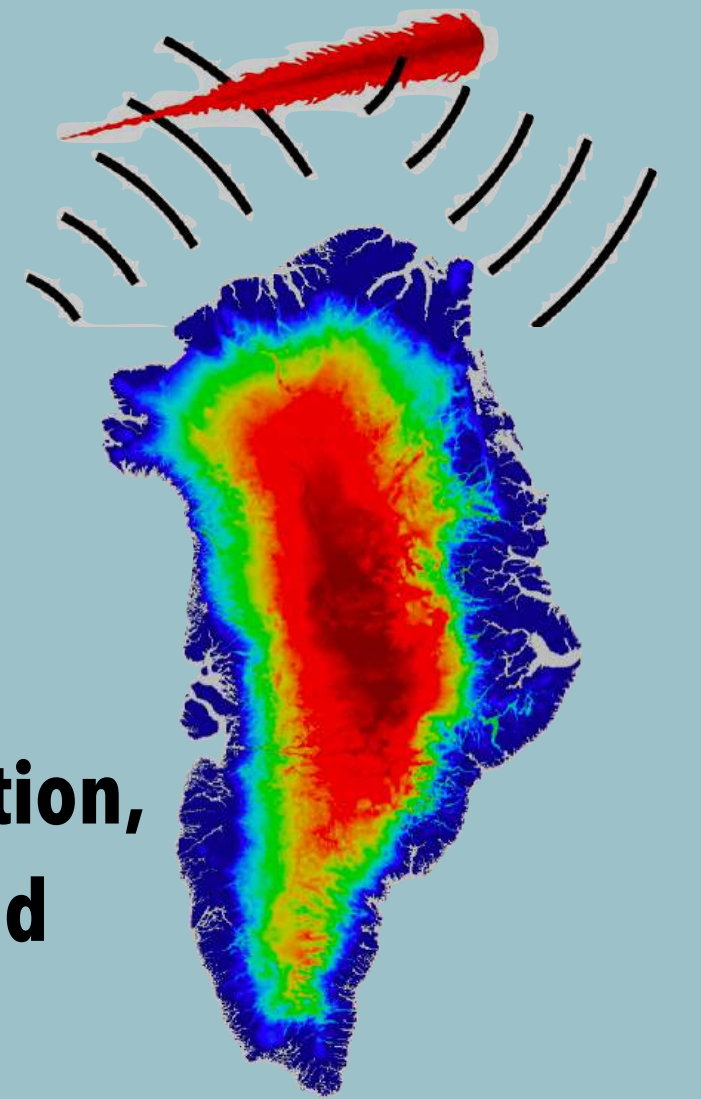


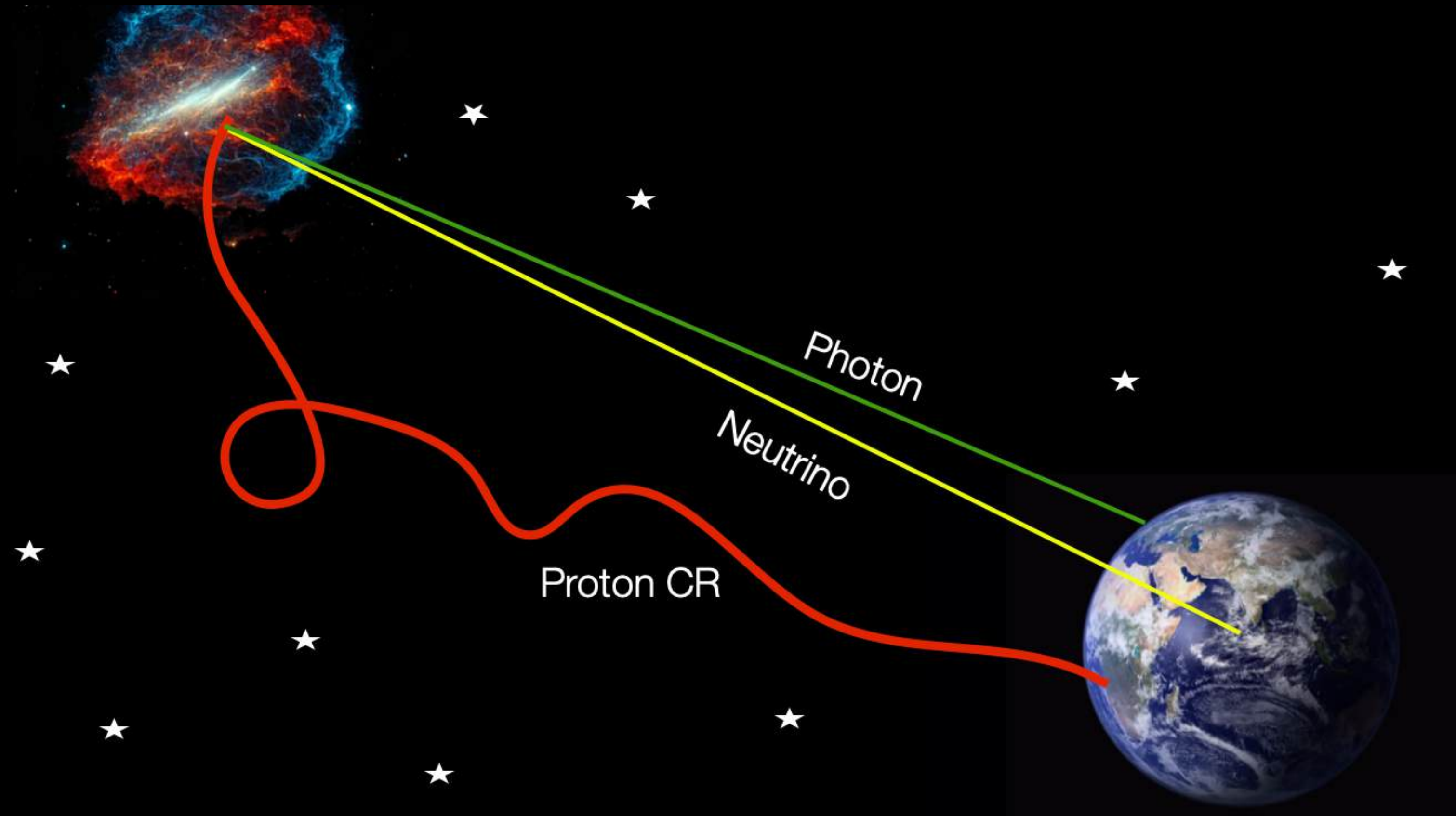
# The Radar Echo Telescope (RET) : A new approach for high energy neutrino detections



**Summit station,  
Greenland**



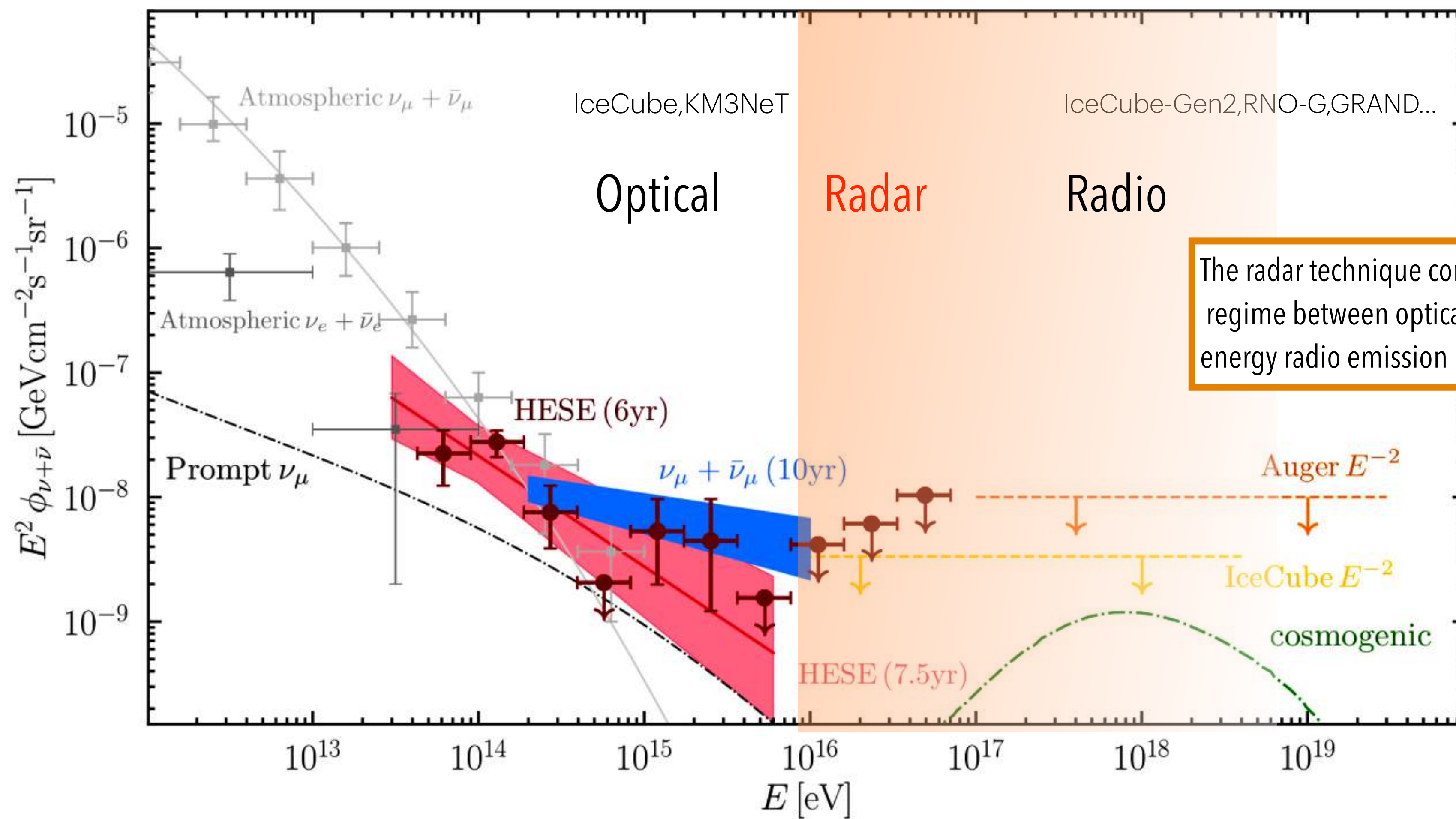
# Neutrinos as important multi-messengers



**Neutrinos can travel large distances without any interactions**  
**Directly tracing back to the sources ( no deflections in galactic magnetic fields)**

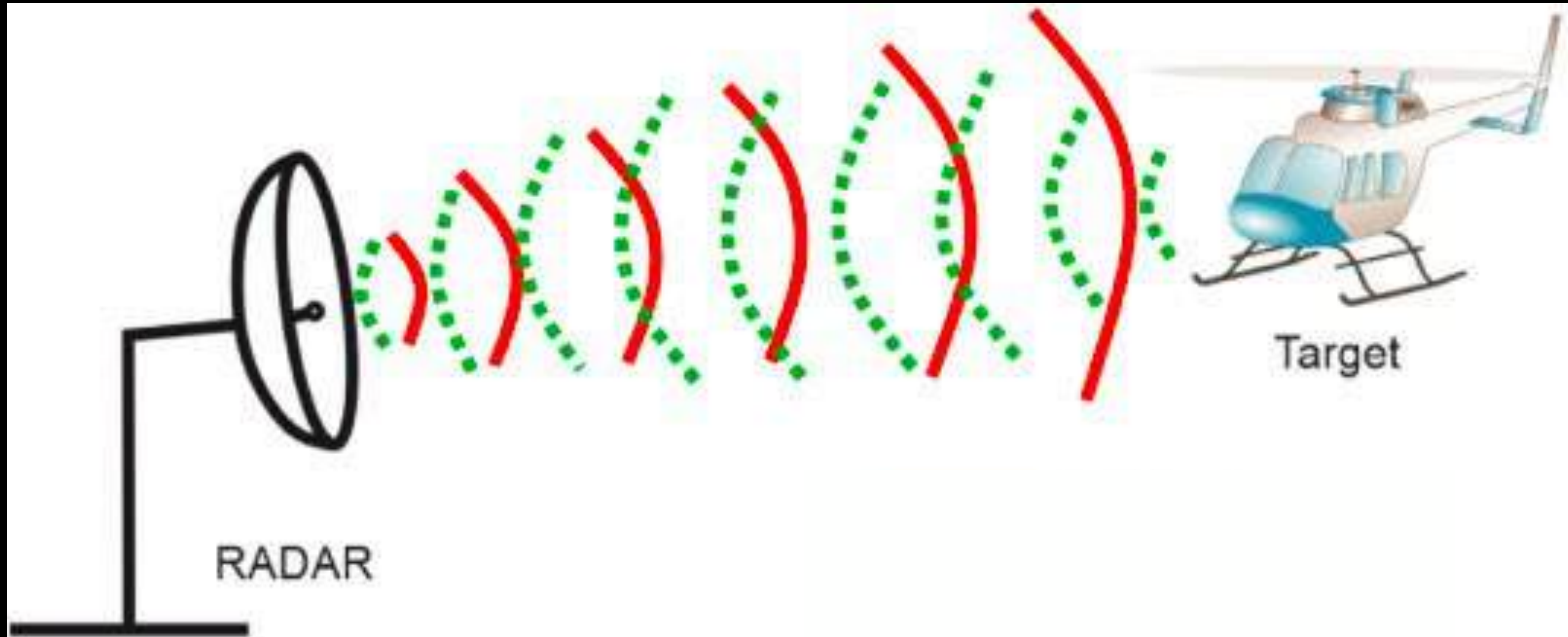


# Current Neutrino detection techniques



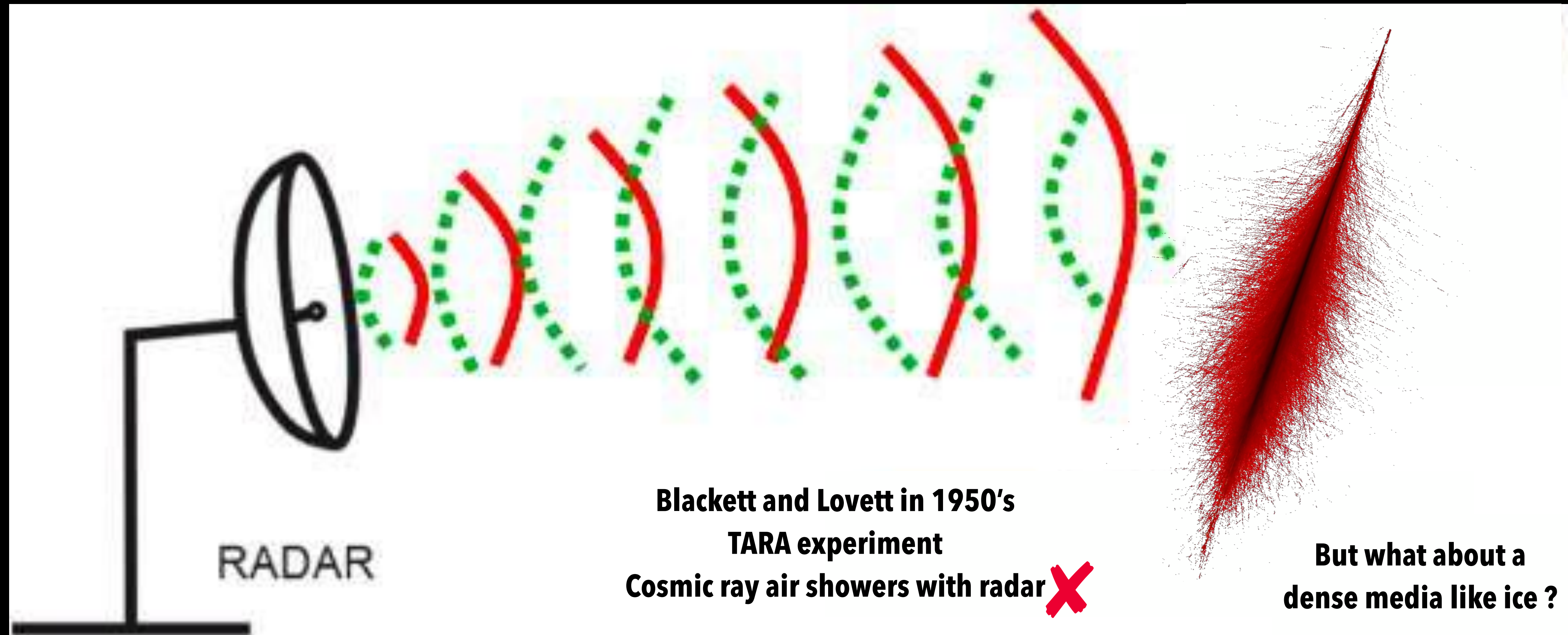
The radar technique complements the gap in the energy regime between optical cherenkov neutrino detection experiments and high energy radio emission based detectors!

# The Radar Method





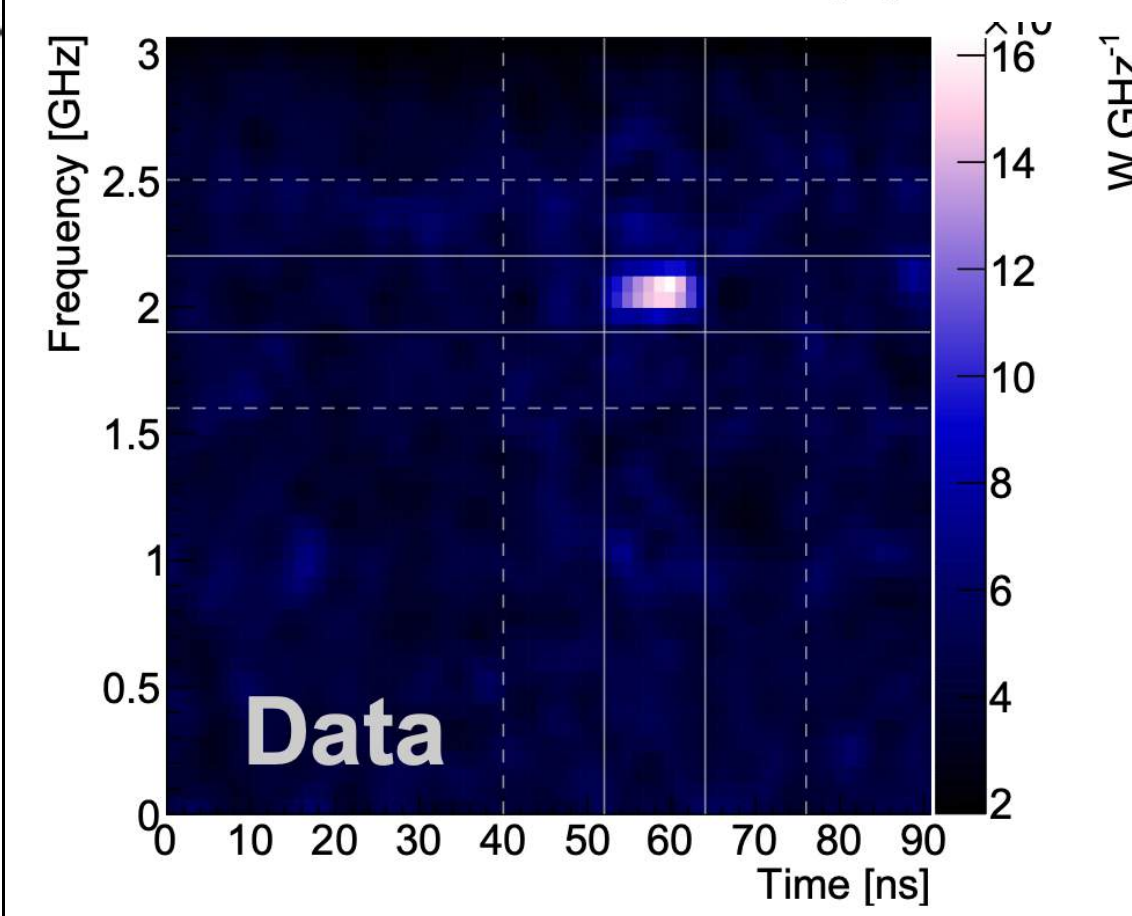
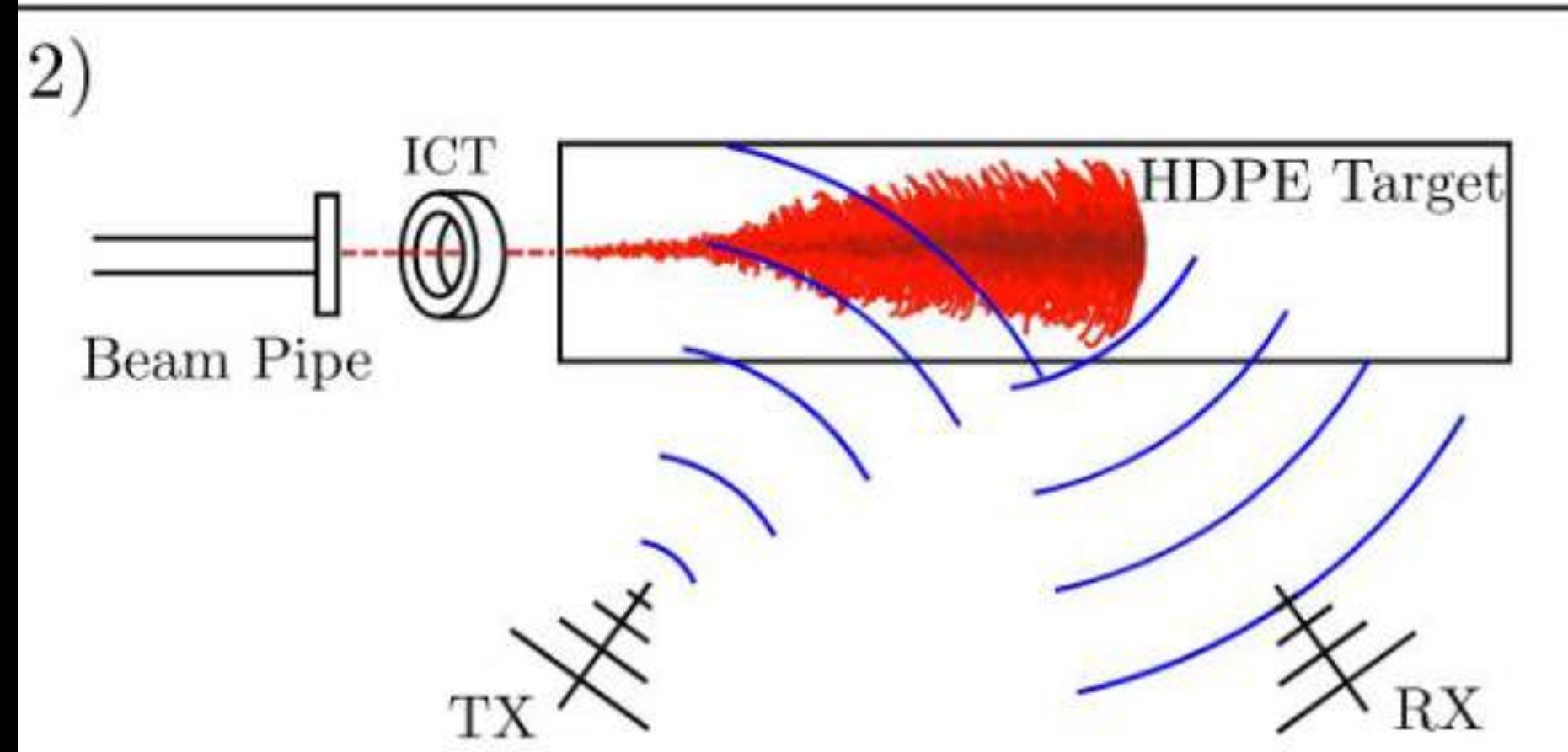
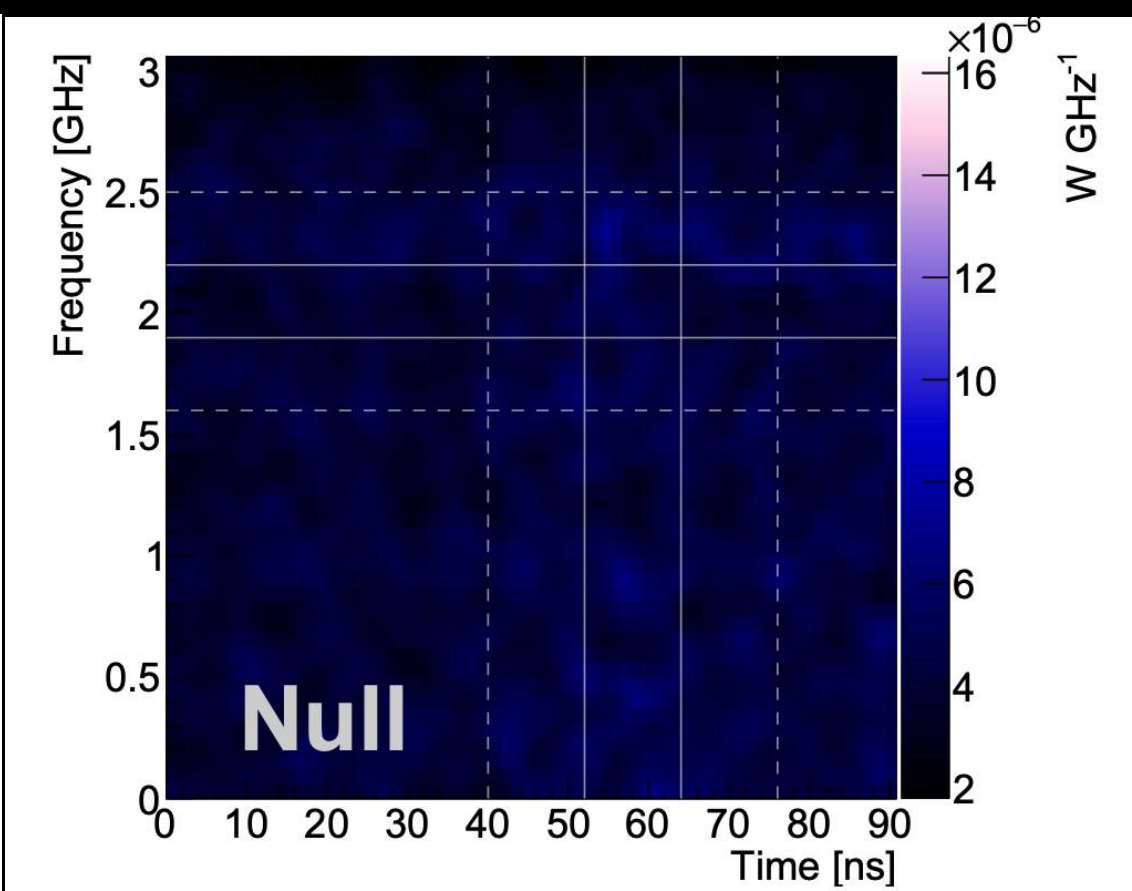
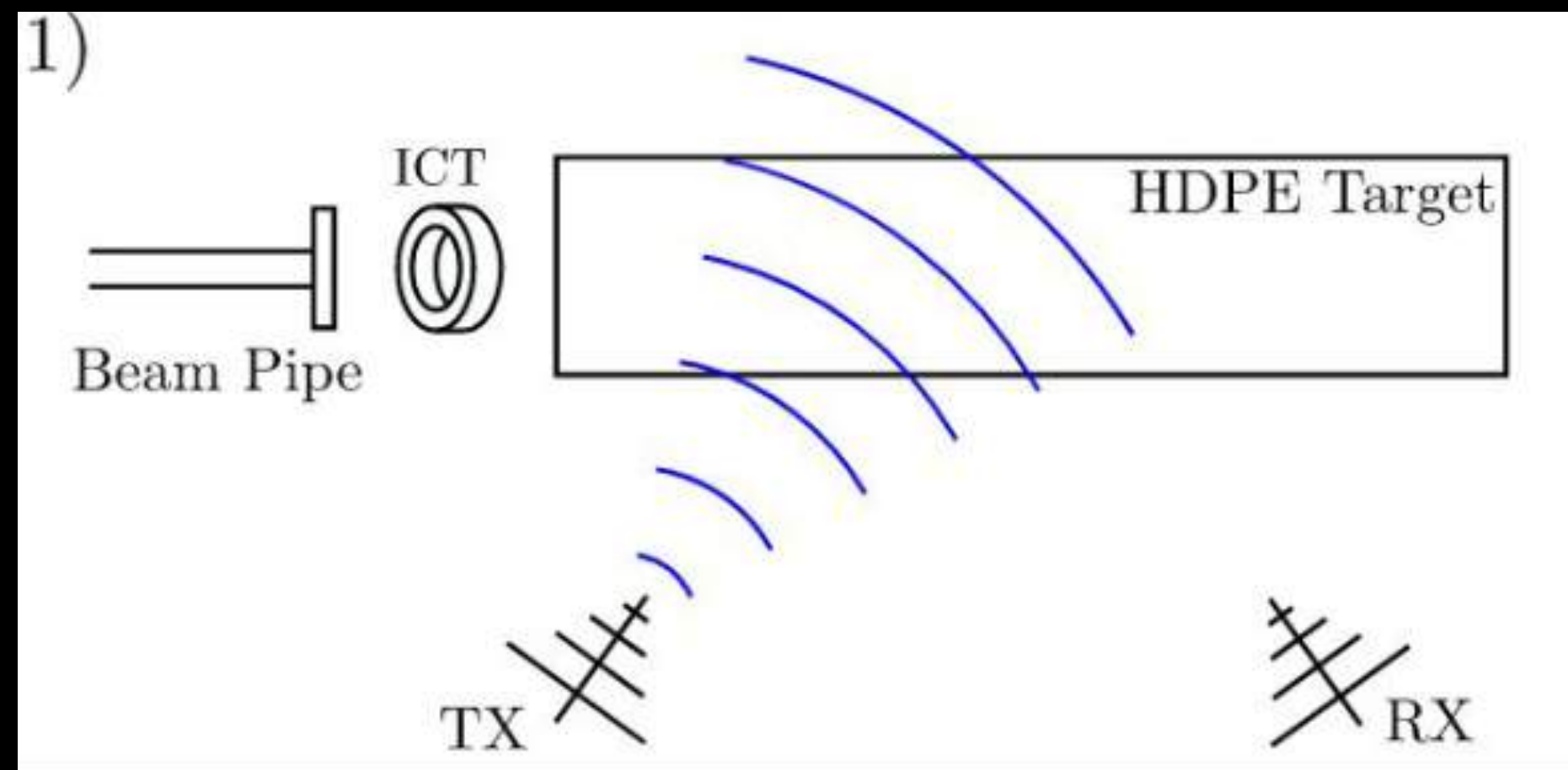
# Question : Can particle cascades be detected with a radar?



**Radar reflections off the plasma left behind after the high energy particle cascade?**



# SLAC T-576 Experiment(2020)



The density of the particle cascade was similar to that of a greater than  $10^{16}$  eV neutrino induced shower in ice

arXiv:1910.12830

**A successful detection of a radar echo in LAB ✓**

**A successful detection of a radar echo in nature ?**

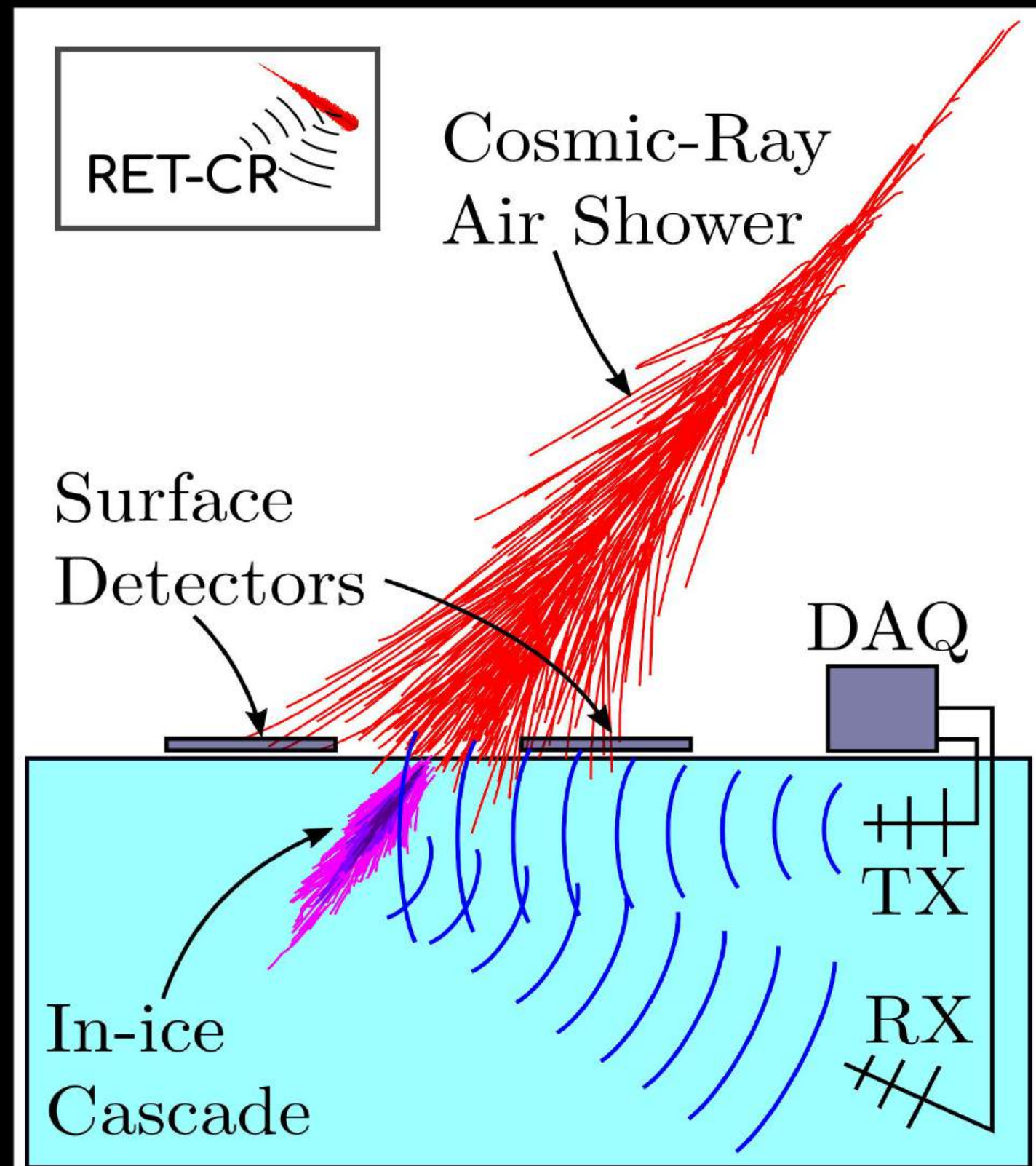


# The Radar Echo Telescope for Cosmic Rays (RET-CR)

**Test Bed Experiment!**

**Cosmic ray air showers - in-nature  
"test beam" for  
the radar method in ICE!**

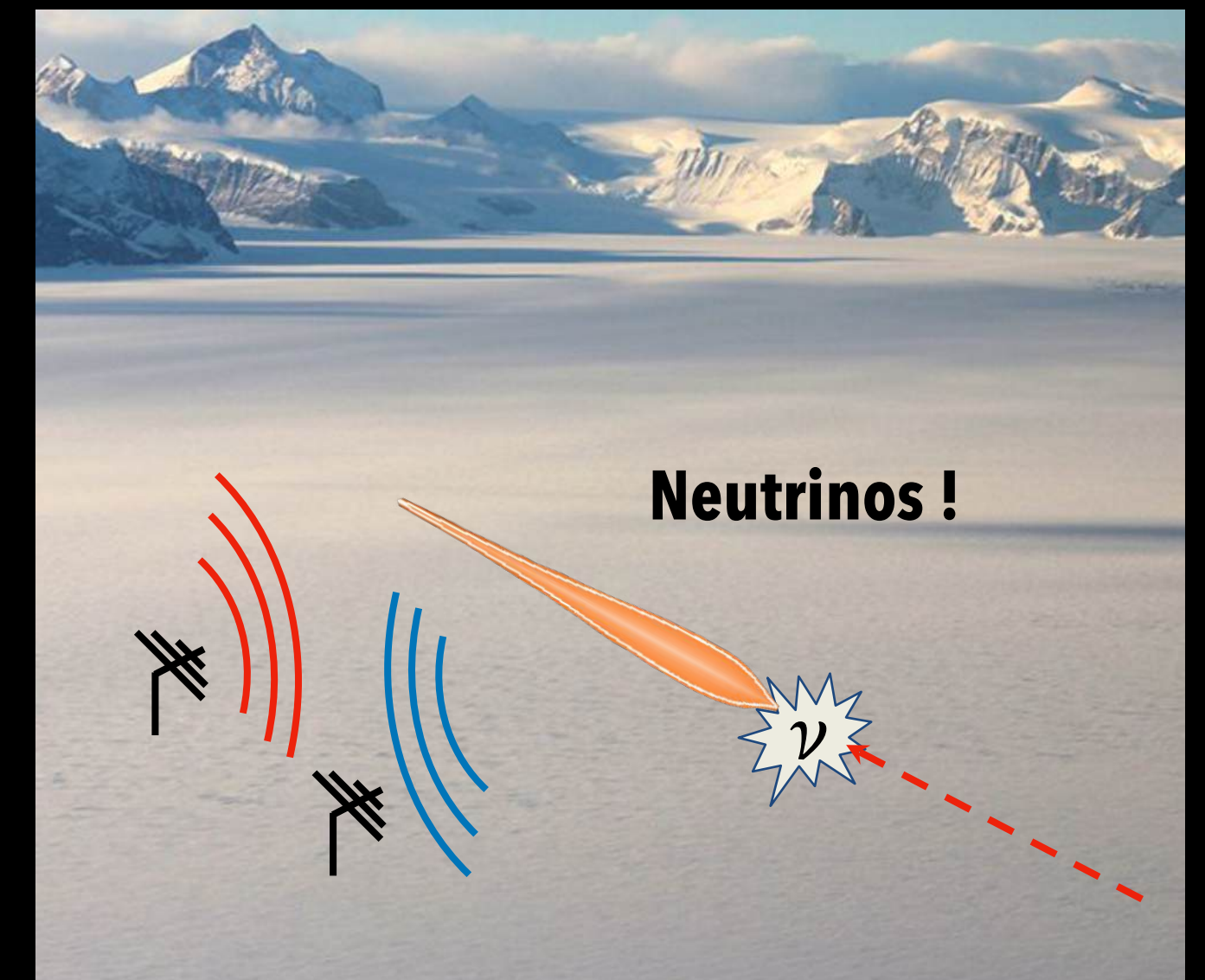
**The Radar Echo Telescope  
for Cosmic-Rays (RET-CR)**



arXiv:2104.00459

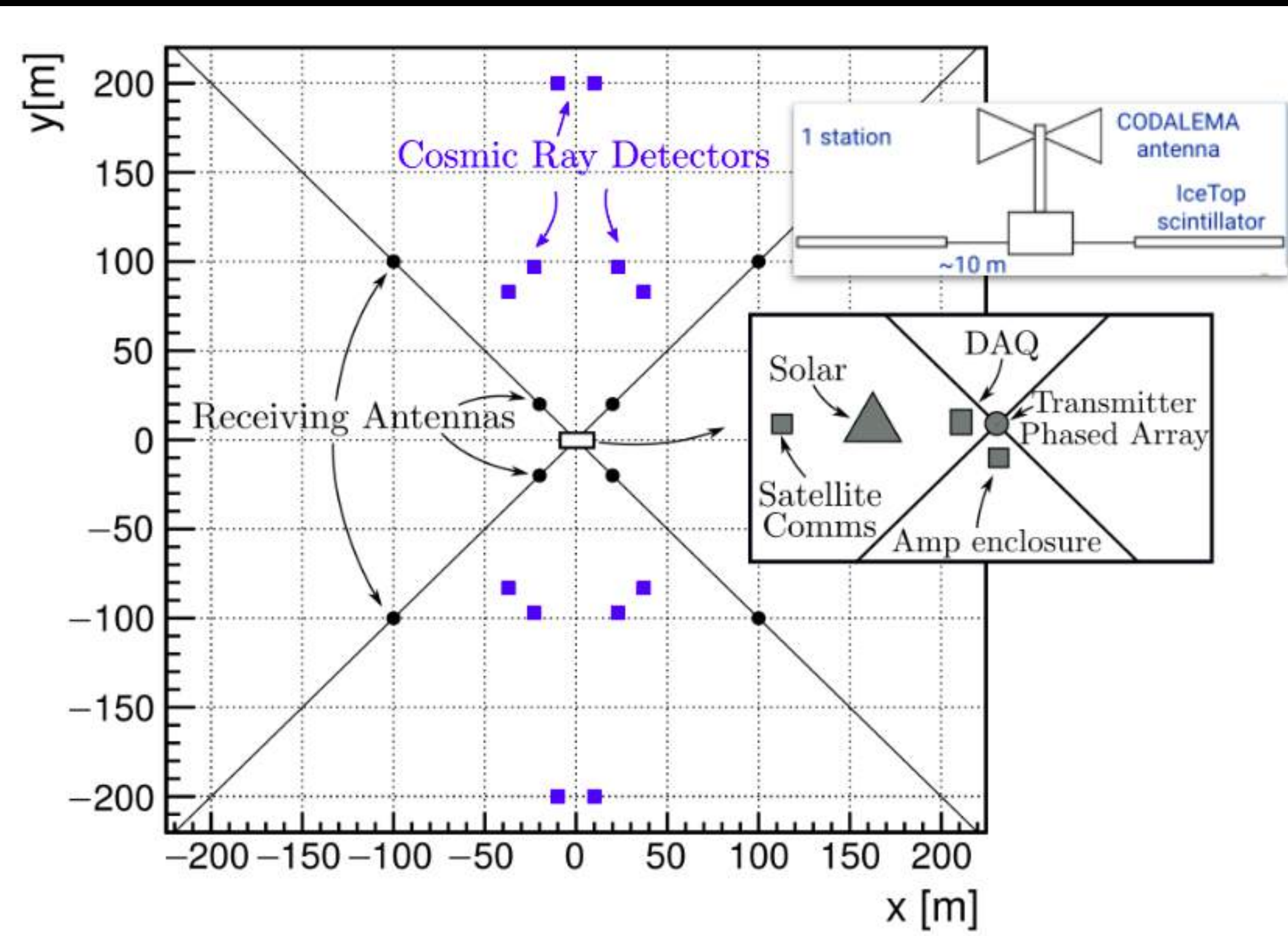
**The detection of this in-ice secondary  
cascade by cosmic ray air shower with  
the radar method!**

**The Ultimate Goal !  
The Radar Echo Telescope for  
Neutrinos (RET-N)**





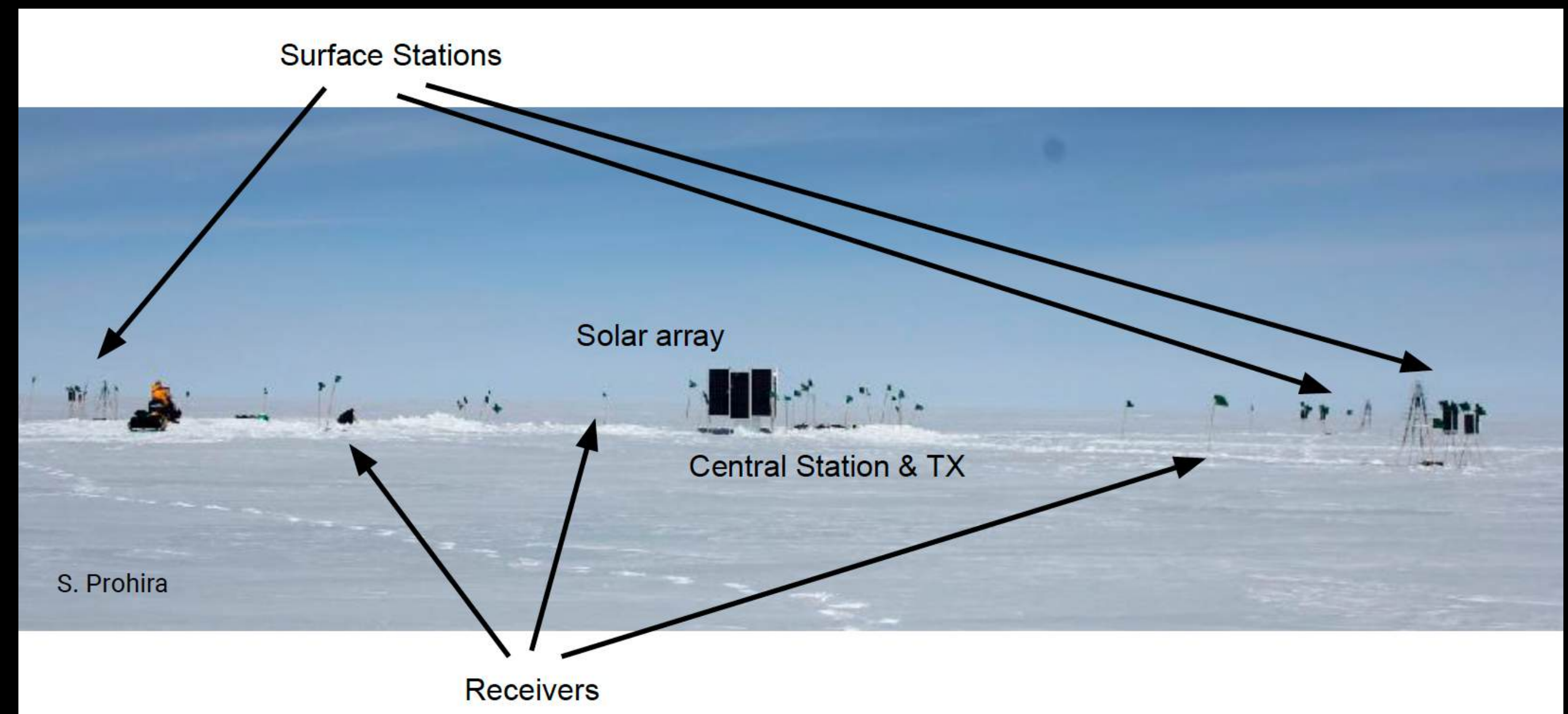
# Experimental Set-Up of RET-CR



arXiv:2104.00459

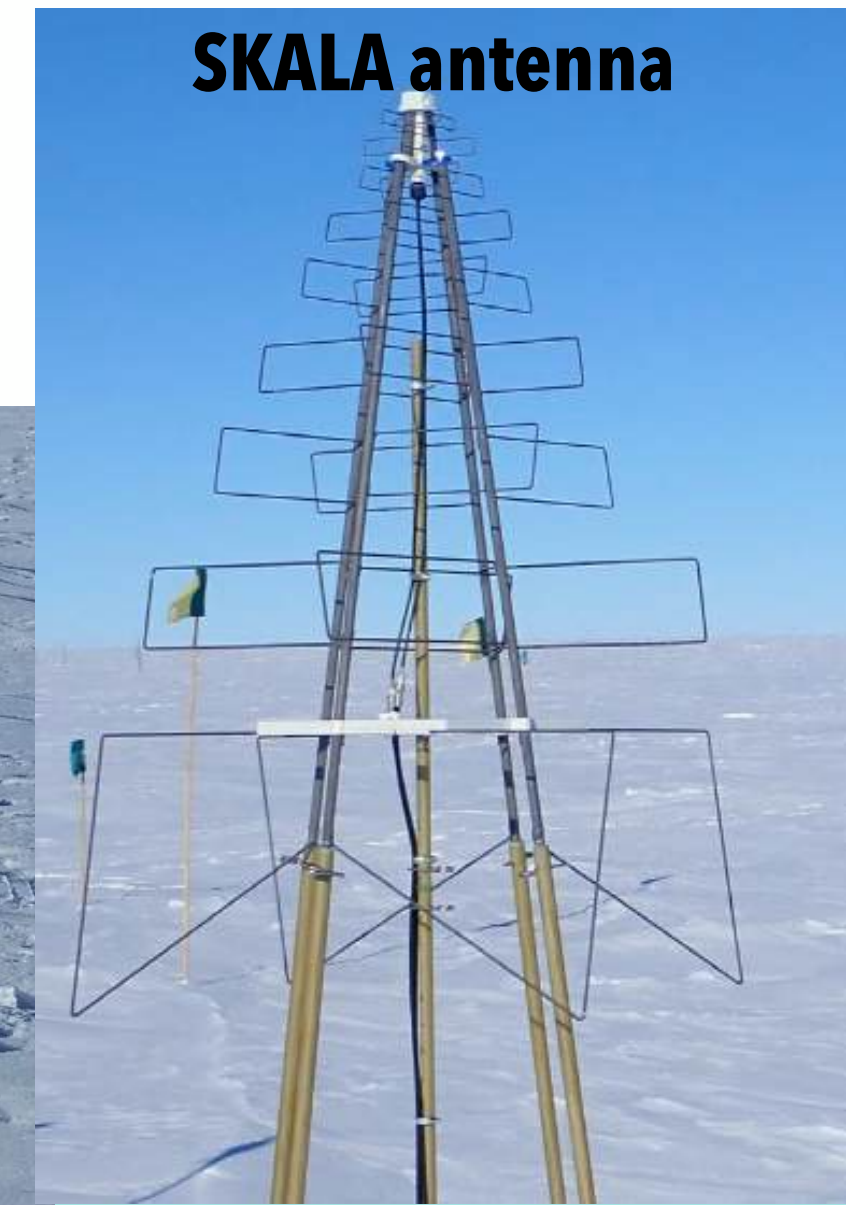
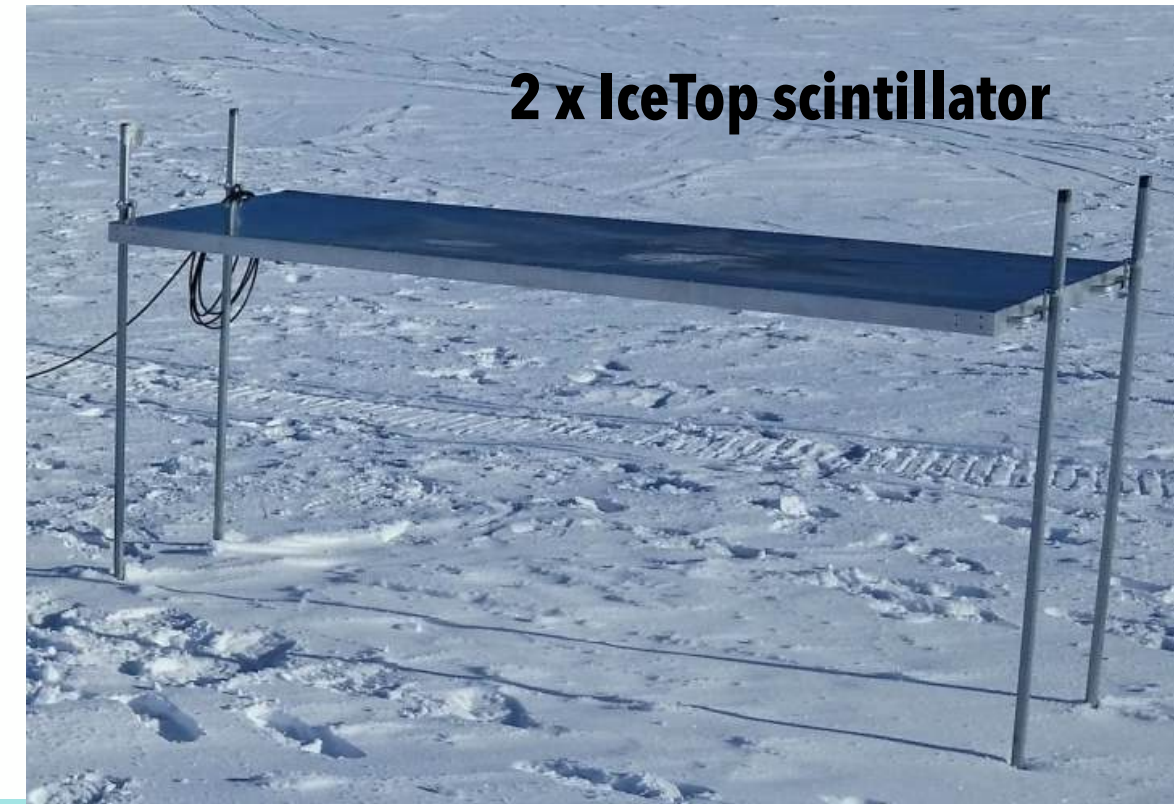
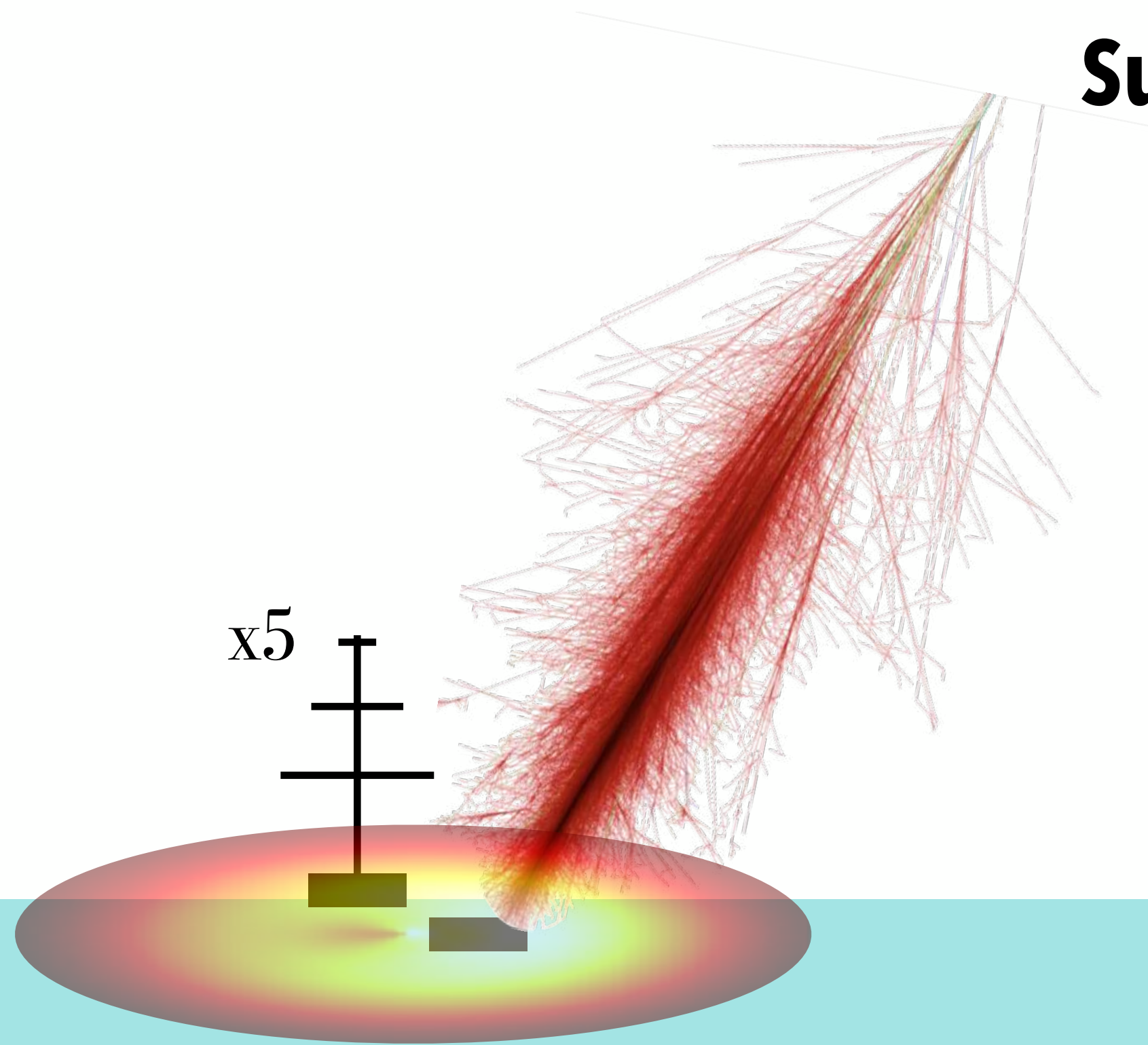
**Surface stations trigger on an incoming high energy cosmic ray air shower**  
**- Its own independent reconstruction strategy**

**The Radar system - detects the in-ice cascade and reconstructs the properties in compliment to the surface stations**





# Surface Stations of RET-CR



## INDEPENDANT RECONSTRUCTION

- ◆ Energy of the primary particle
- ◆ Core position reconstruction
- ◆  $X_{max}$  reconstruction

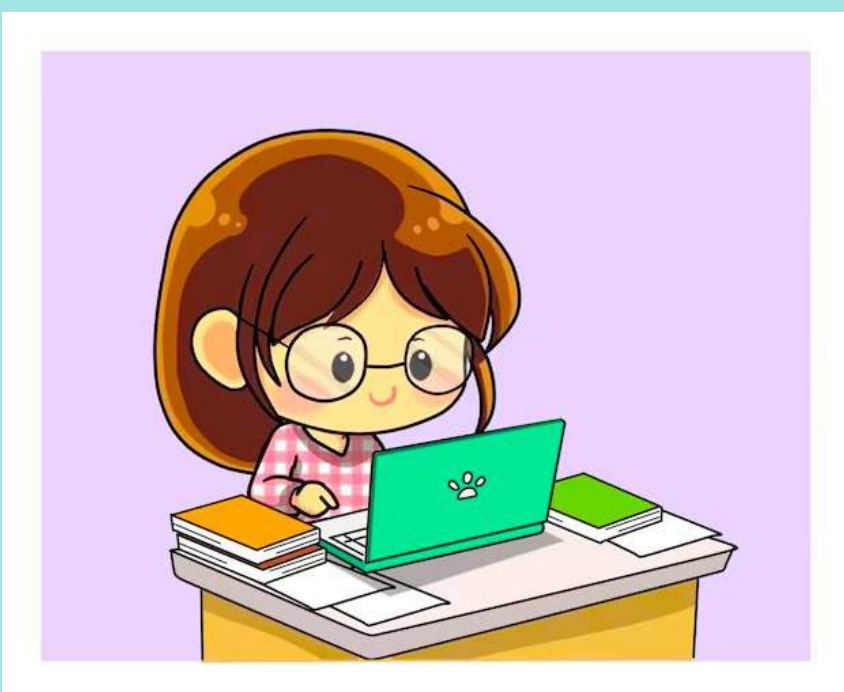
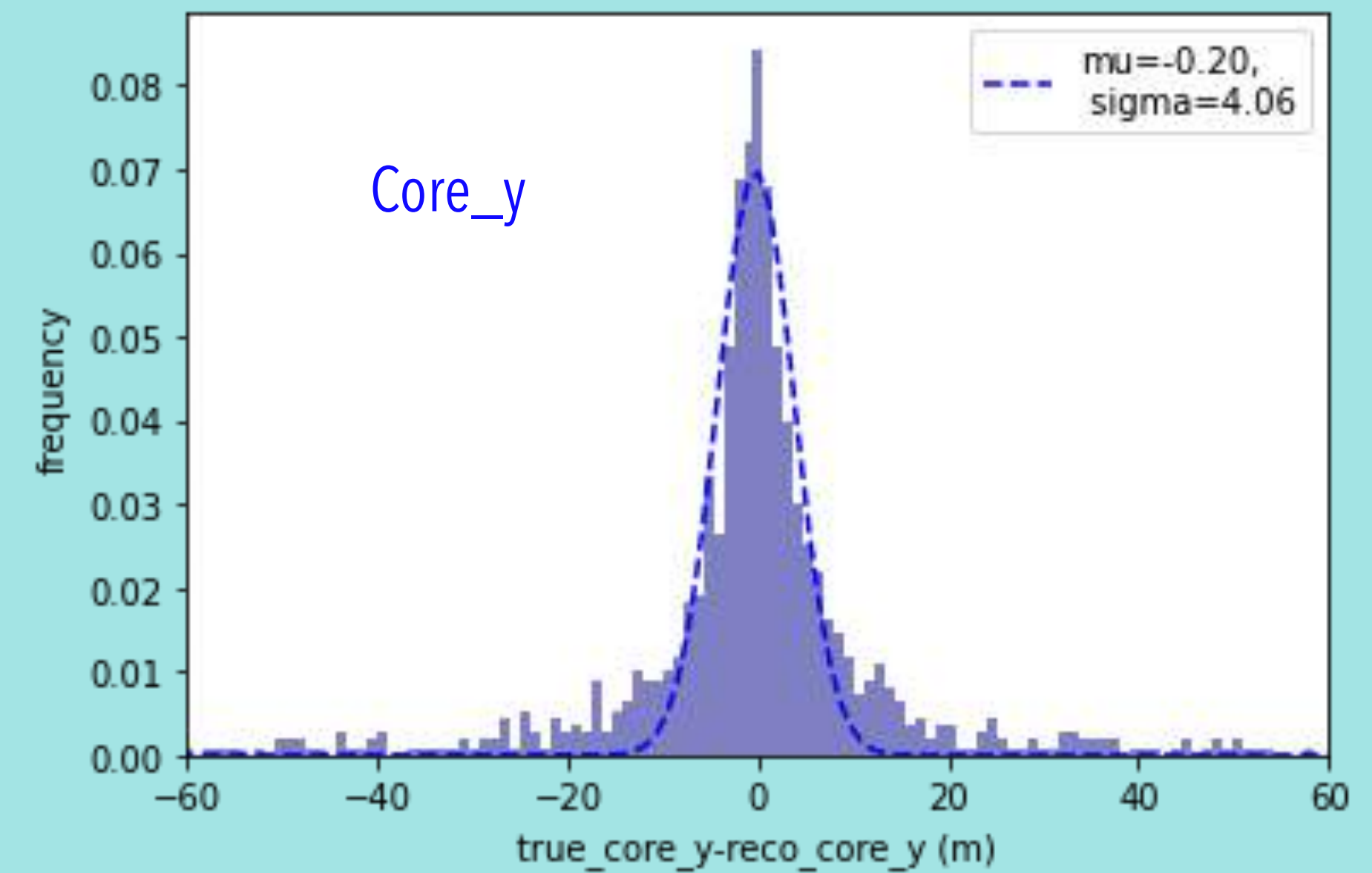
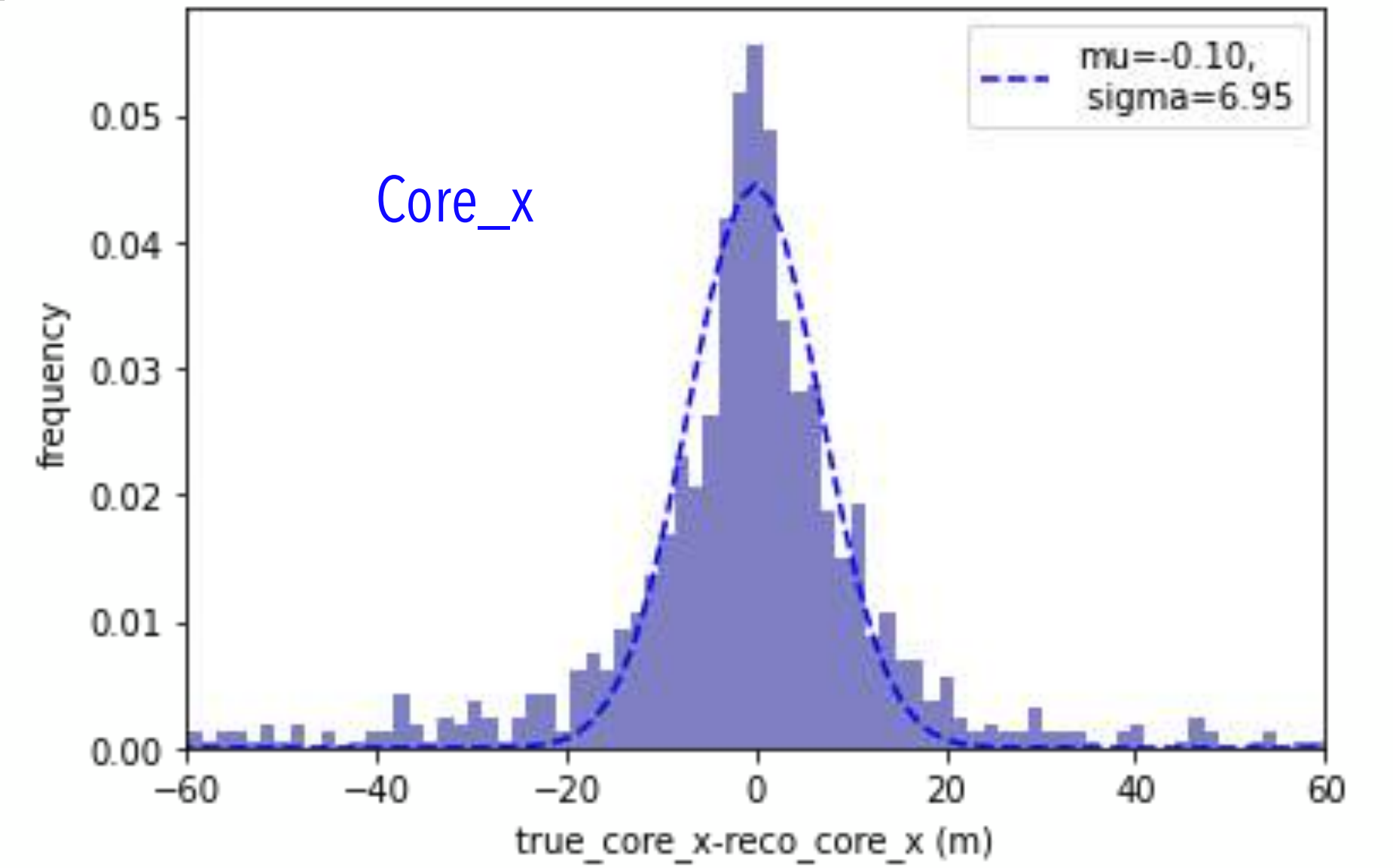
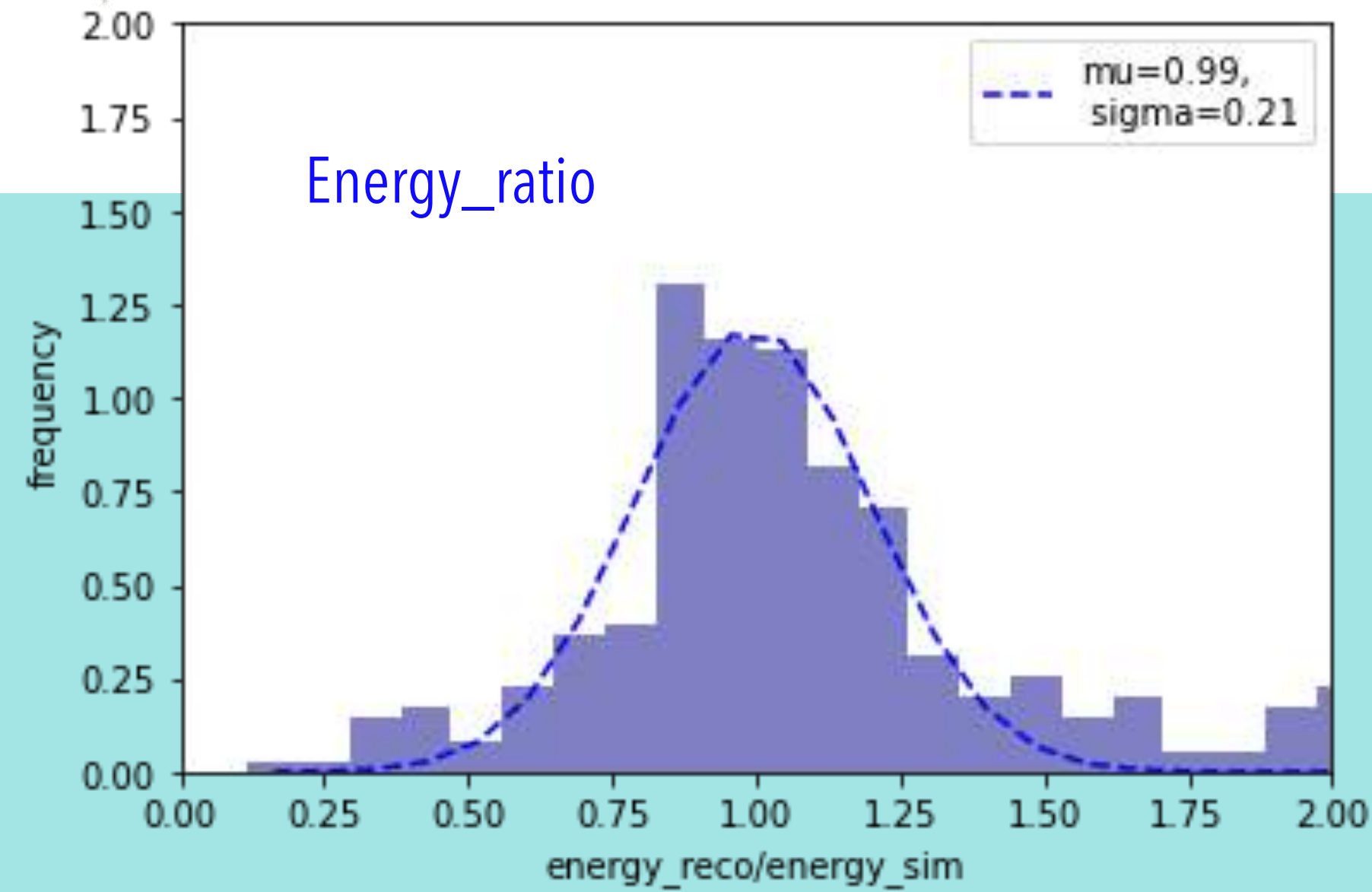
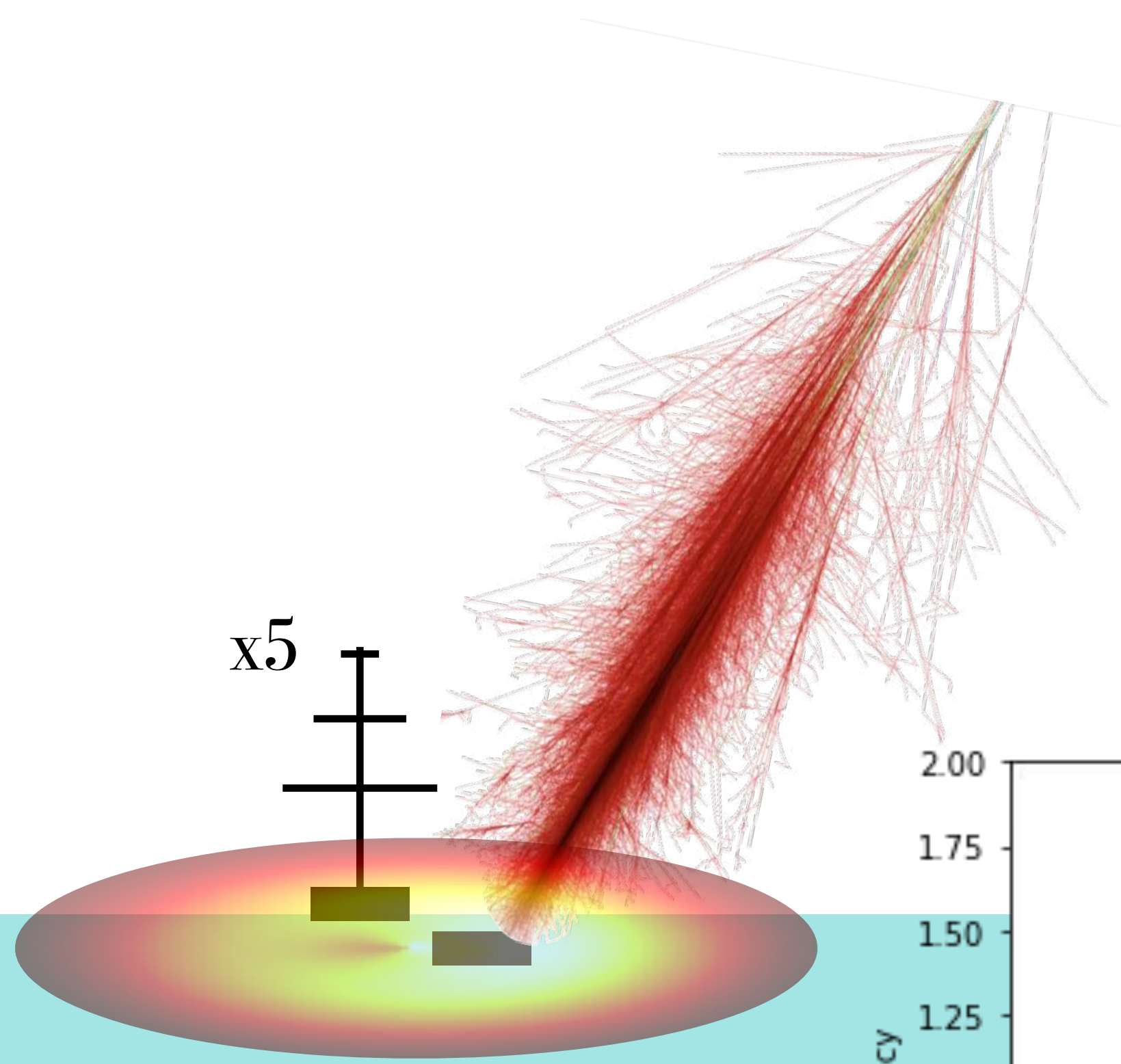
**Develop reconstruction technique with minimal number of stations**



**(What I work on currently)**



# Surface Stations of RET-CR

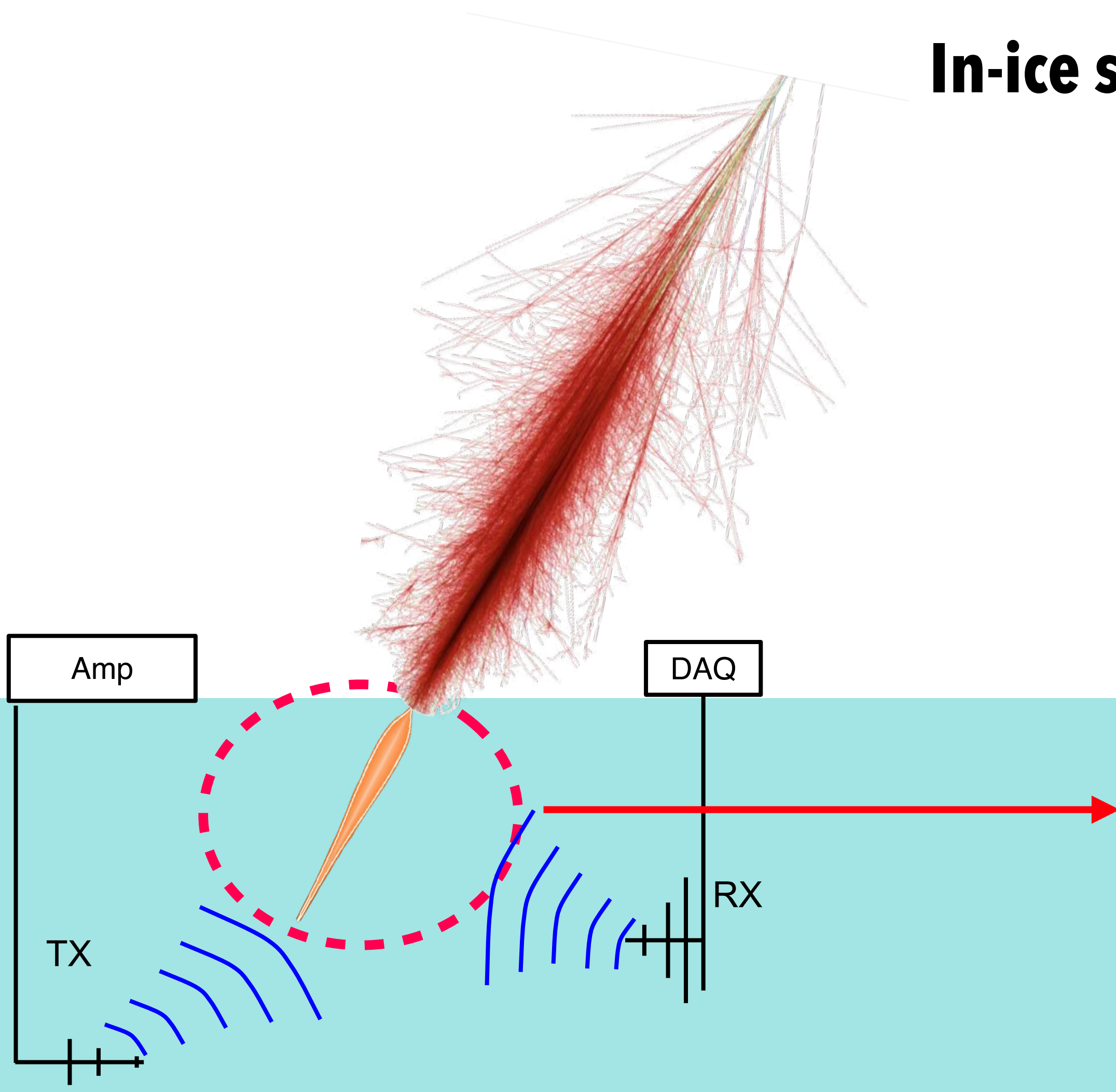


(What I work on currently)

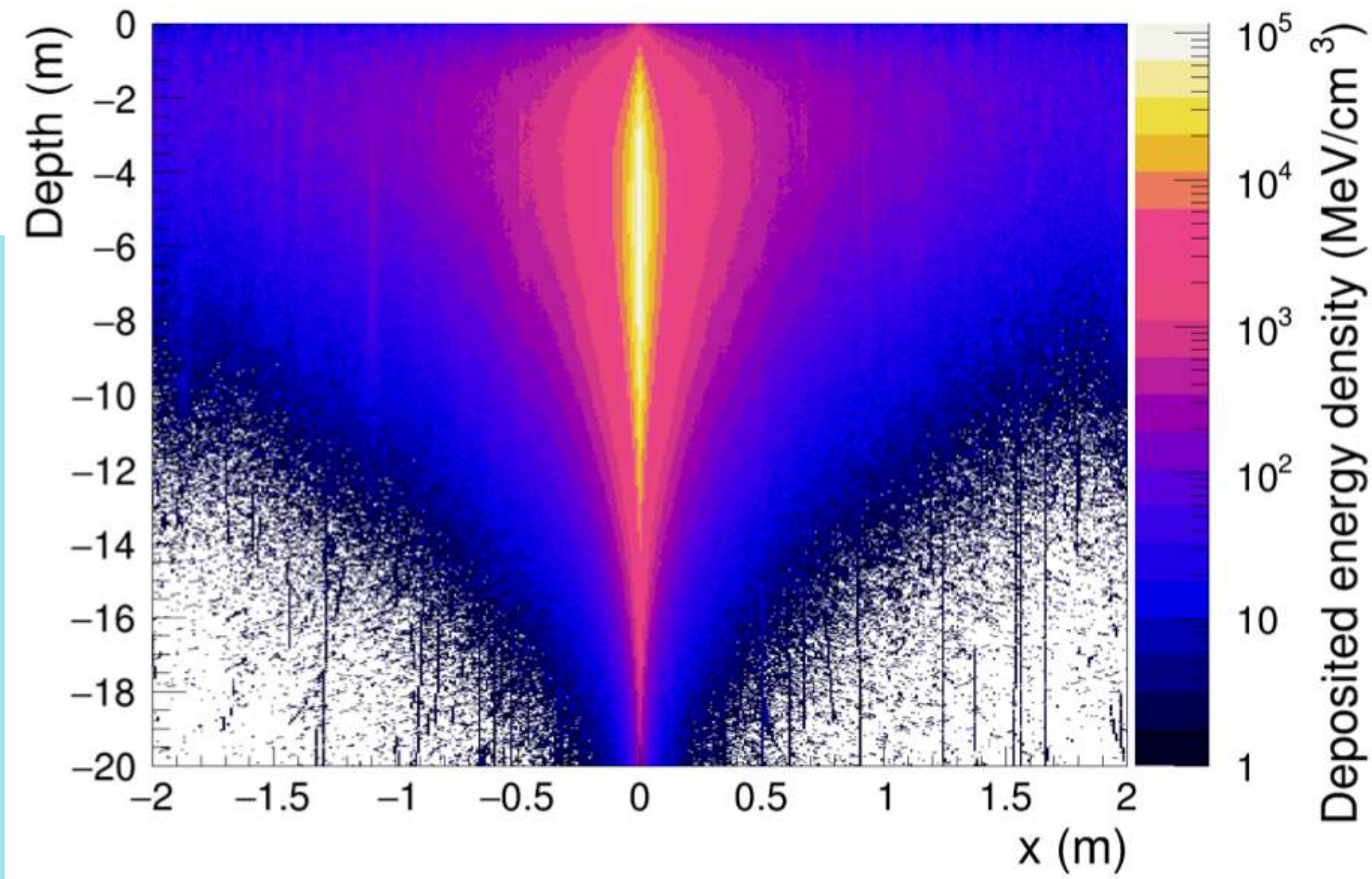
**Develop reconstruction technique with minimal number of stations**



# In-ice secondary cascade



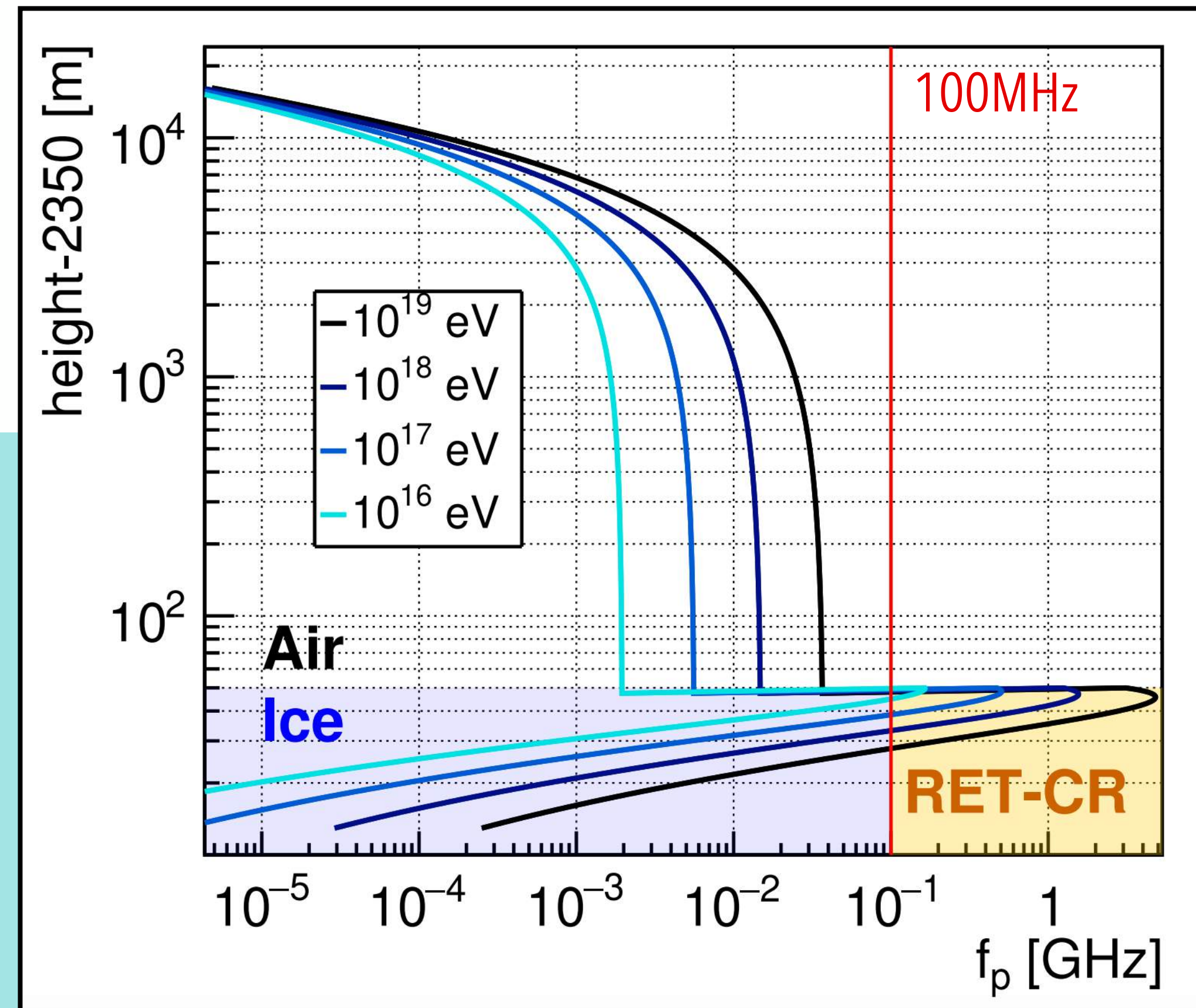
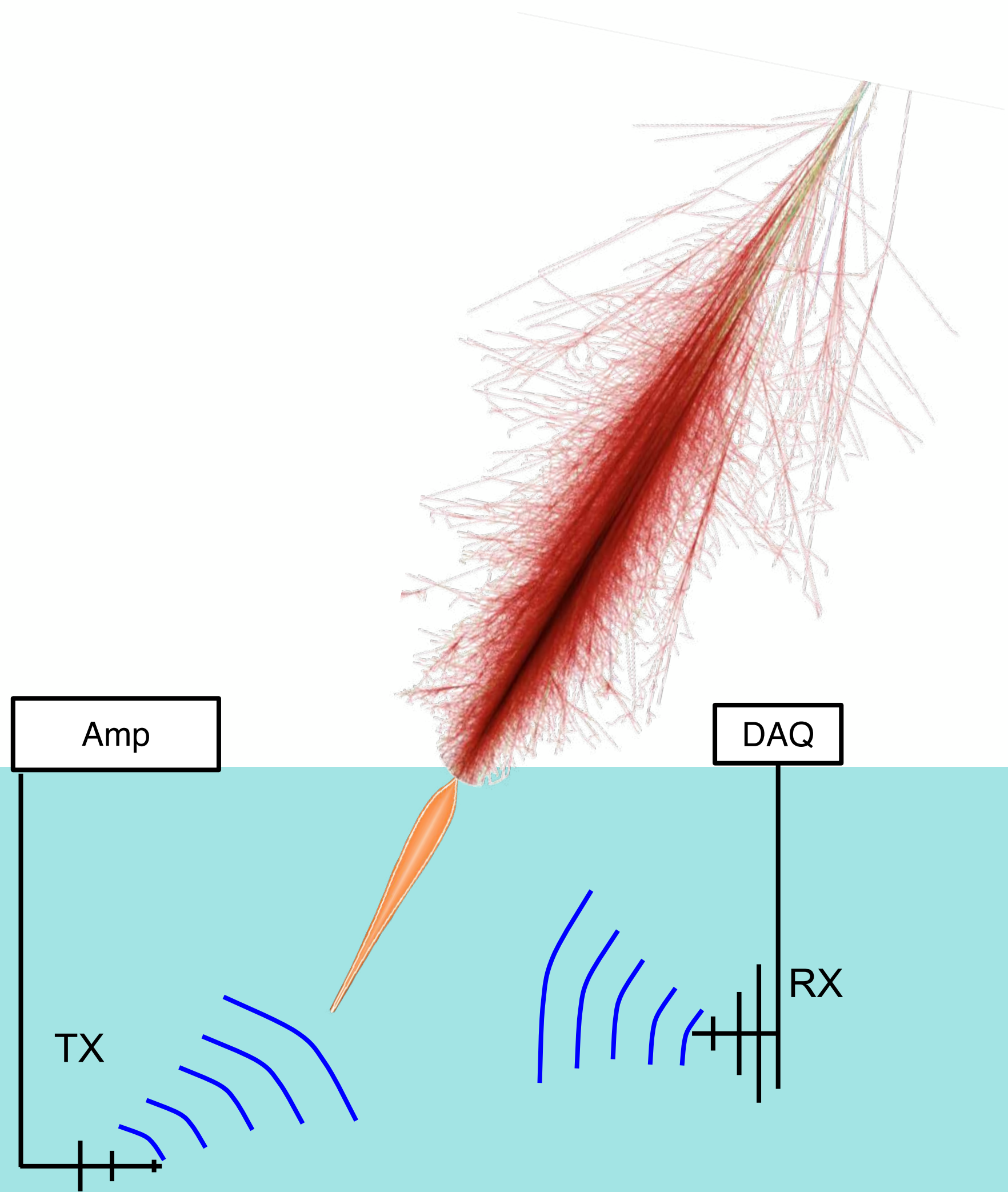
$E = 10^{17} eV$  proton primary



[arXiv:2202.09211](https://arxiv.org/abs/2202.09211)



# In-ice secondary cascade



arXiv:2104.00459

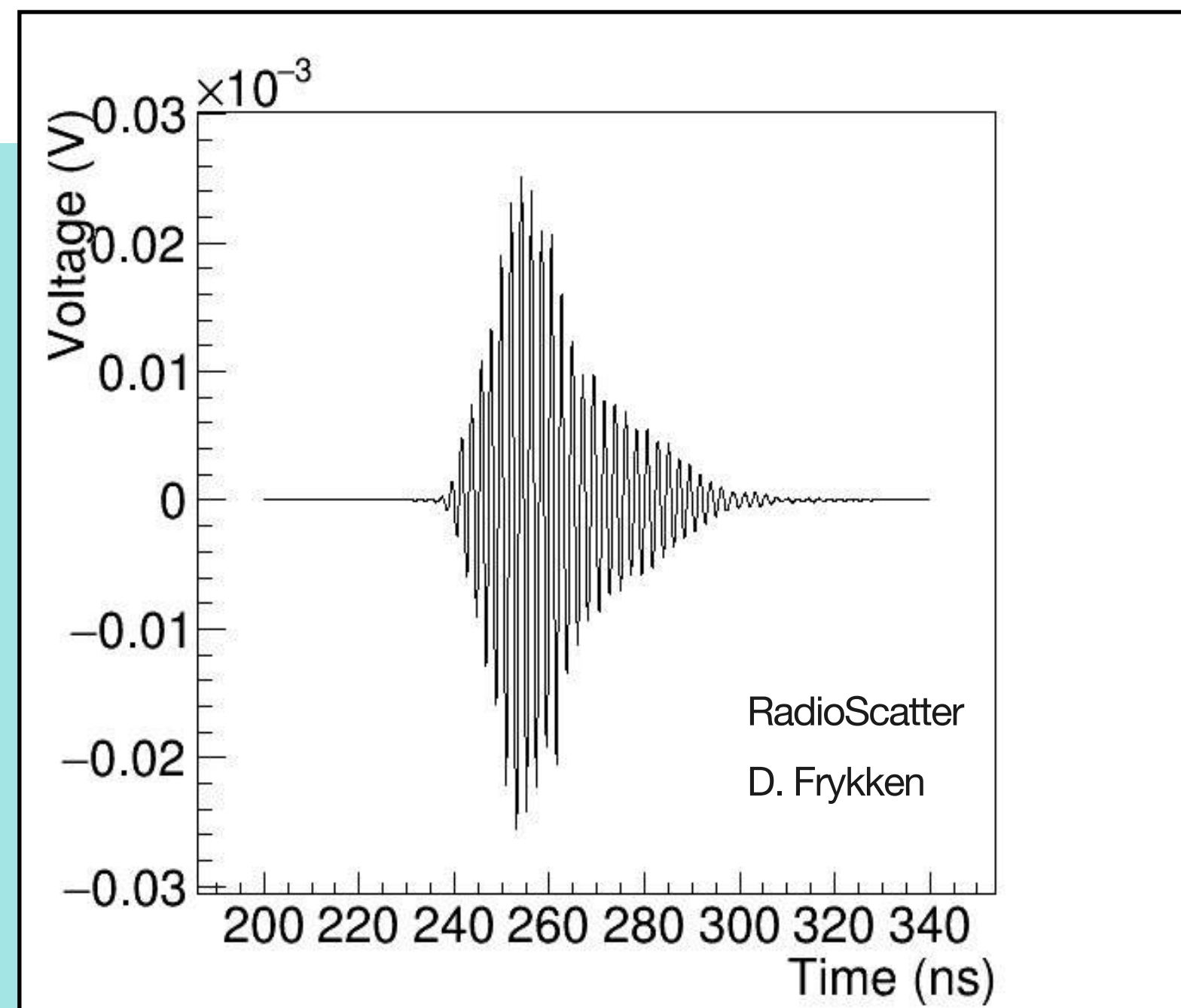
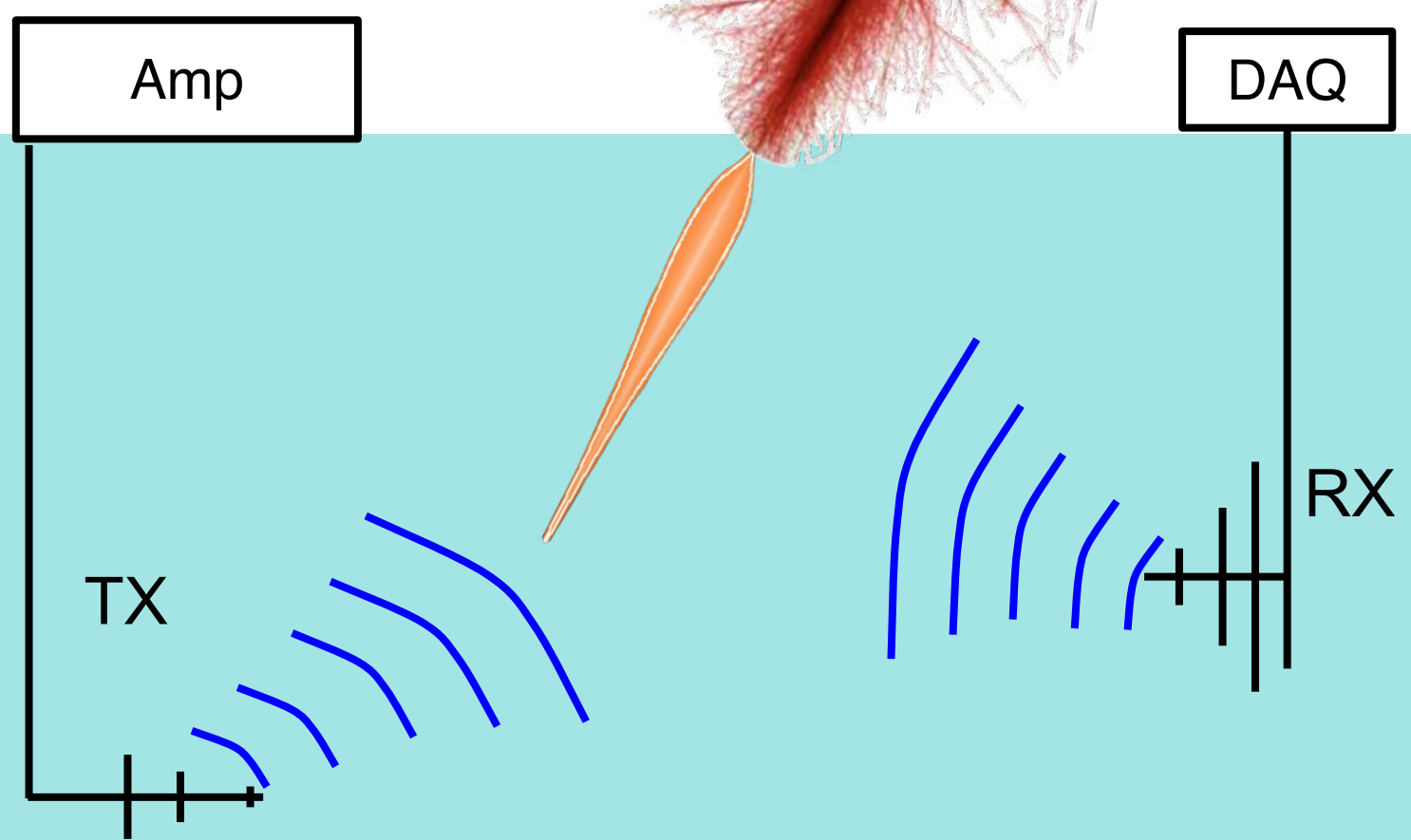
Detectable via radar -  
 $E = 10^{16} eV$



# In-ice secondary cascade

## Radar detection depends on :

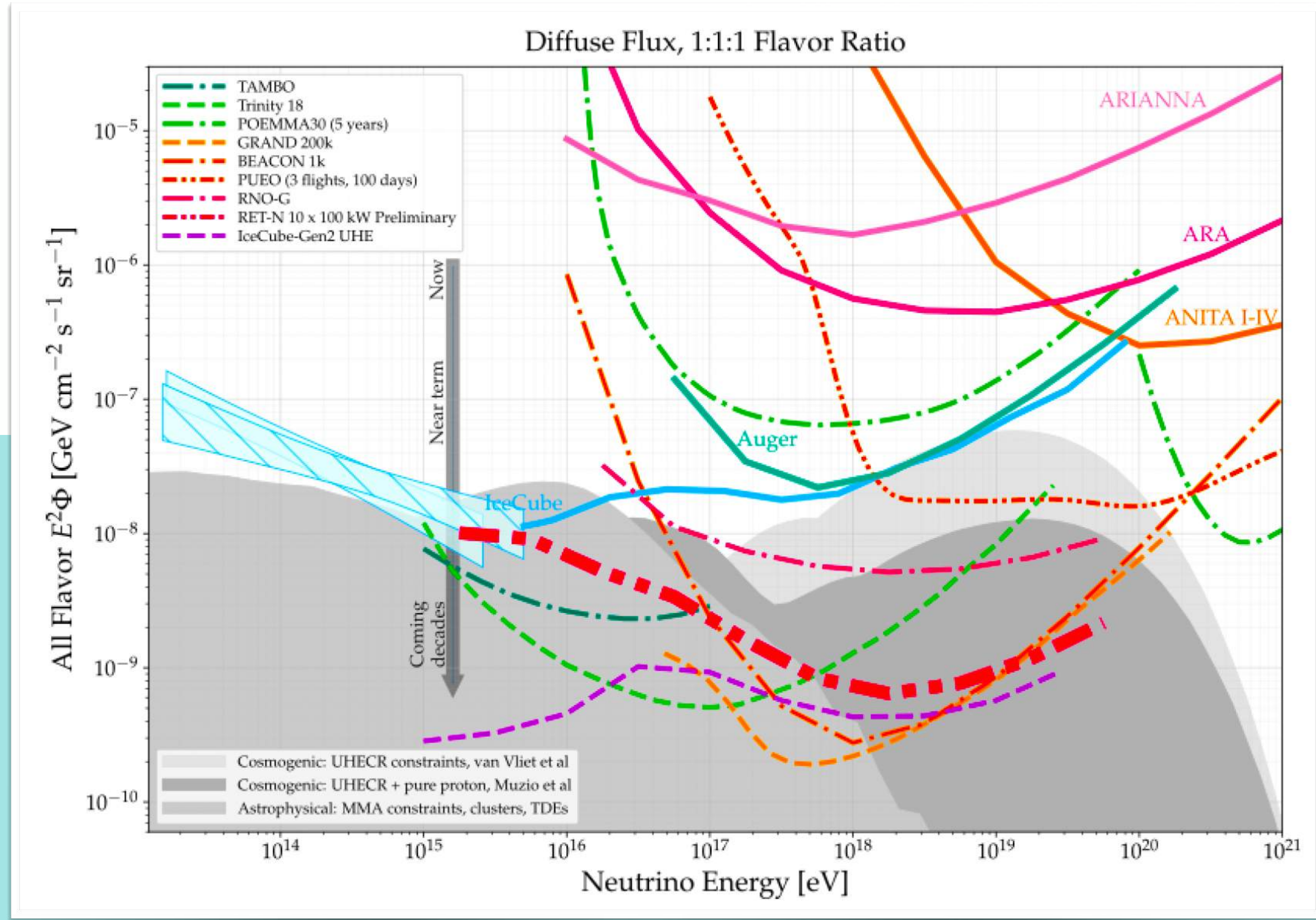
- Medium: density of ionization plasma
- Plasma lifetime: function of medium temperature and purity (10 ns)
- Probing frequency ( we can control )
- Cascade properties : energy, direction



- Signal strength scales with energy
- Signal arrival time gives vertex position
- Frequency content gives arrival direction



# RET-N sensitivity



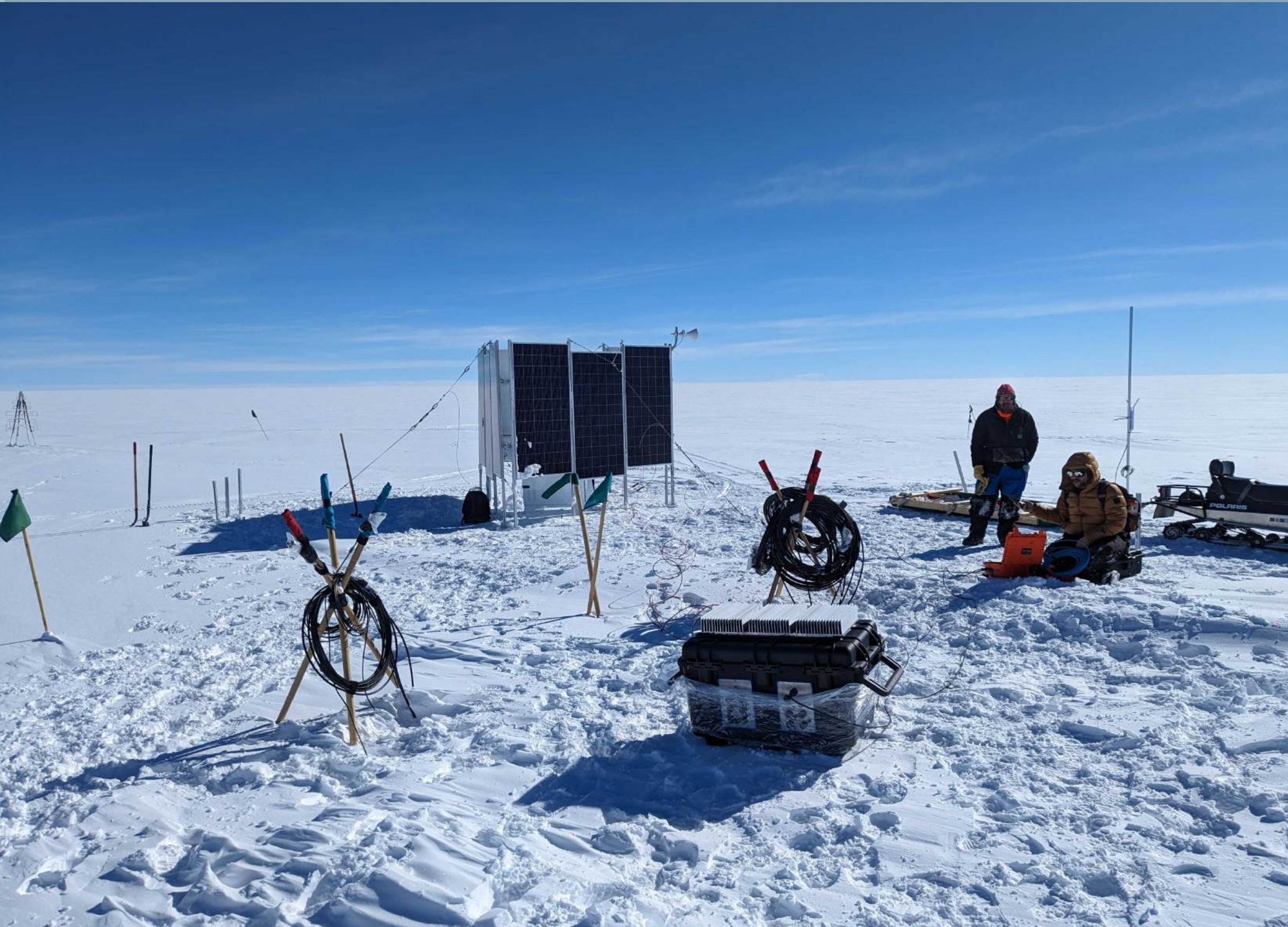
[arXiv:2203.08096](https://arxiv.org/abs/2203.08096)



# Into the bright future

## Updates : Deployment 2024

The RET-CR have started taking data  
All surface stations deployed  
New receiver antenna added





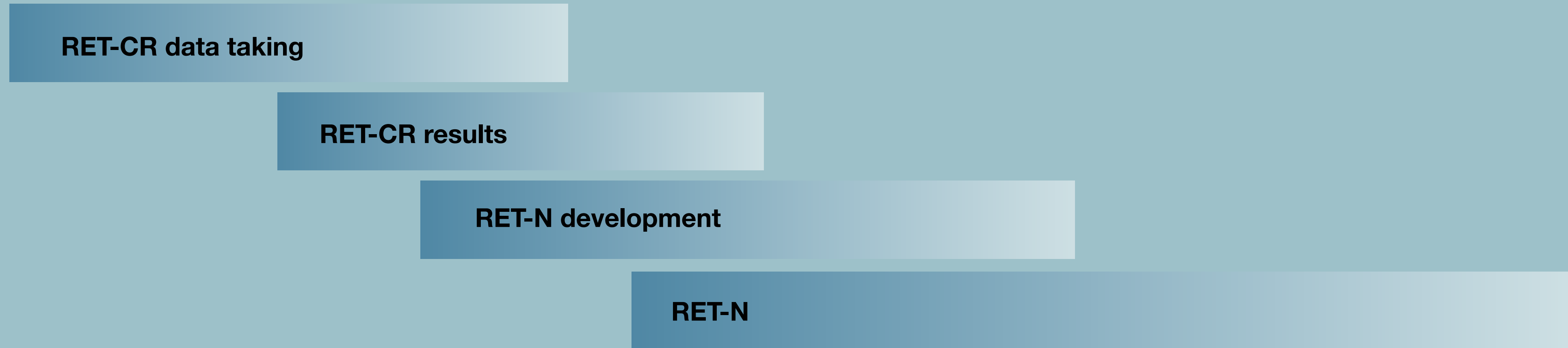
# Into the bright future





# Into the bright future

2023      2024      2025      2026      2027



Thanks!!



Radboud University



THE UNIVERSITY OF CHICAGO



PennState



National Taiwan University





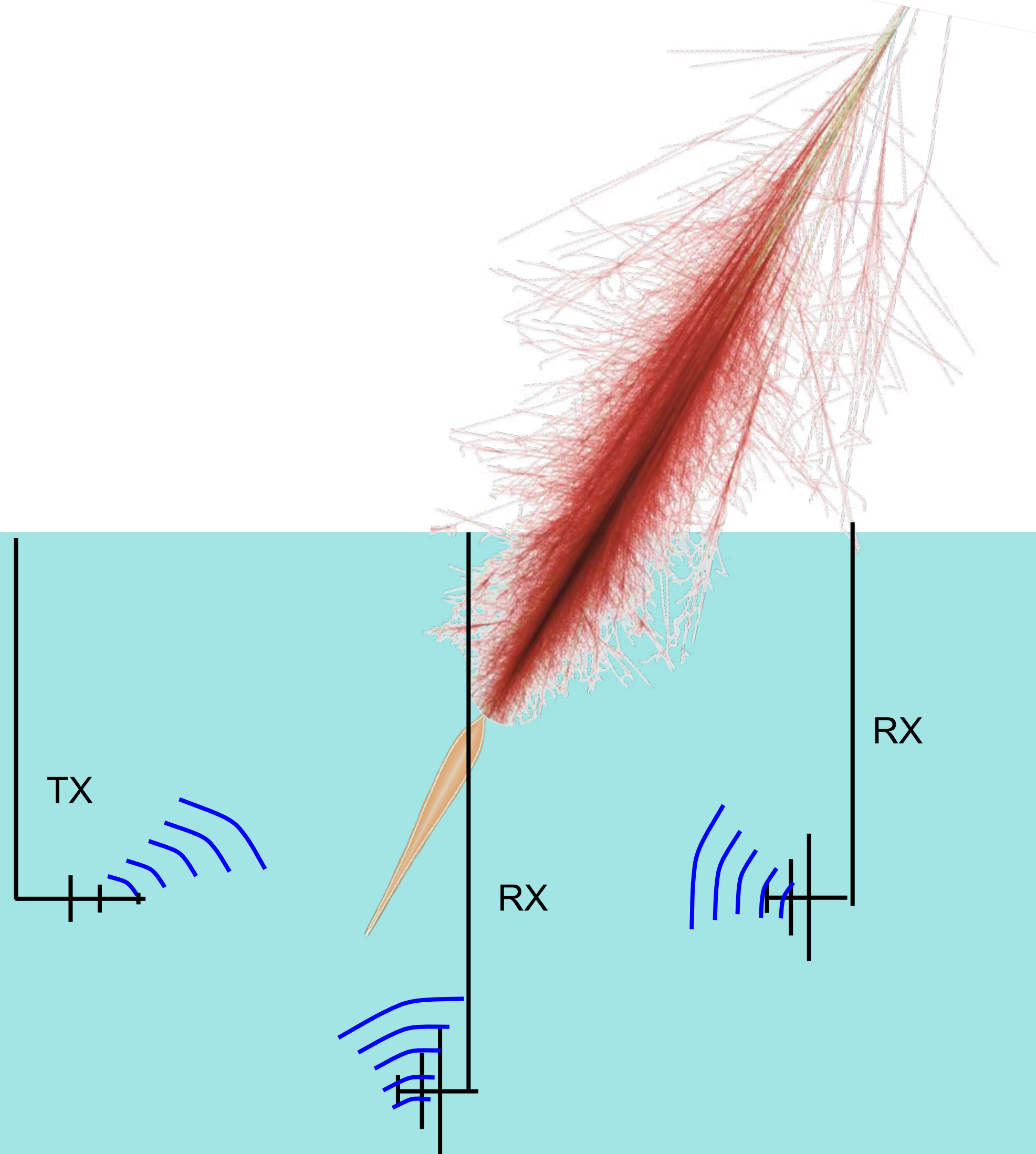


# In-Ice secondary cascade:

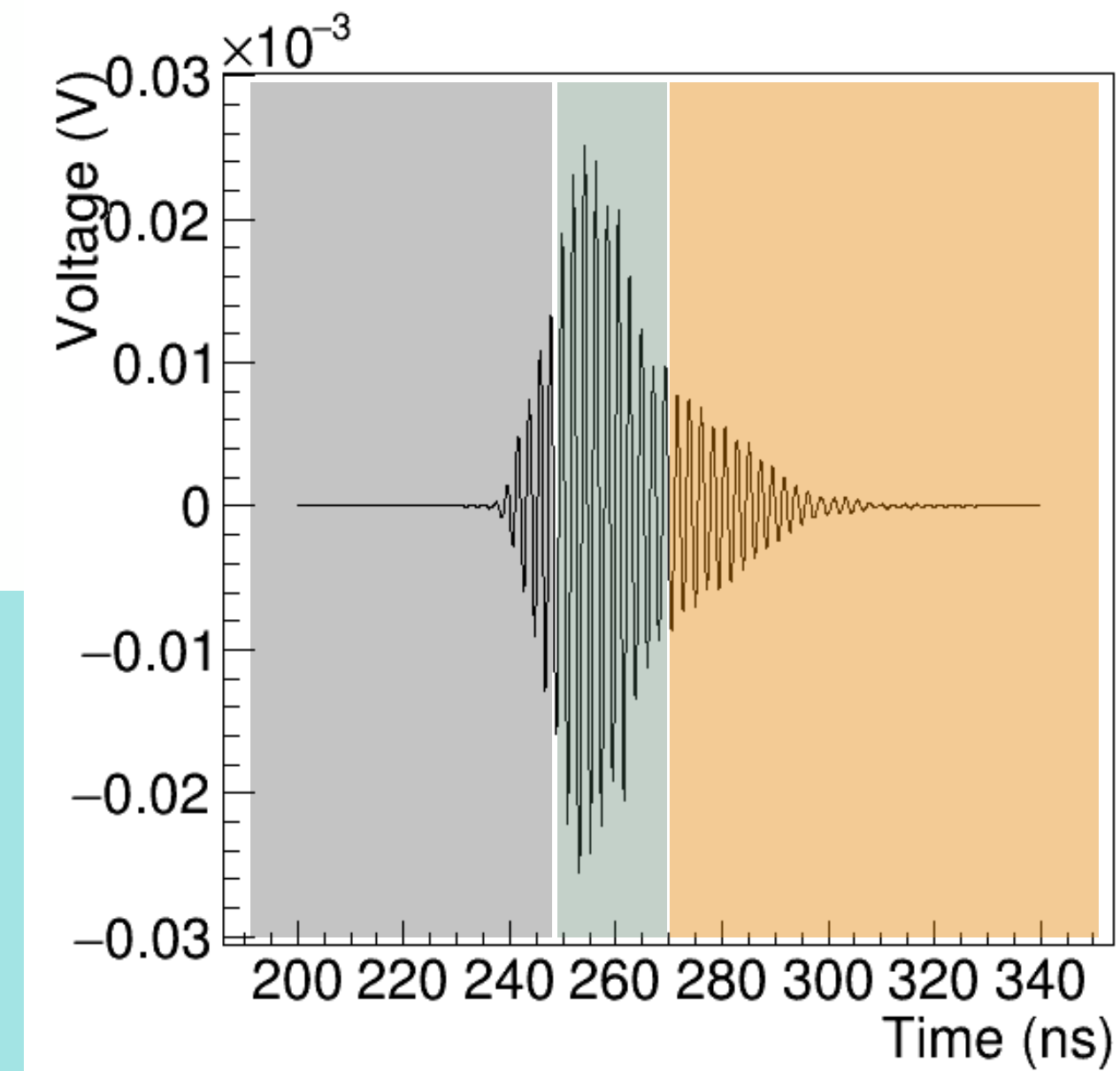
## Radar echo simulation packages :

**RadioScatter** (in-house radar reflection simulation with GEANT4) , Prohira, Besson Nucl.Instrum.Meth.A 922 (2019)

**MARES: Macroscopic Approach to the Radar Echo Scatter** , E. Huesca Santiago, et al. 2024, arXiv:2310.06731



- Three phases of a RET event:
  - **Cascade development**
  - **Cascade as a static reflector**
  - **Recombination/Attachment**

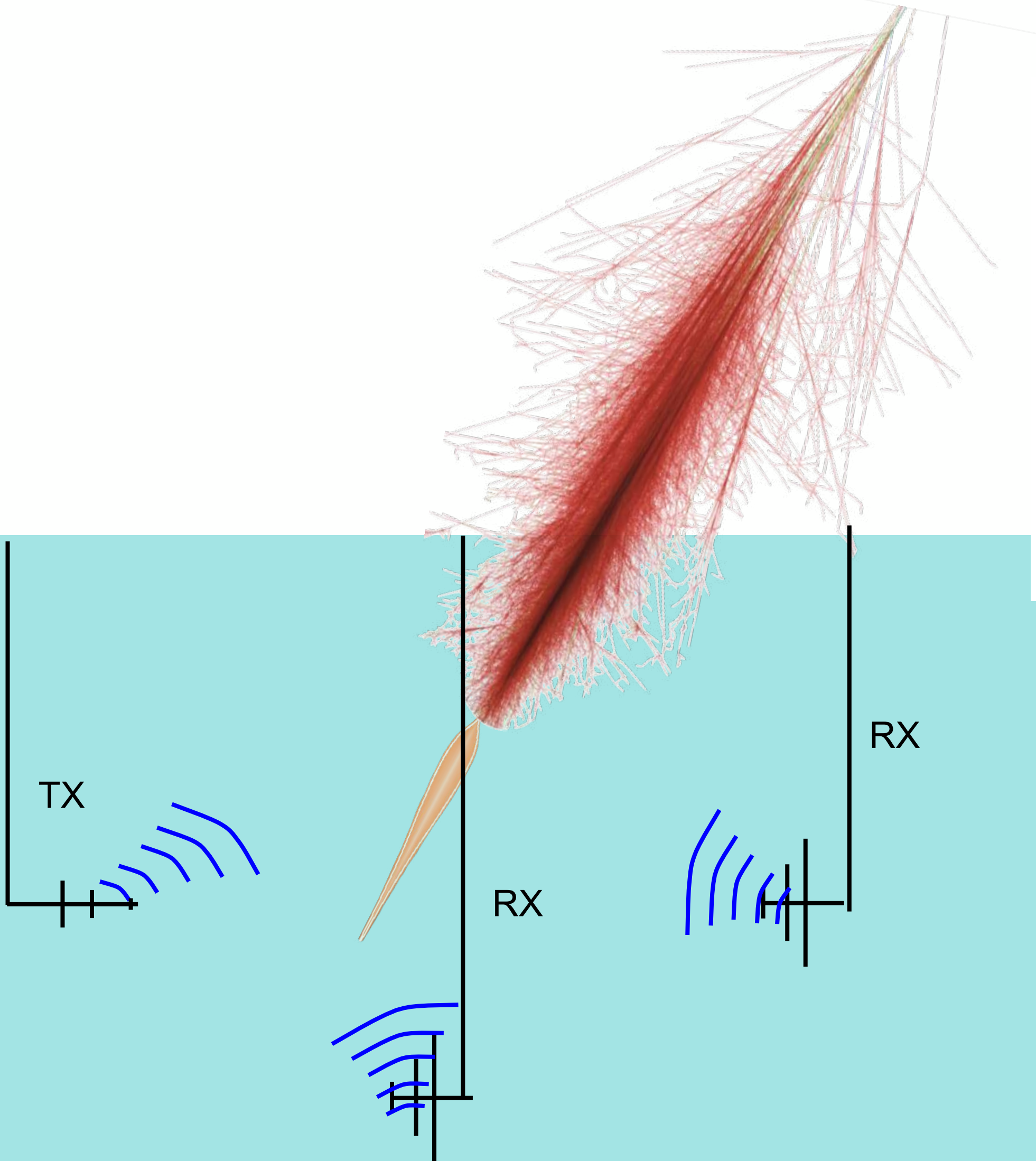


RadioScatter  
D. Frykken

**Need to put label to plots here...**



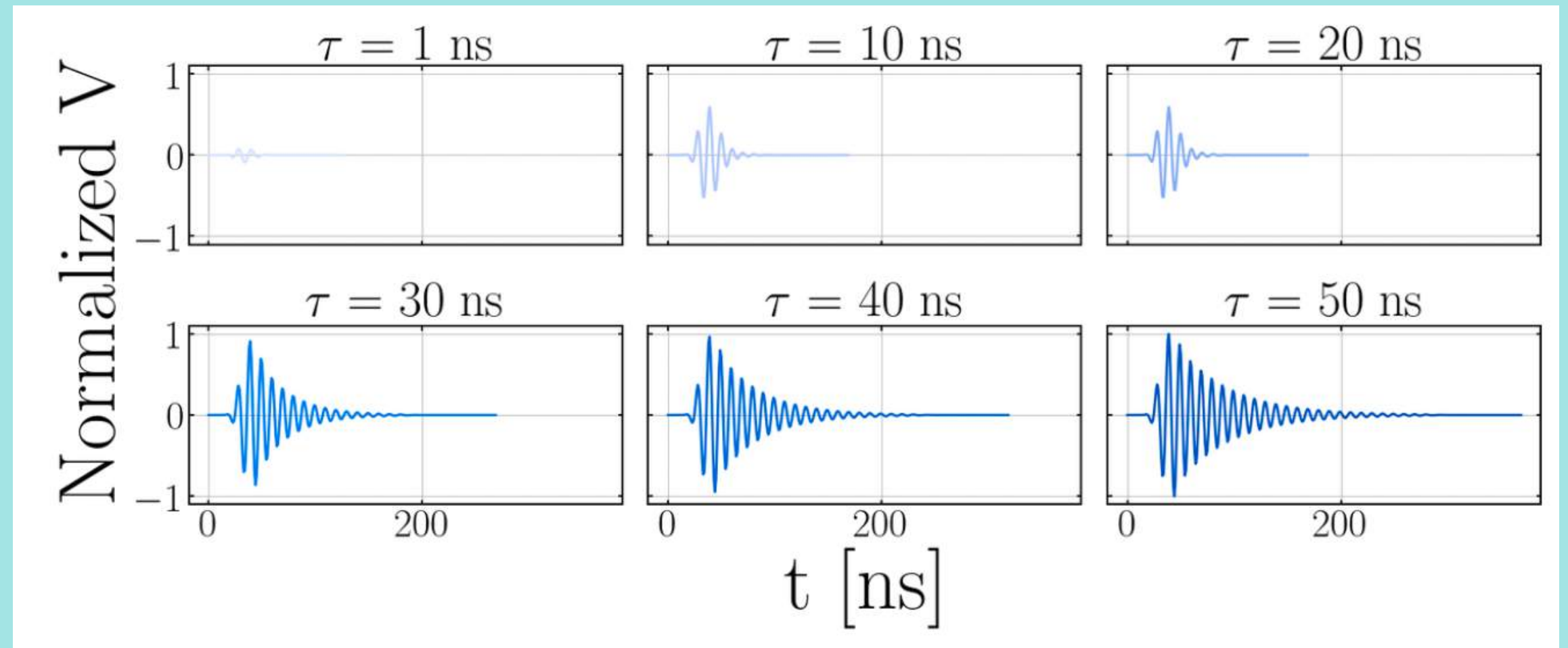
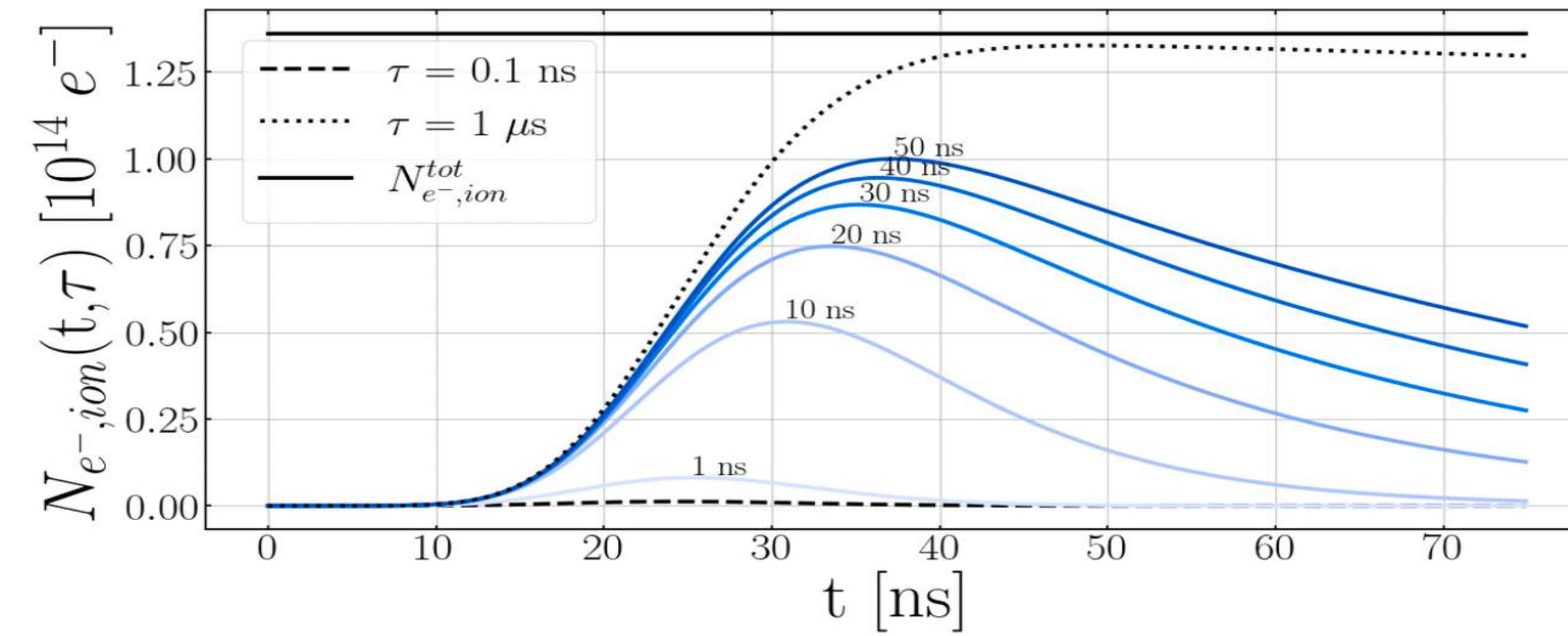
# In-Ice secondary cascade:



# Radar echo simulation packages :

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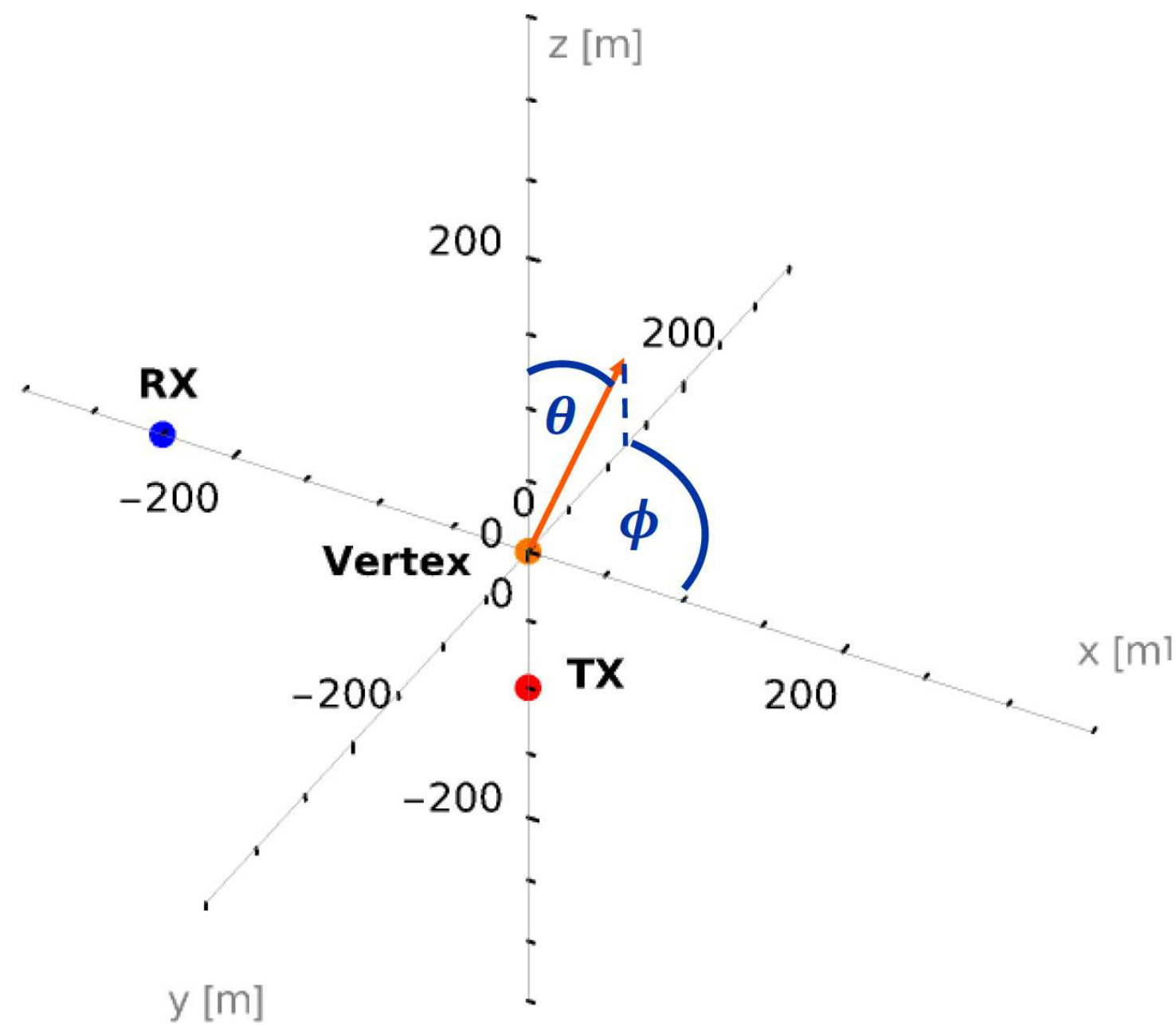
**Need to put label to plots here...**



# In-Ice secondary cascade:

## Simulation parameters

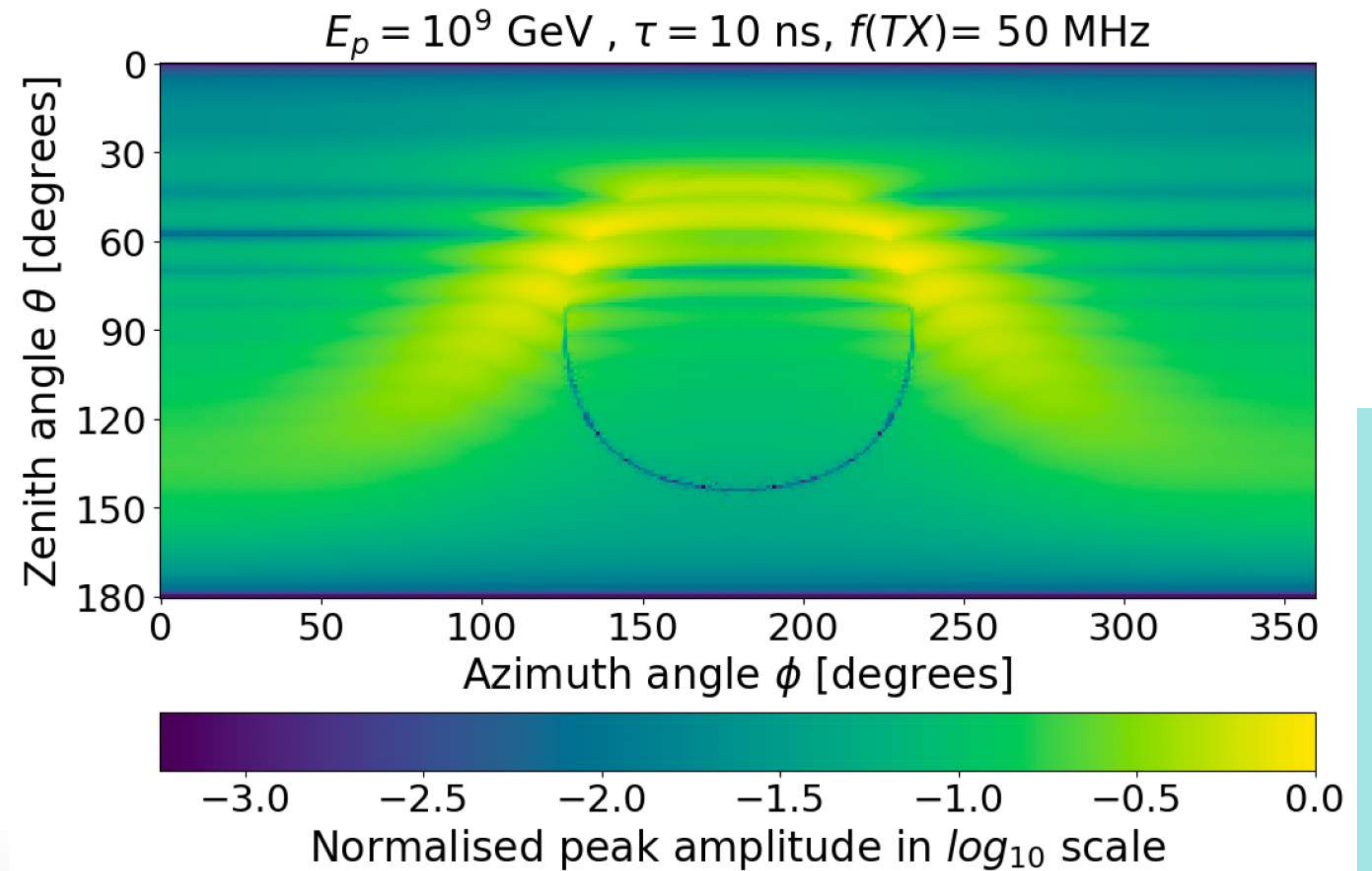
- $\tau_e = 10$  ns
- $E_p = 1$  EeV
- Isotropic antenna
- Power = 1000 W
- Tx freq. = 50 MHz
- $n=1.78$



## Radar echo simulation packages :

**RadioScatter** (in-house radar reflection simulation with GEANT4) , Prohira, Besson Nucl.Instrum.Meth.A 922 (2019)

**MARES: Macroscopic Approach to the Radar Echo Scatter** , E. Huesca Santiago, et al. 2024, arXiv:2310.06731



MARES - J. Loonen