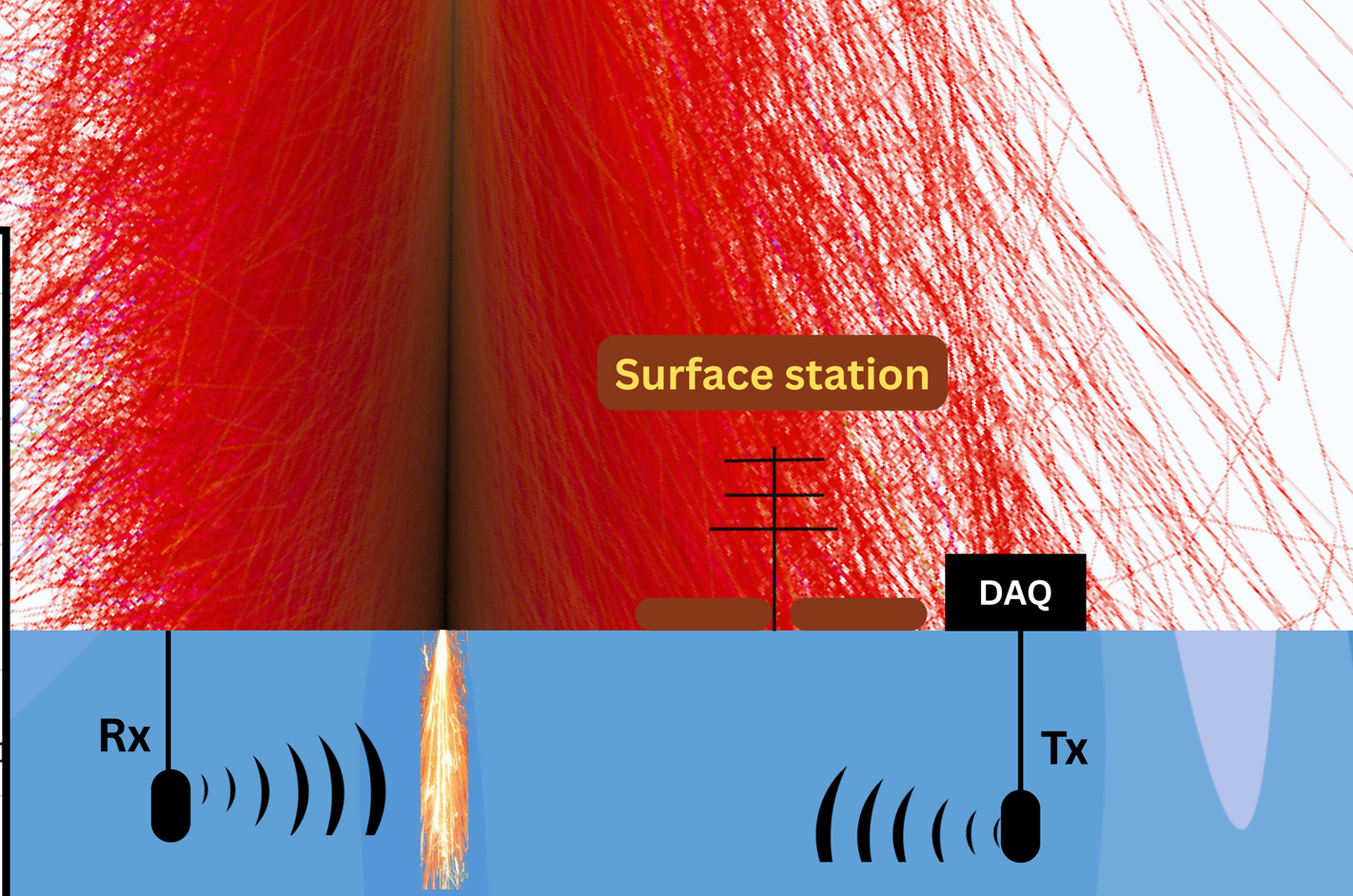


➨ Detection of secondary cascade with a radar

[1] S. De Kockere, K. de Vries, and N. van Eijndhoven, PoS ICRC2021, 1032 (2021).
[2] DOI: 10.1103/PhysRevD.104.102006

The Radar Echo Telescope for Cosmic rays





Deployed in Greenland summit station

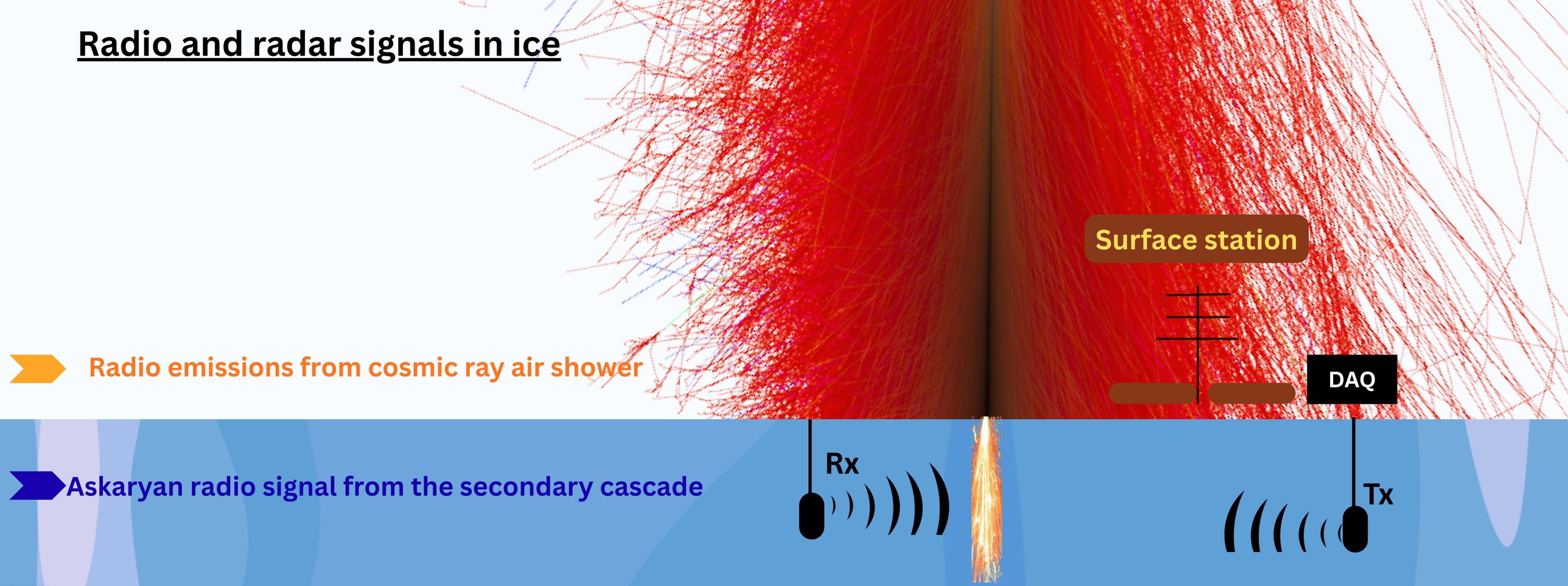
Data taking run in the summer of 2024

RET-CR experimental layout

[1] S. De Kockere, K. de Vries, and N. van Eijndhoven, PoS ICRC2021, 1032 (2021).

[2] DOI: 10.1103/PhysRevD.104.102006

Radio and radar signals in ice



Radio emissions from cosmic ray air shower

Askaryan radio signal from the secondary cascade

Radar signal

Simulation softwares :

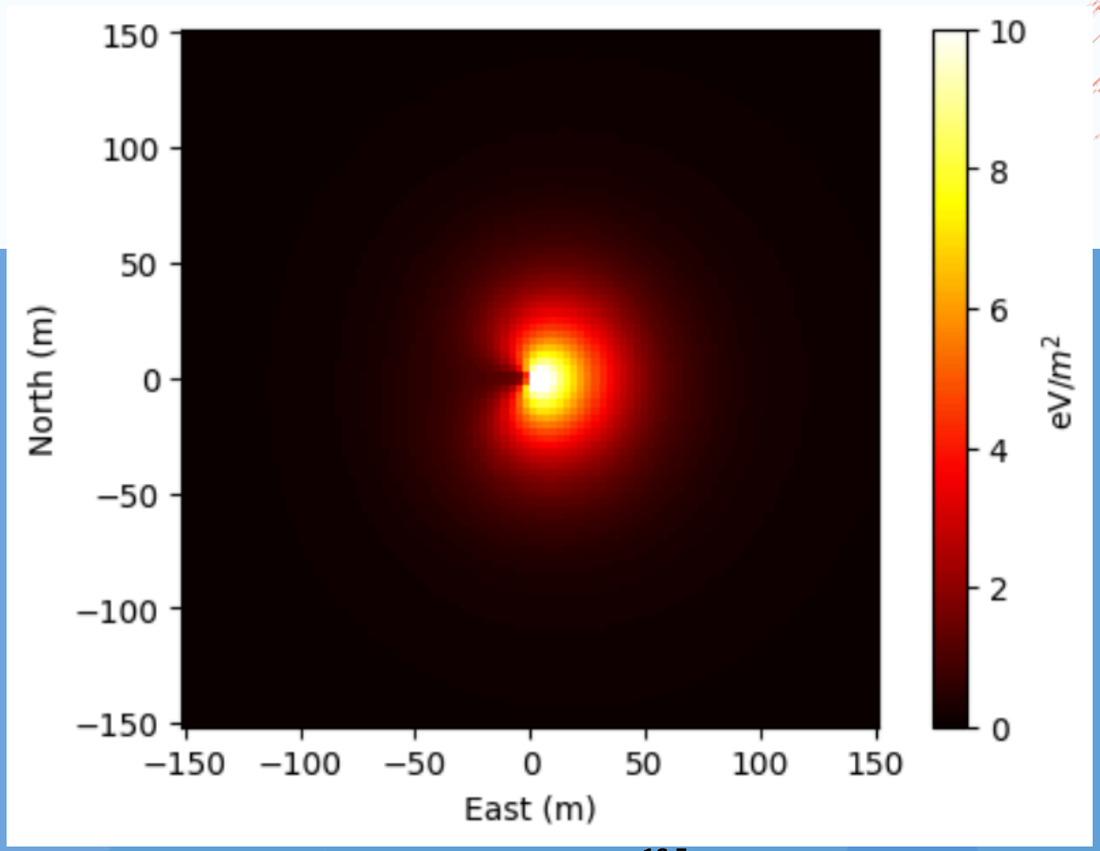
FAERIE - CORSIKA + GEANT4 (for Radio simulations)

MARES (for Radar simulations)

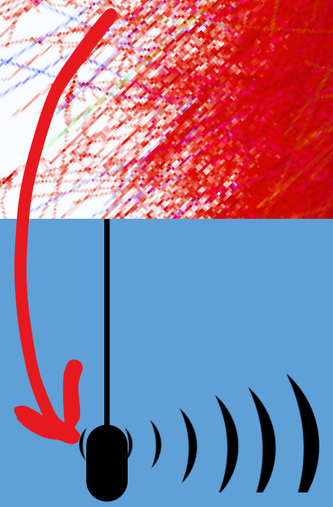
https://doi.org/10.48550/arXiv.2409.02185
https://doi.org/10.1103/PhysRevD.109.083012

In-air radio emission

Geomagnetic and Askaryan emissions

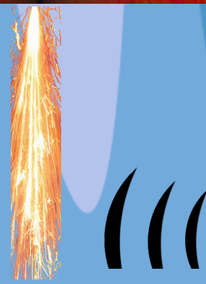


Primary energy = $10^{16.5}$ eV



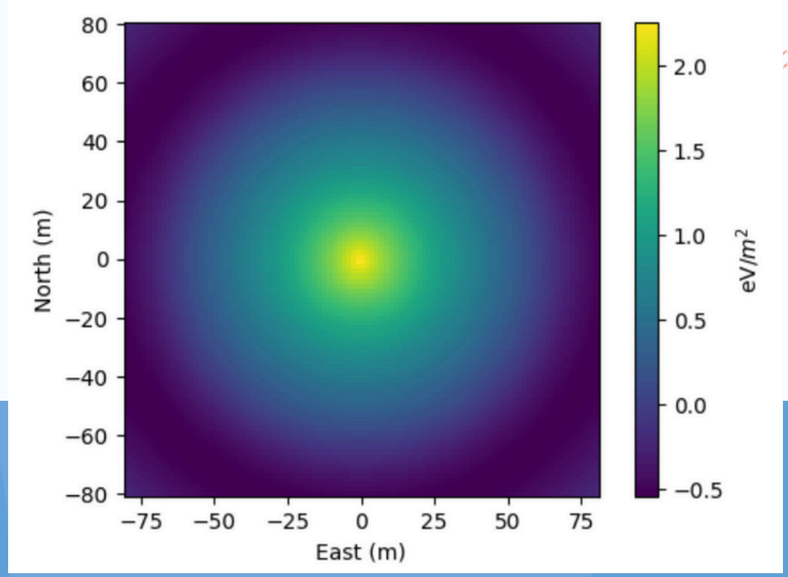
Rx

Depth = 10m in ice



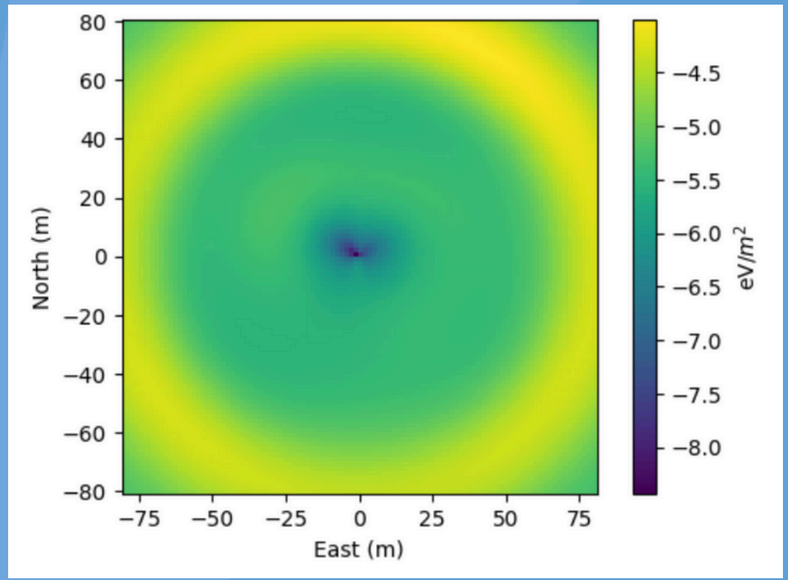
In-ice secondary cascade emission

Depth = 10m in ice

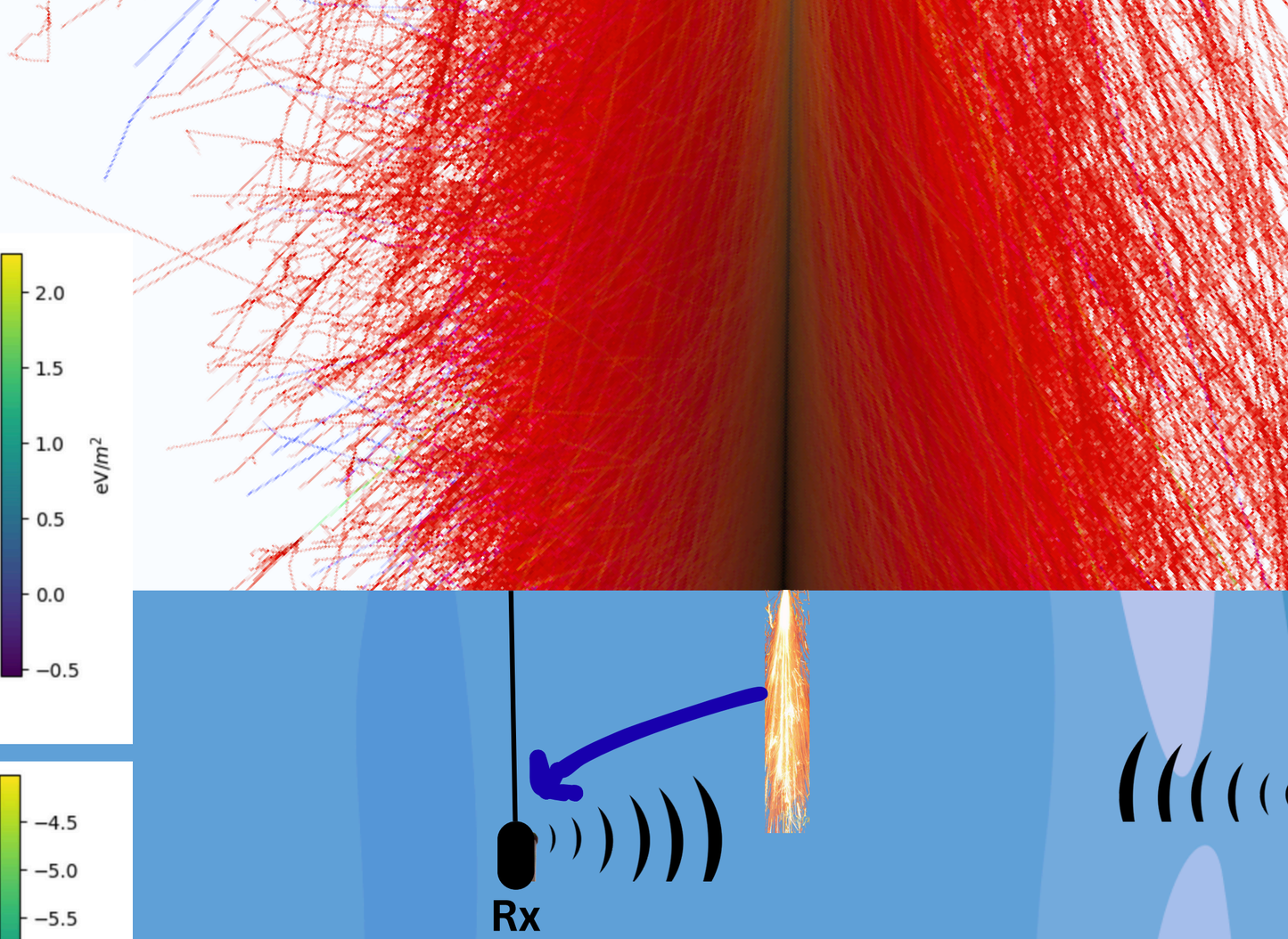


Primary energy = $10^{16.5}$ eV

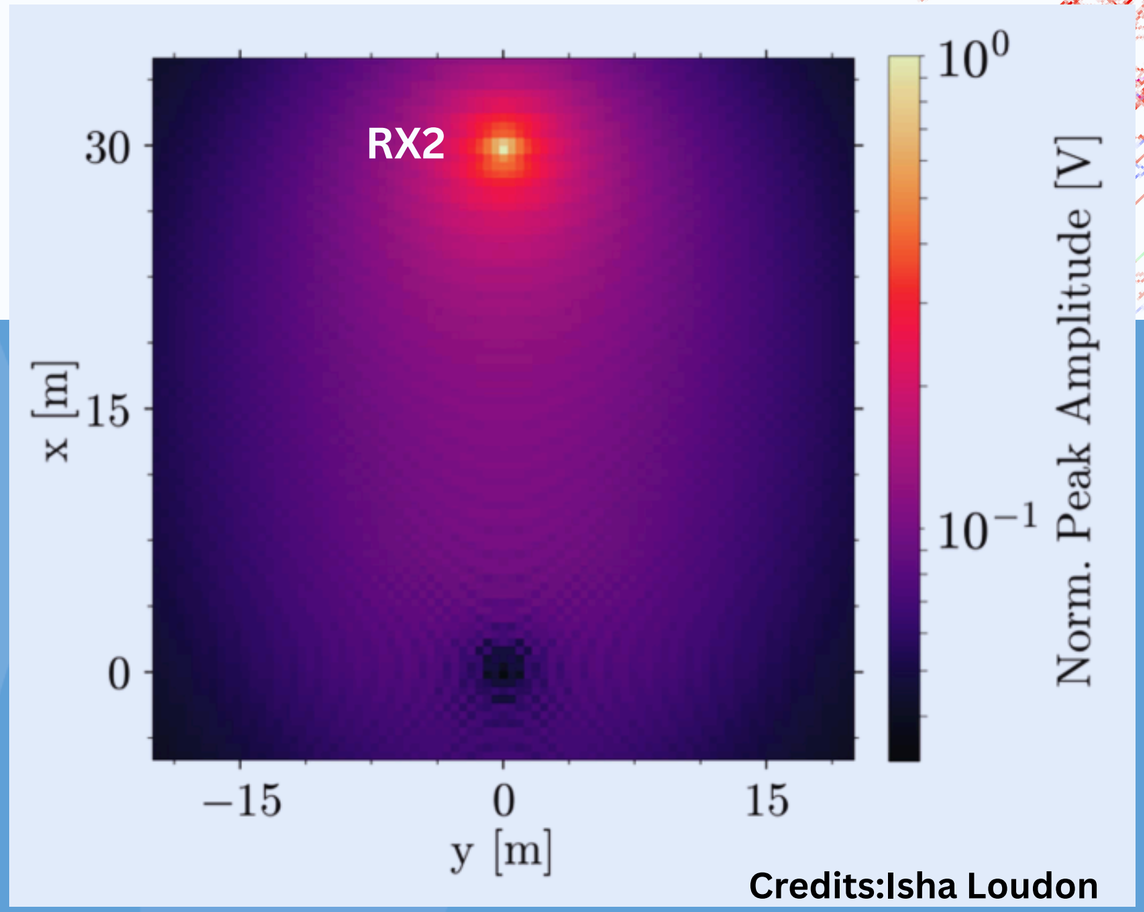
Depth = 100m in ice



Primary energy = $10^{15.0}$ eV

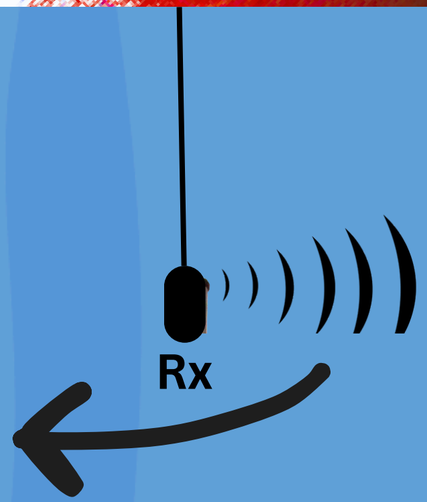


Radar Emission

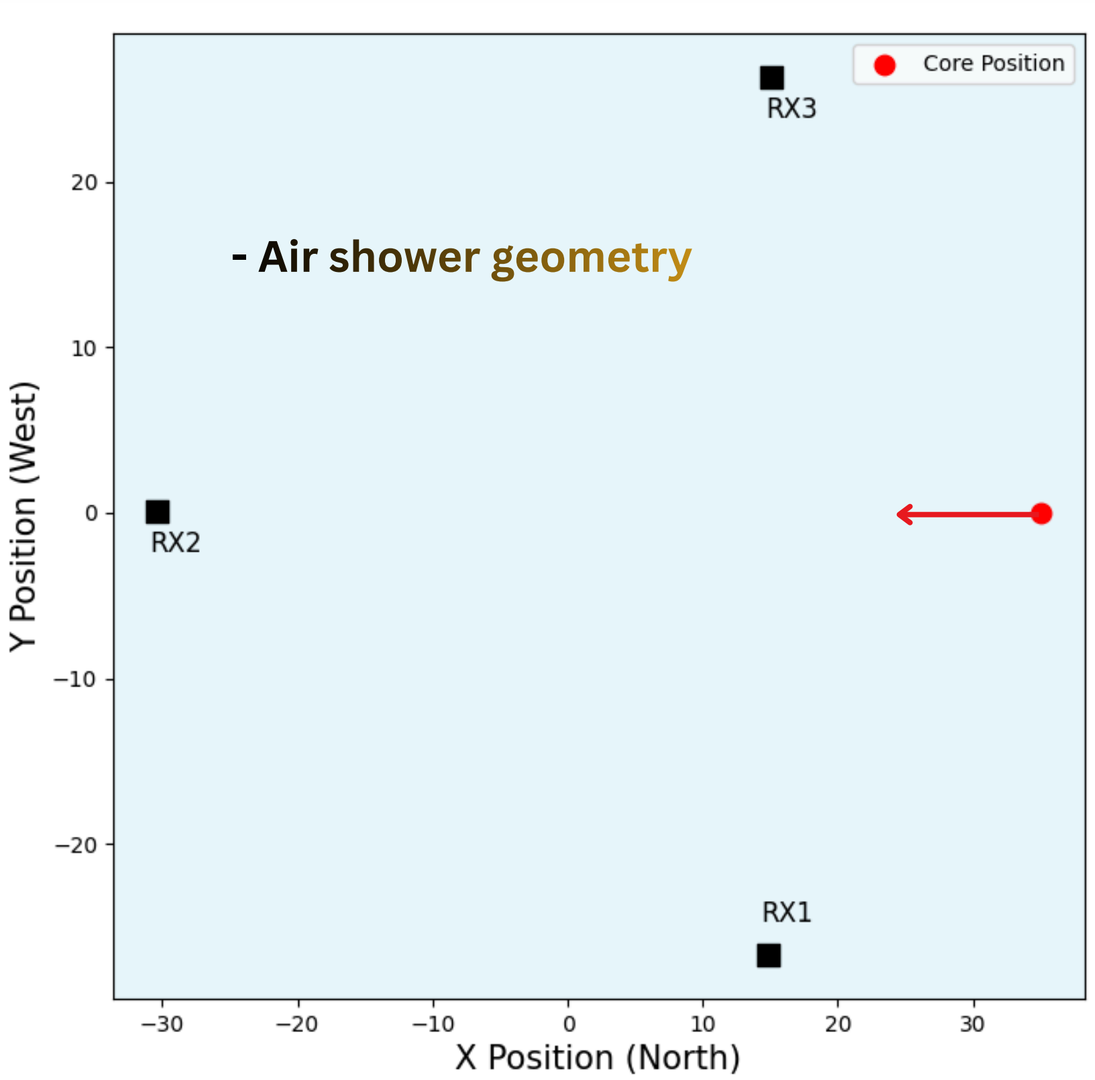


Credits:Isha Loudon

Primary energy = 20PeV

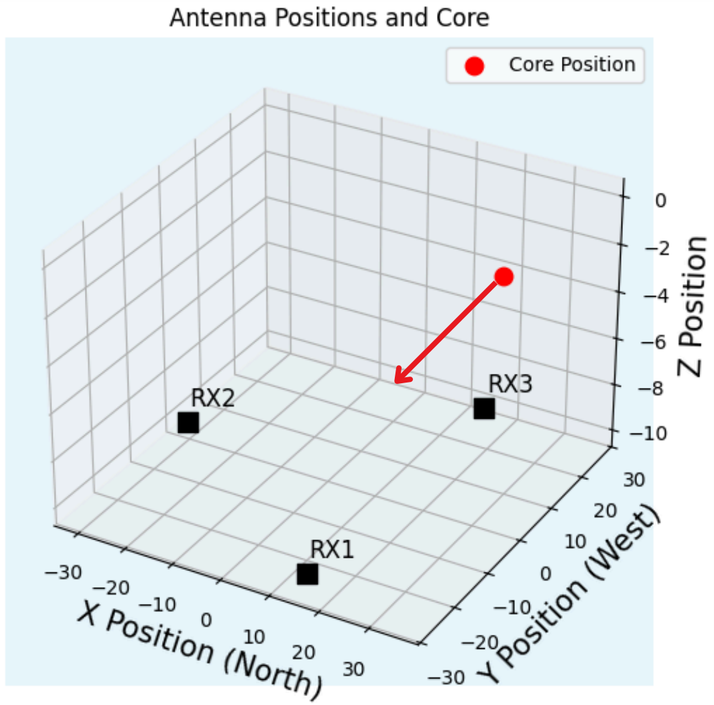


Case study

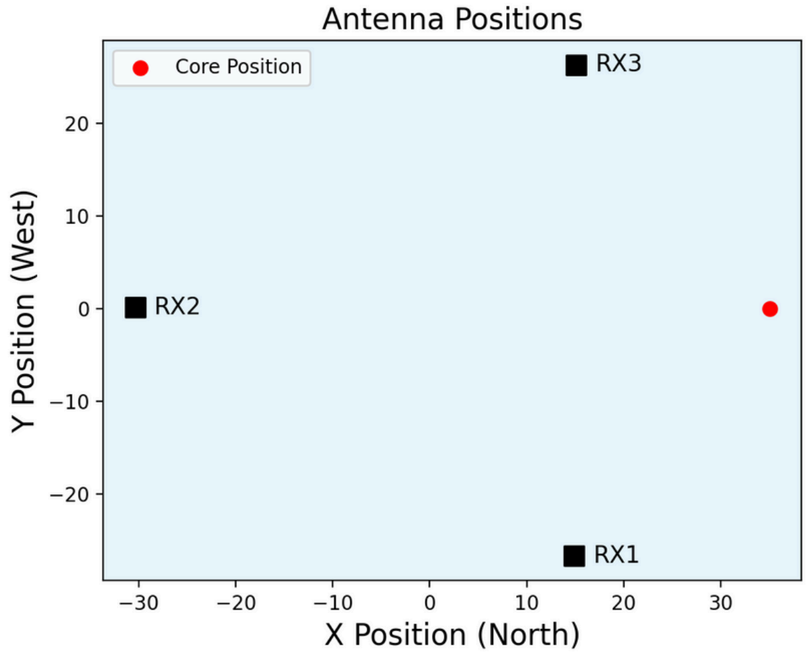


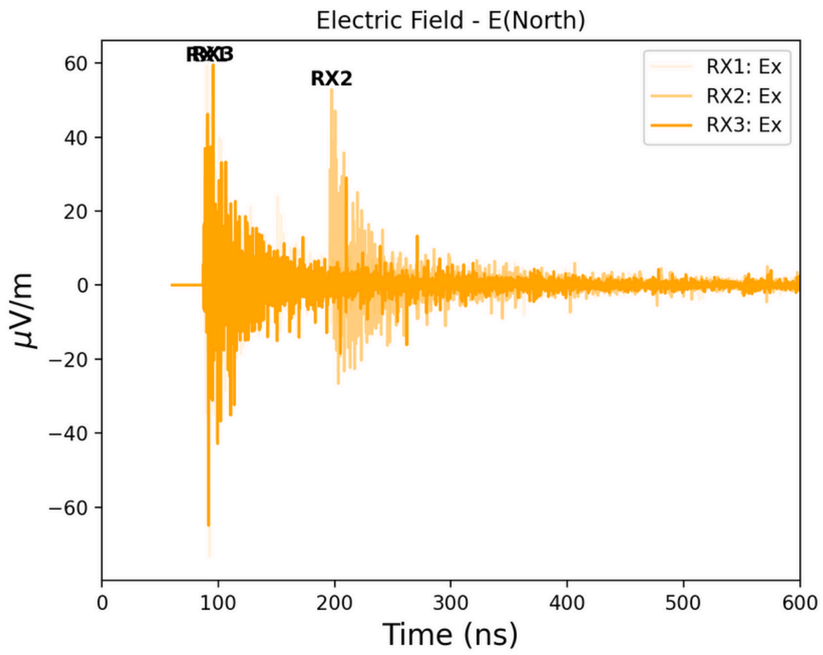
- Core position = 35 [m] [N] , 0 [m] [W]
- Zenith angle = 45° , Azimuth = 180°
- Energy = $10^{16.5}$ eV
- All receivers at 10m depth

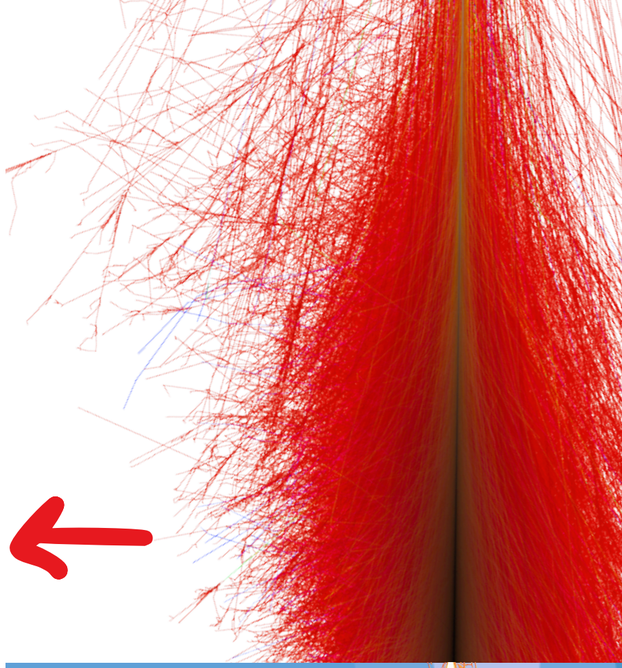
In 3D:

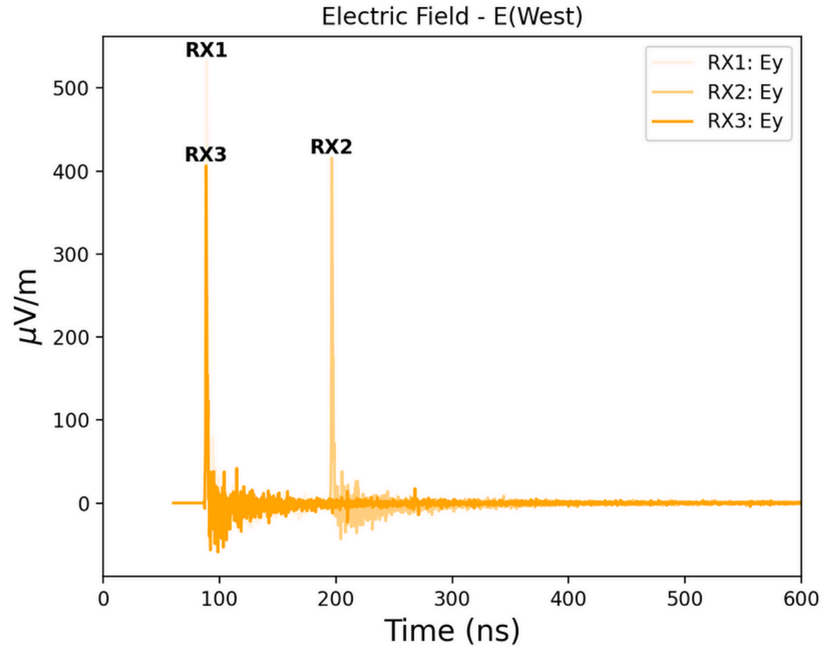


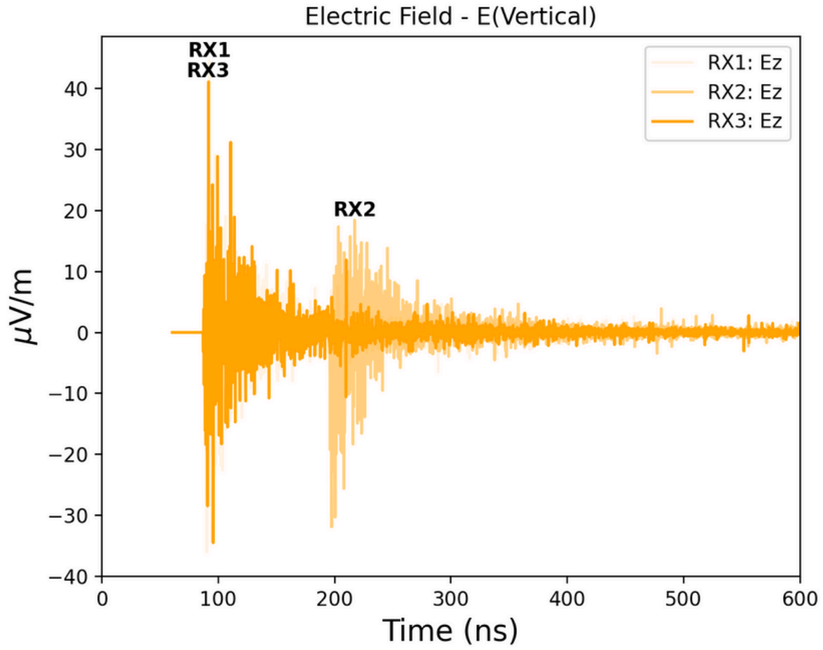
Case study: In-air radio emission



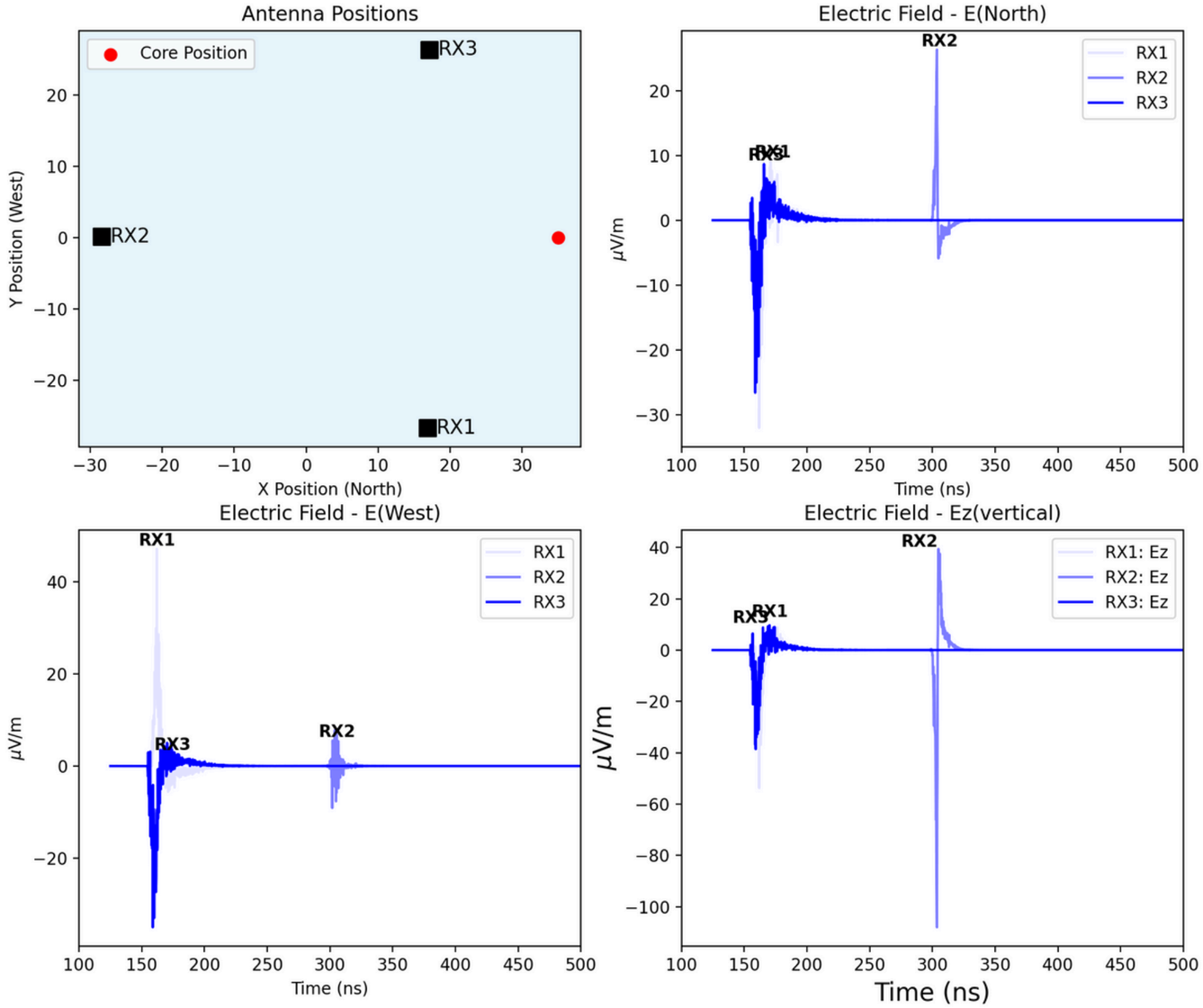




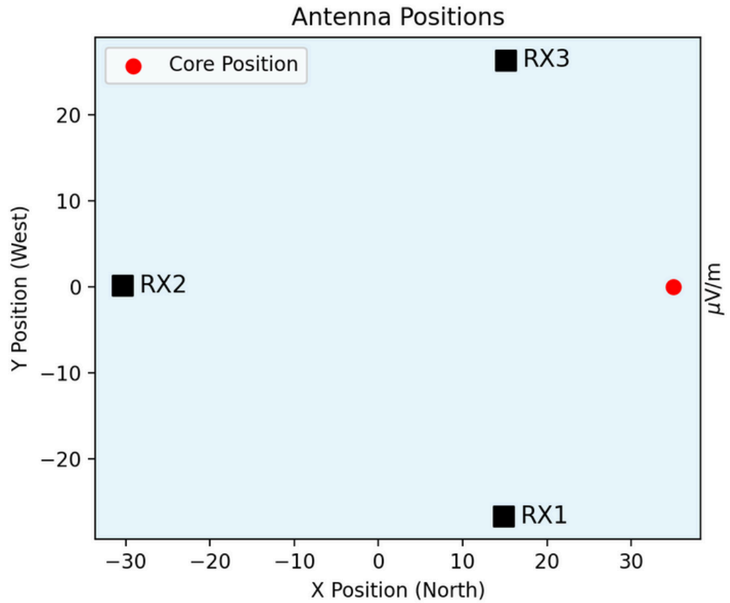


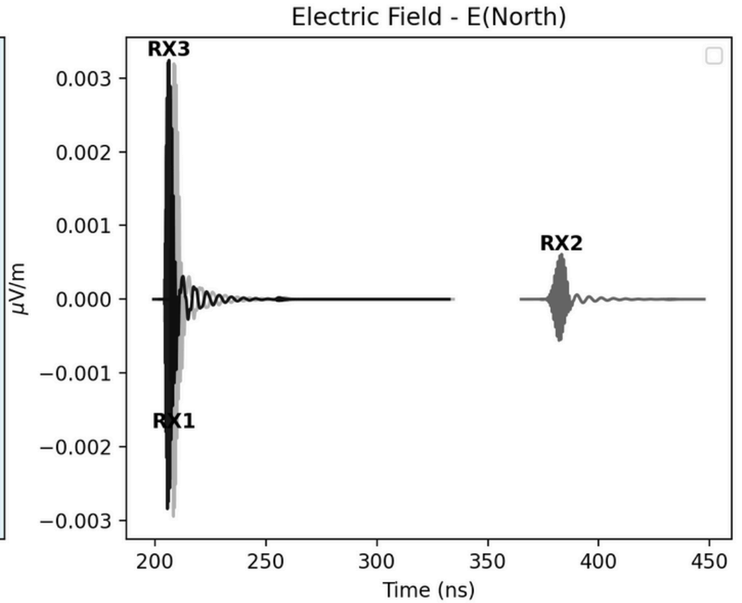


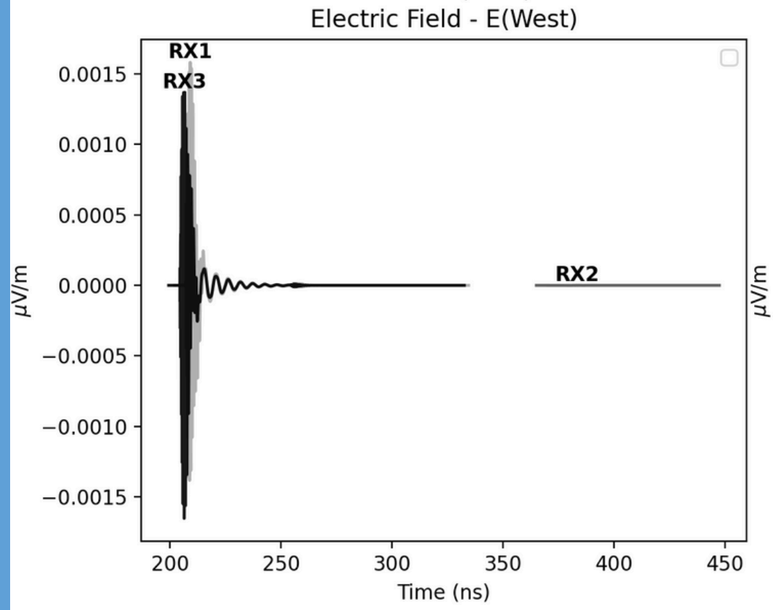
Case study: In-ice secondary cascade emission

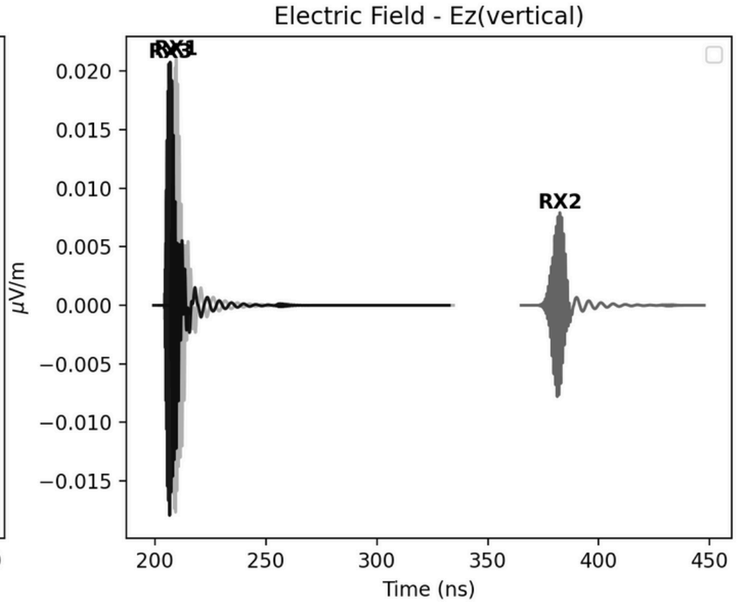


Radar signals

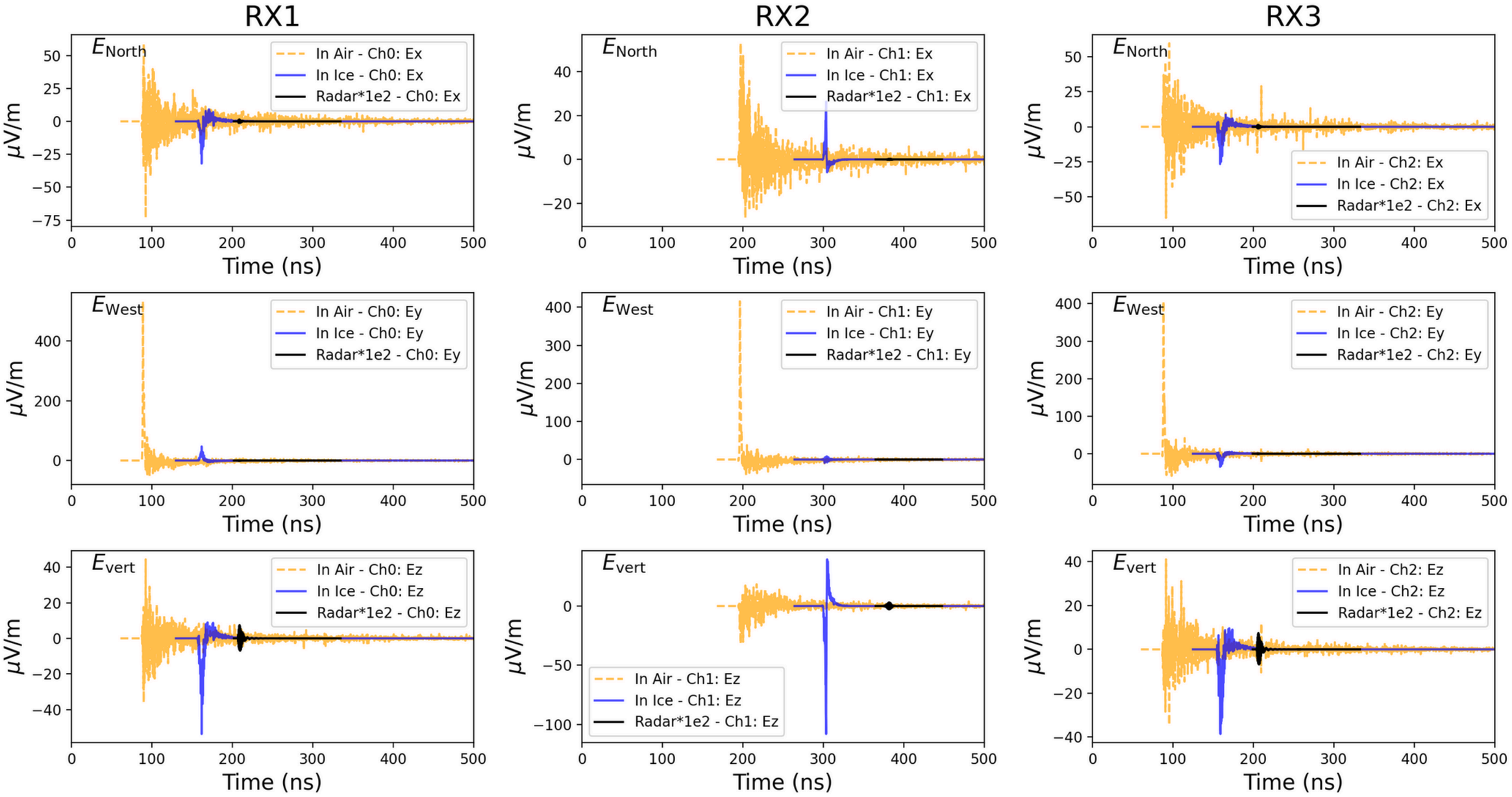




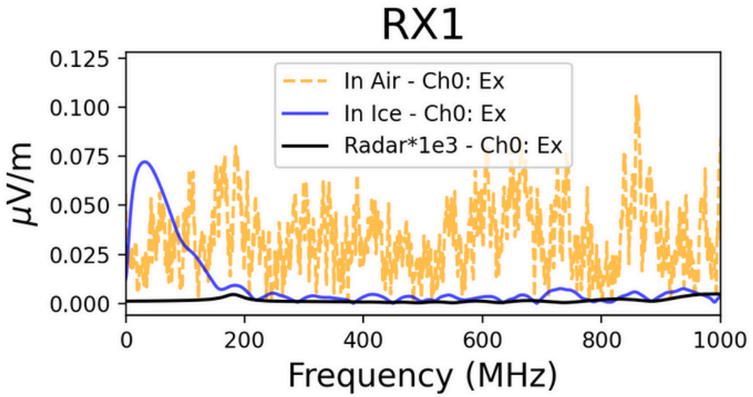


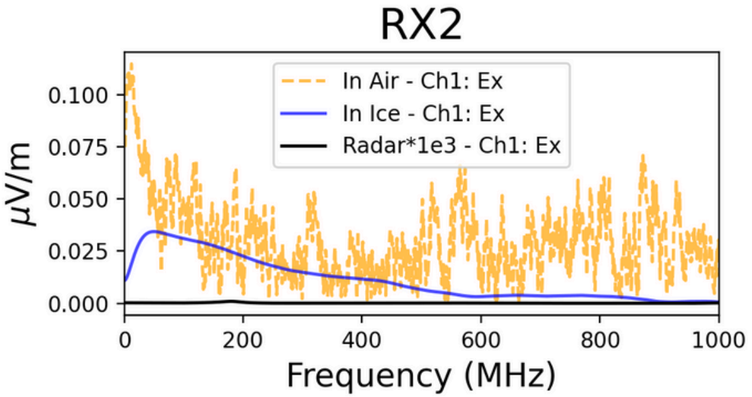


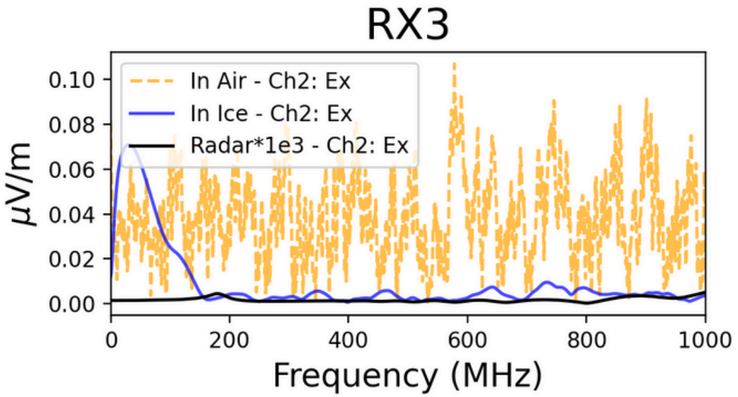
Case study: Combined signal

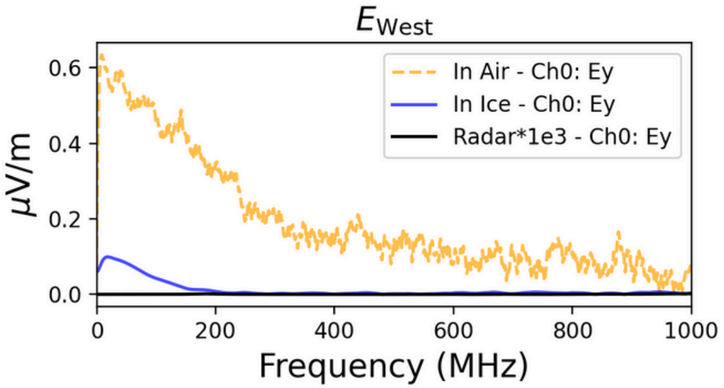


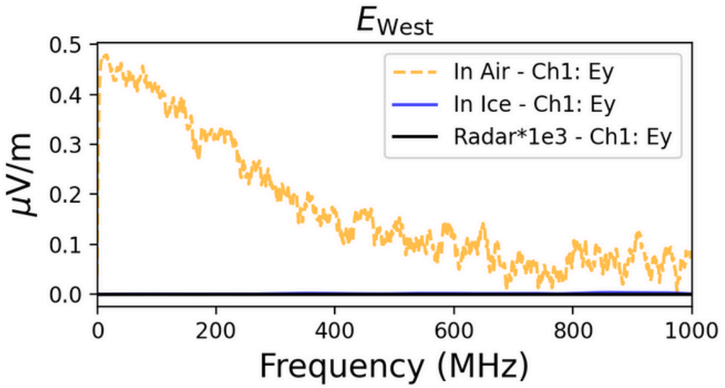
Case study: Combined spectrum

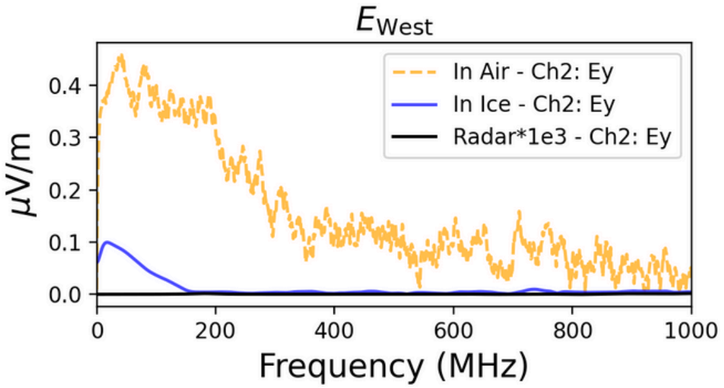


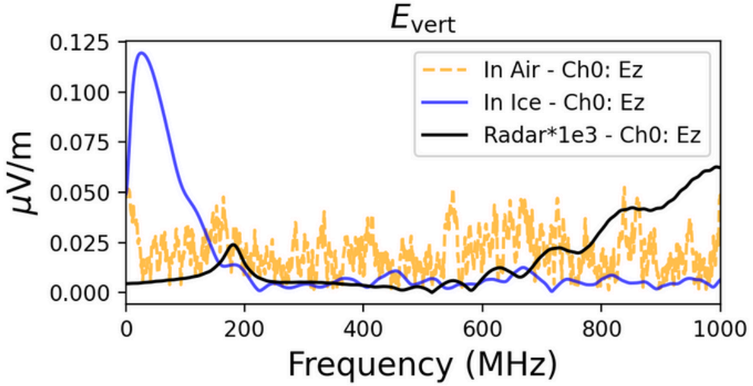


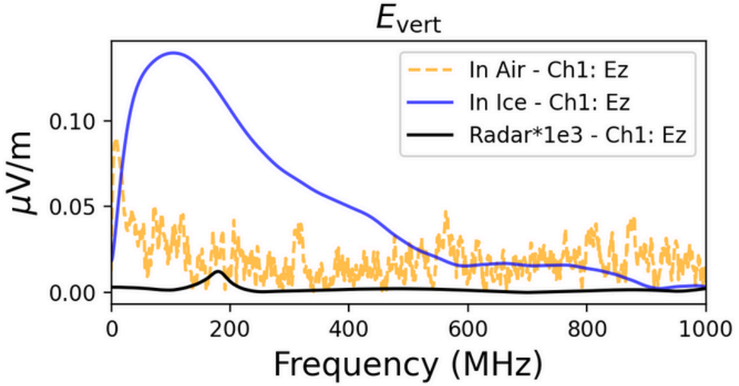


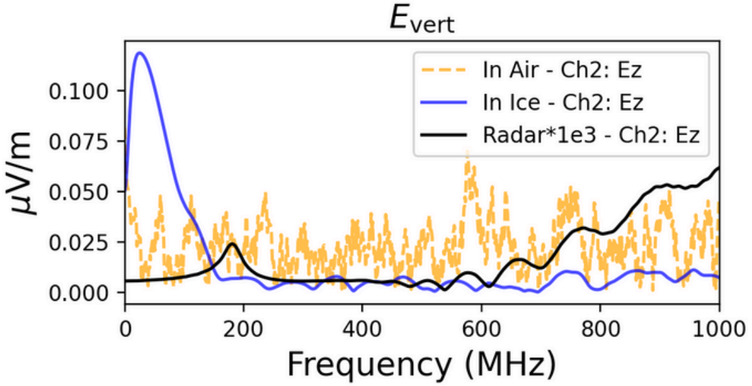




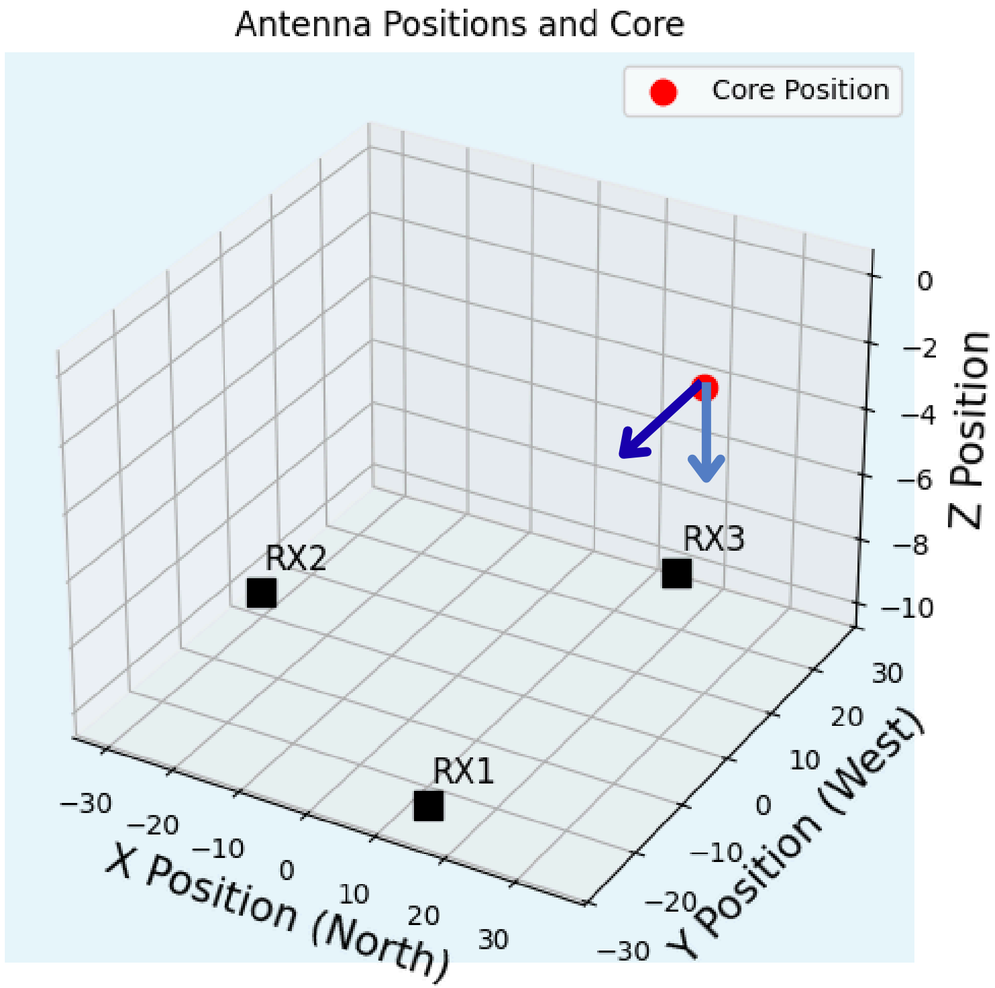


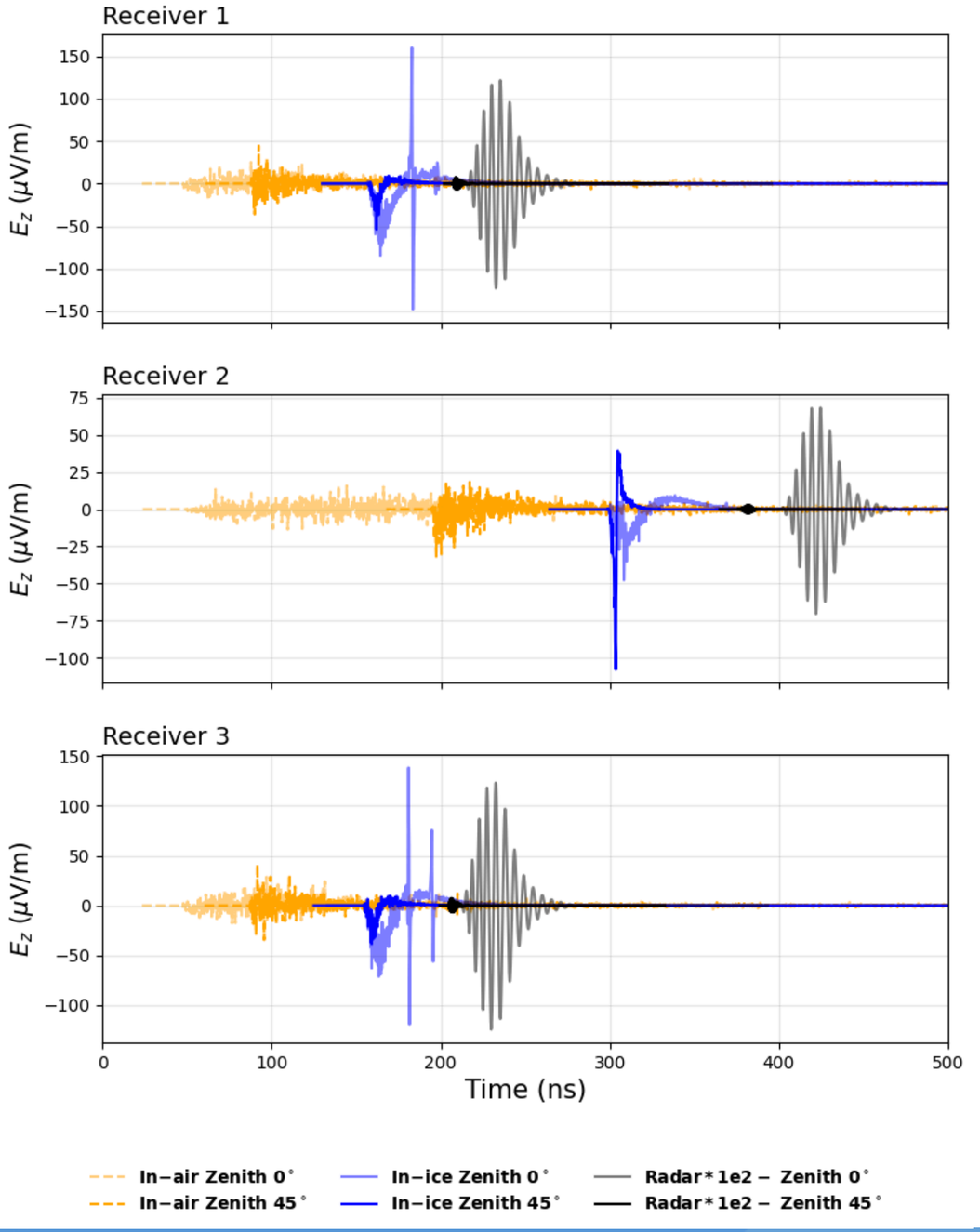






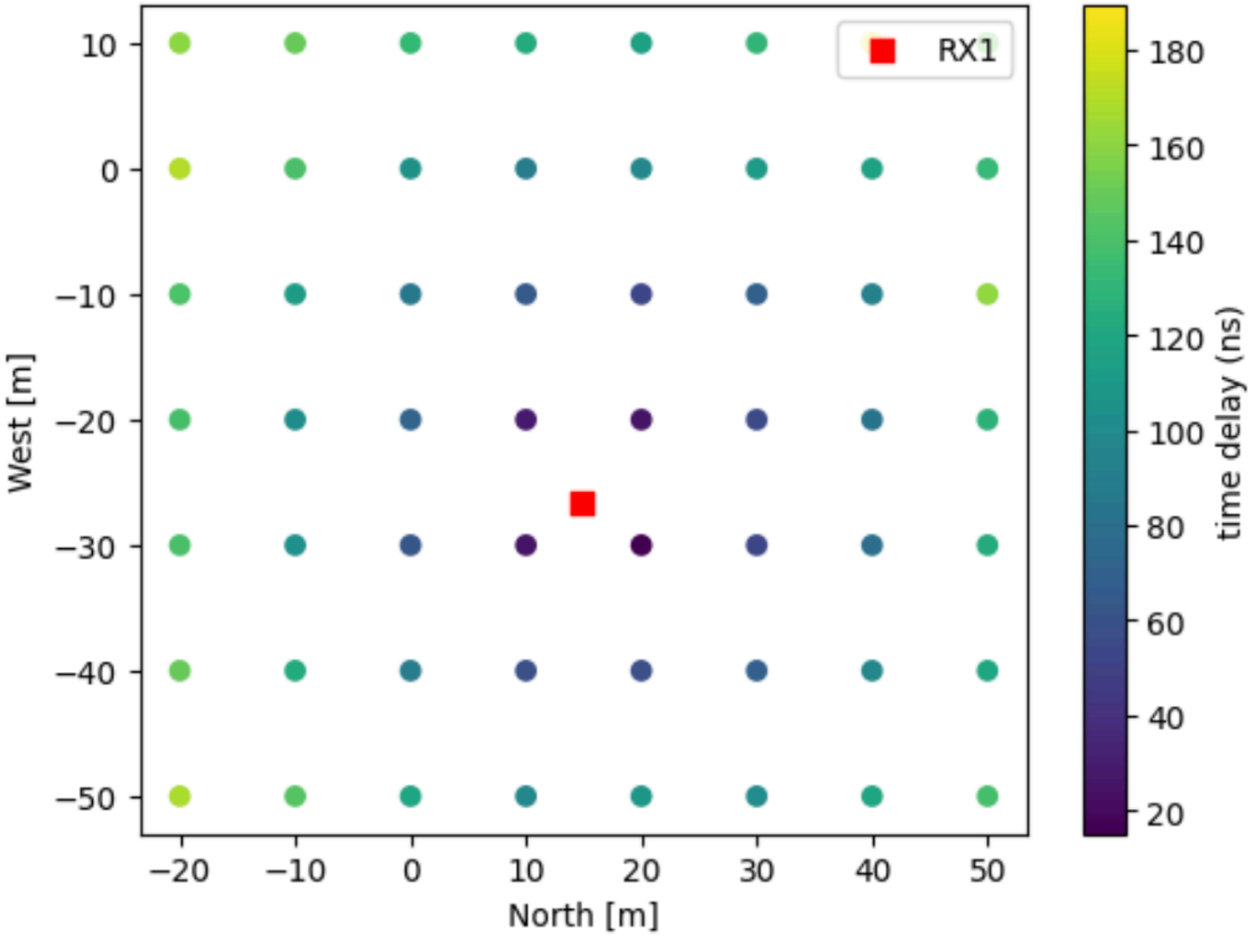
Different arrival directions



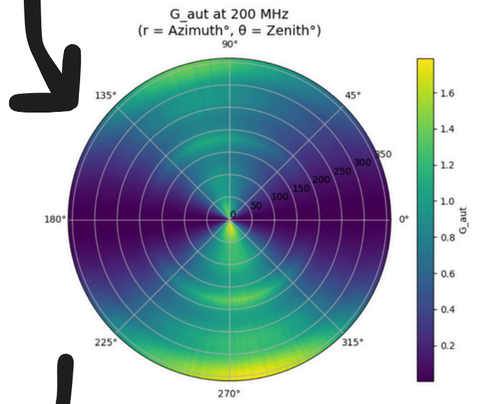


Timing Study (Ongoing)

Core position dependant timing delays between In-air and radar signal at RX1



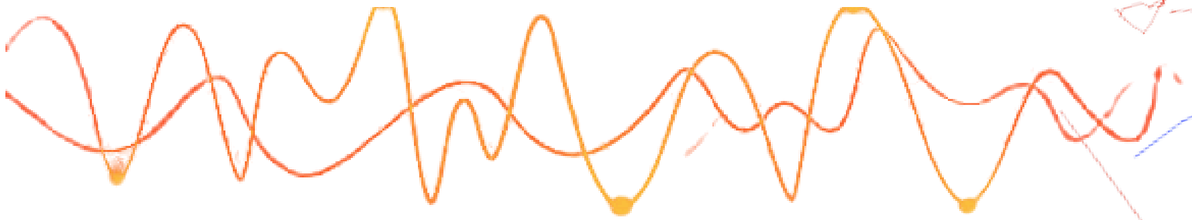
Realistic signal studies: (Ongoing)

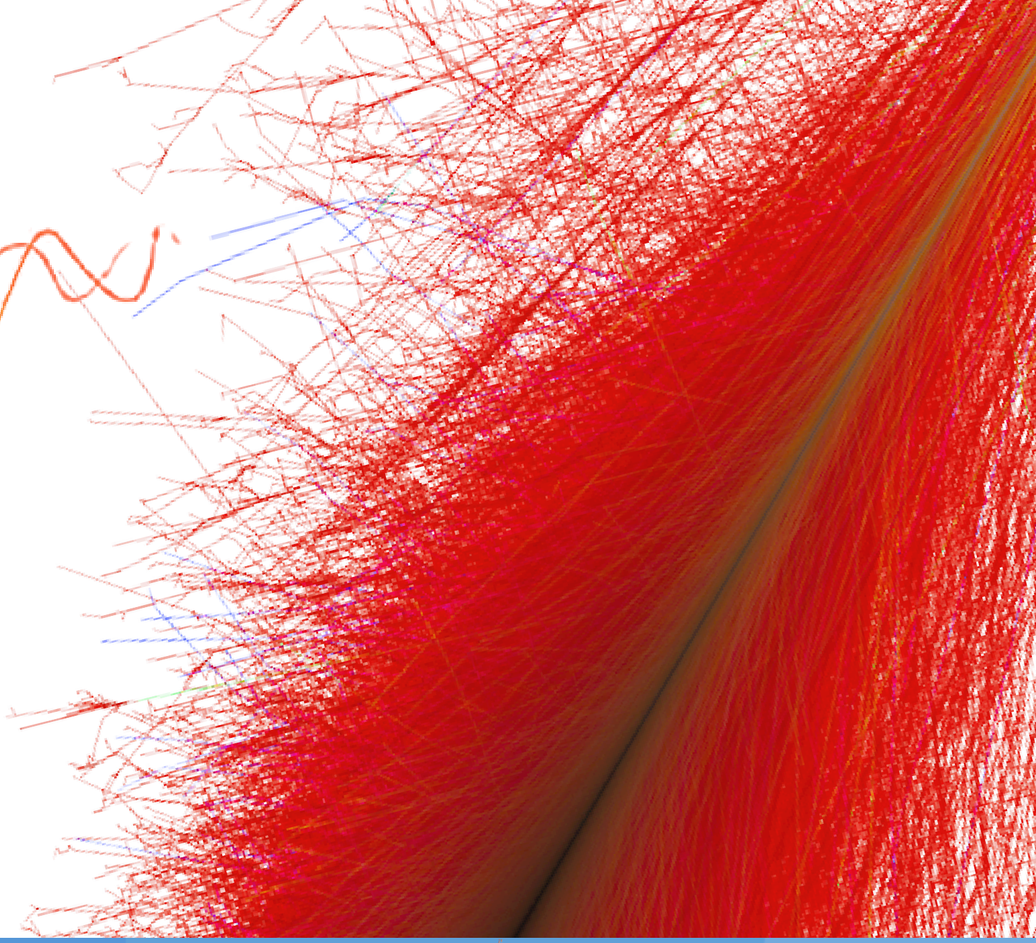


Antenna Modeling

VOLTAGE OUTPUT

Conclusions





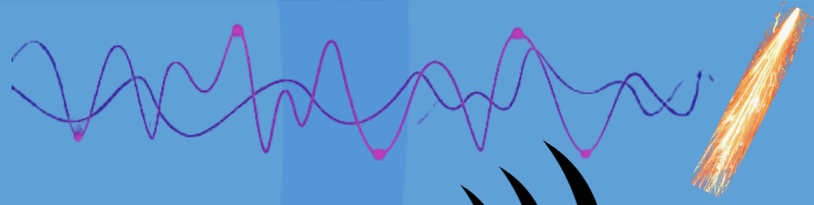
From the radar signal:

The timing of the signal could provide information on the vertex positions

The Frequency content of the signal depends on the arrival direction

The Energy of the primary can be estimated from the signal amplitude

- We also have the radio footprints in our detector
- Three signal signatures for the same event



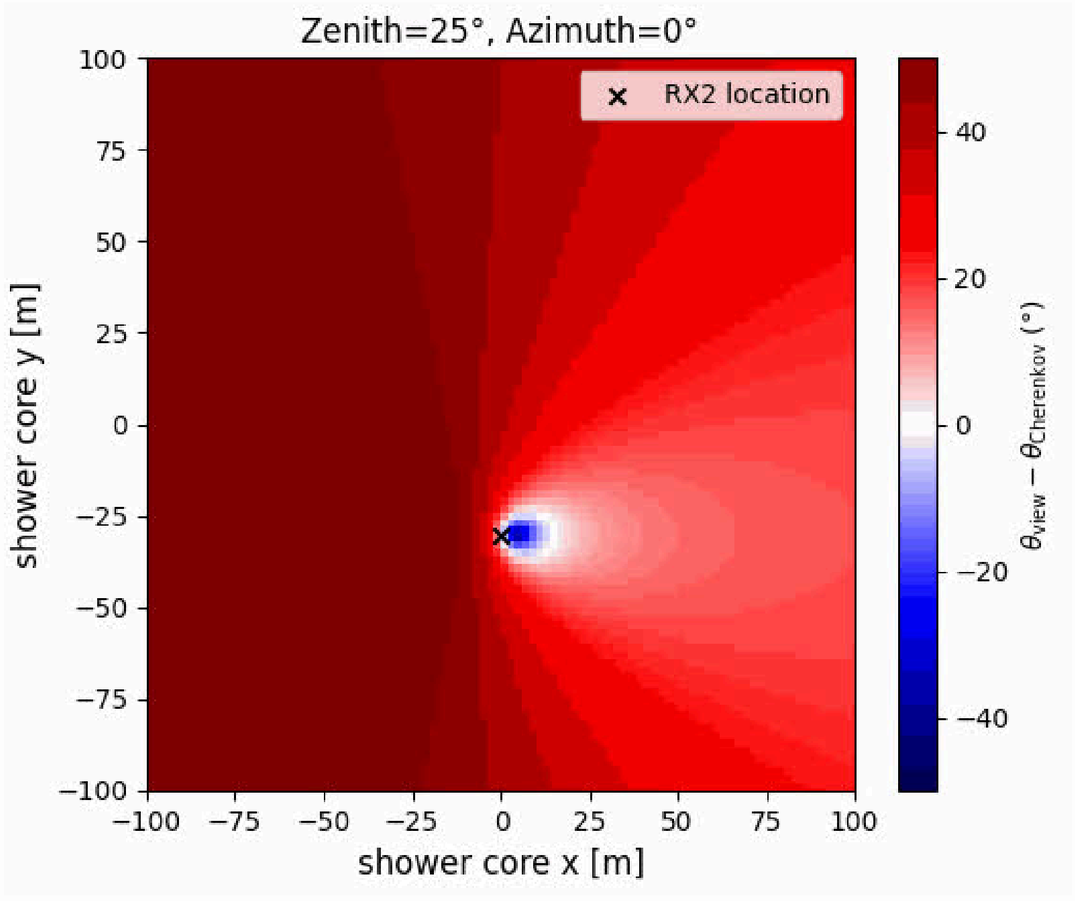
RADAR ECHO TELESCOPE

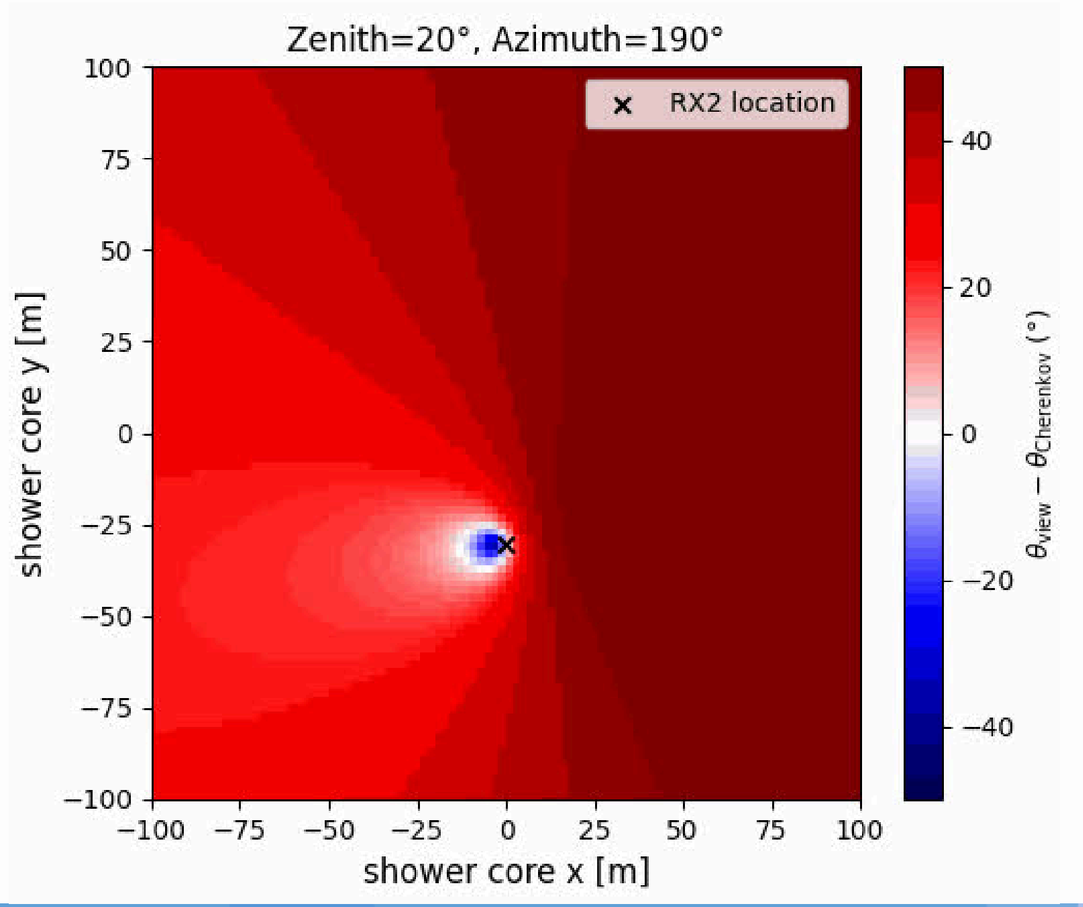
In-ice secondary cascade emission

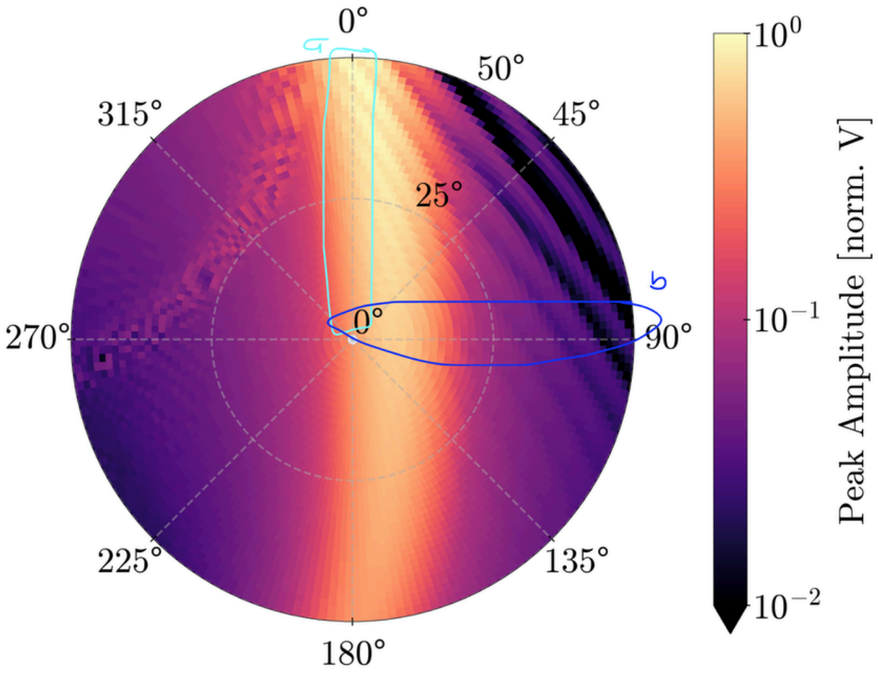
Assumptions:

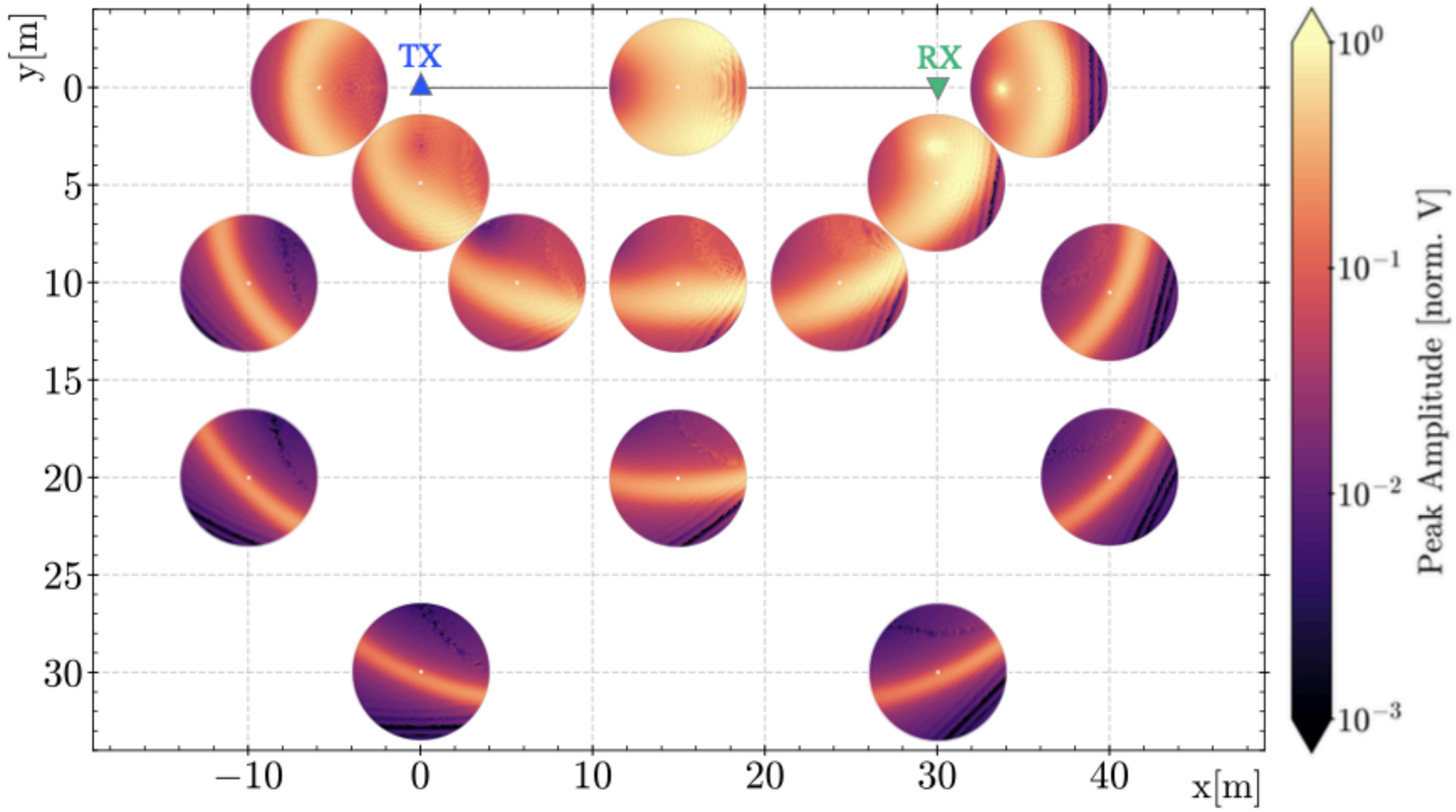
- Shower maxima of secondary cascade at ~5m
- Cherenkov angle in ice kept at 45°

Theoretical calculations for position of receiver with different corepositions in the cherenkov region:









Credits:Isha Loudon