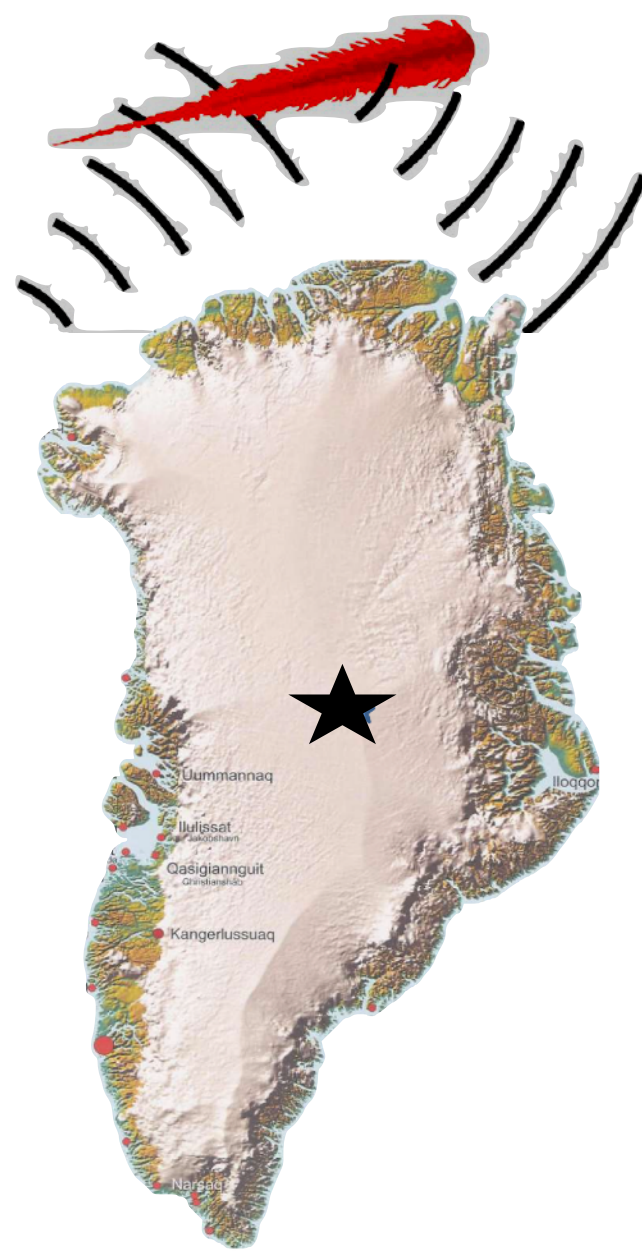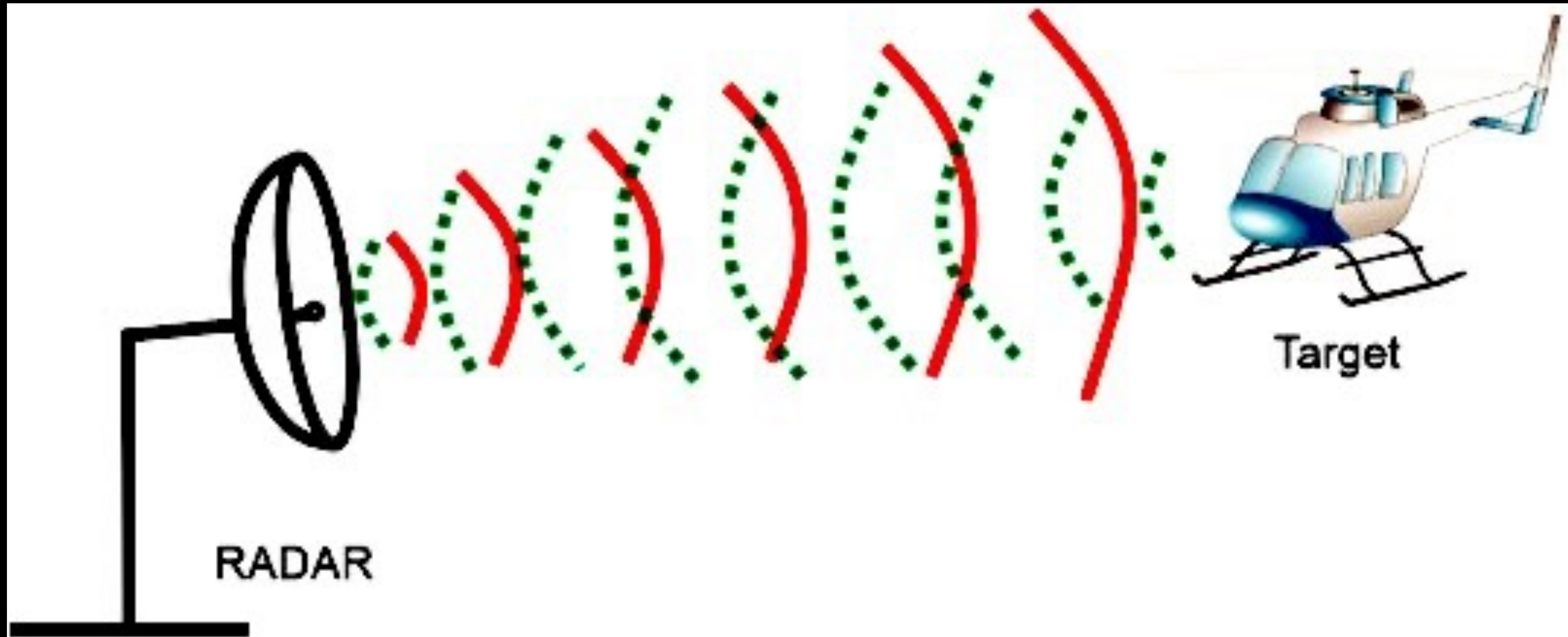# The Radar Echo Telescope (RET) : A new approach for high energy neutrino detections

FLASH TALK

Summit station, Greenland
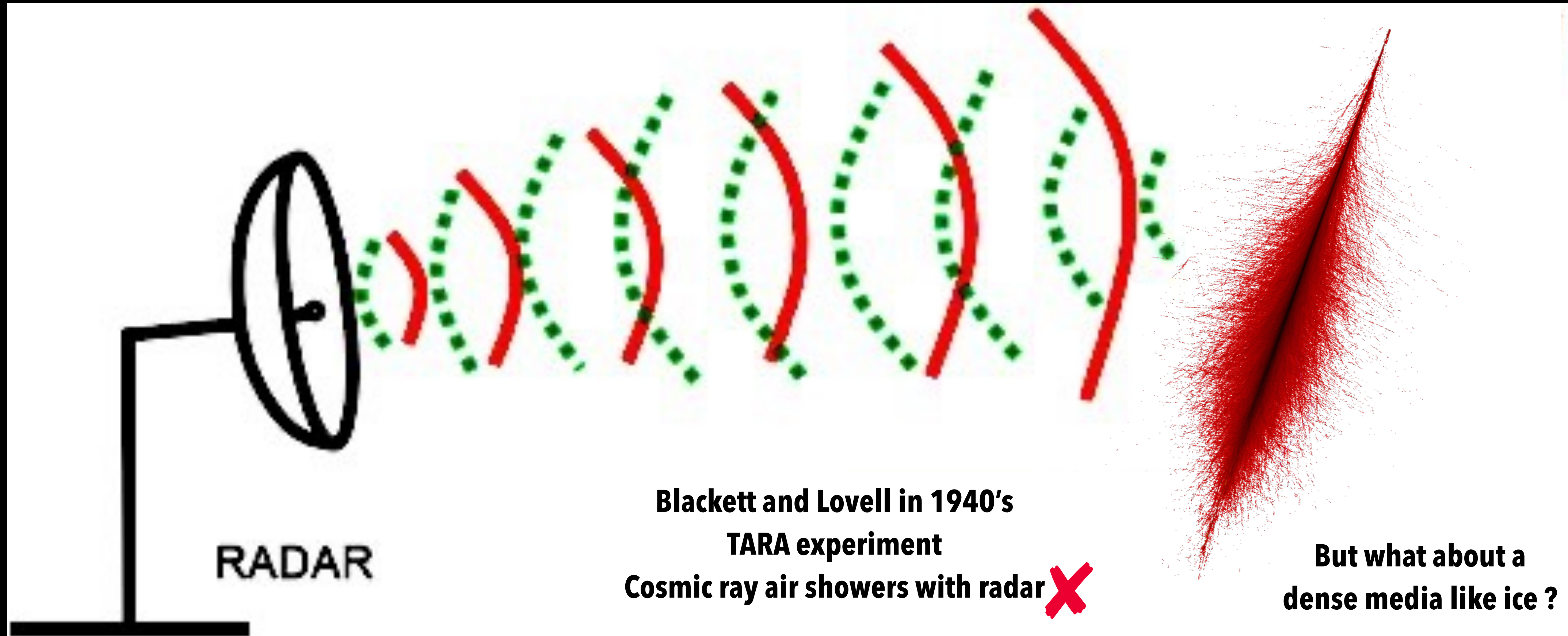
The Radar Method
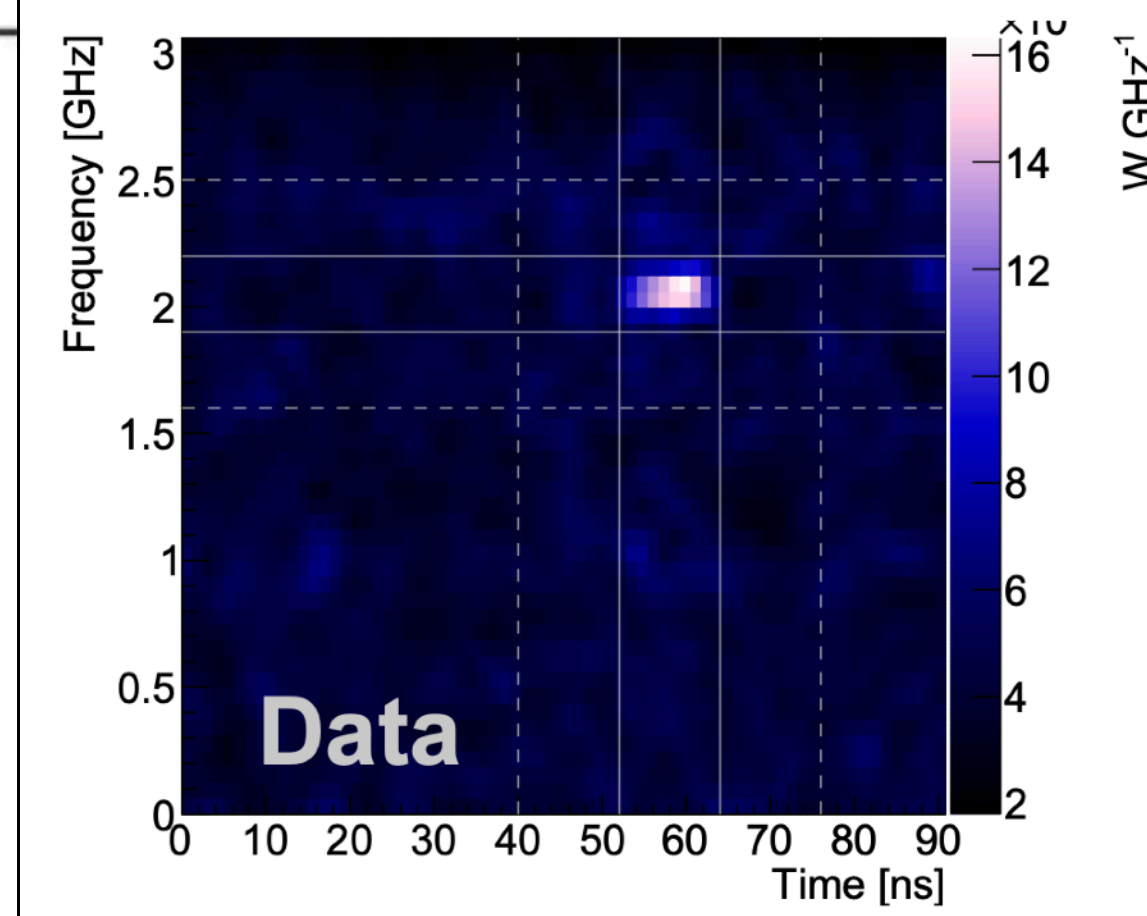
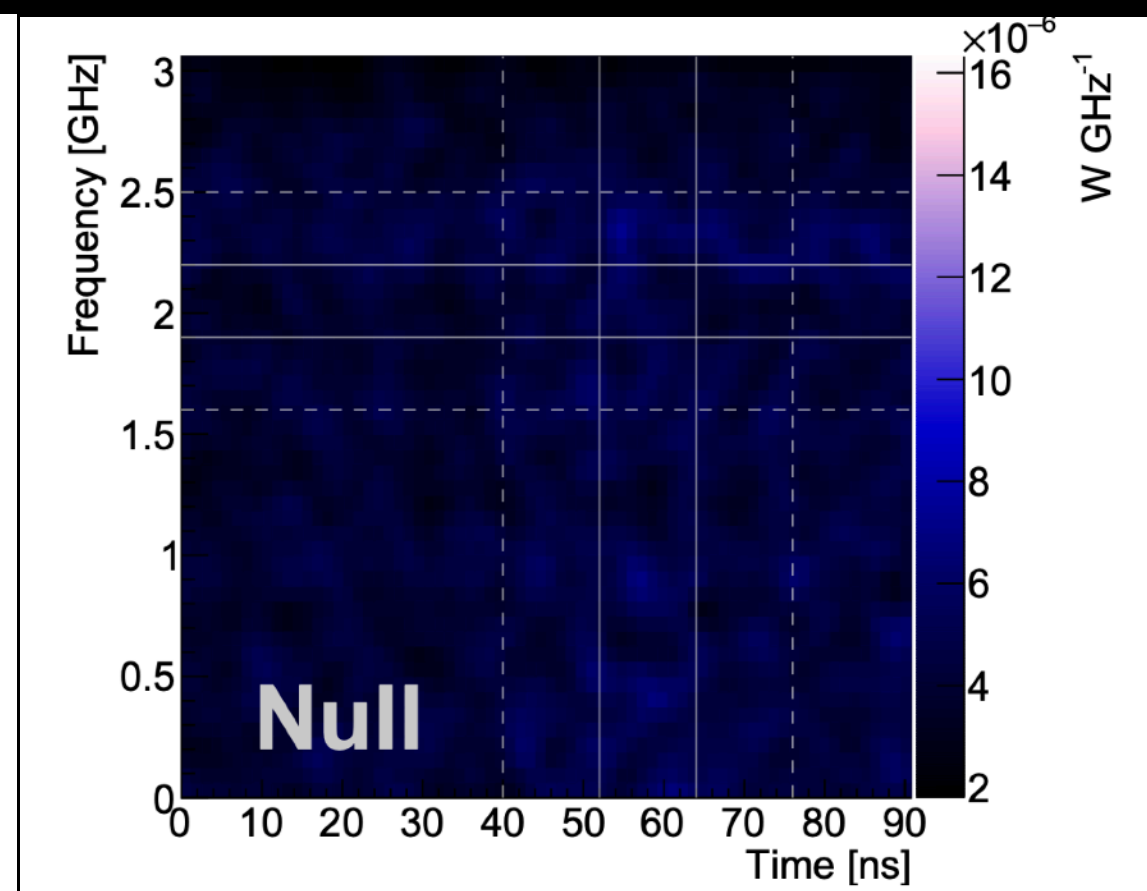# Question : Can particle cascades be detected with a radar?

RADAR

Blackett and Lovell in 1940's
TARA experiment
Cosmic ray air showers with radar ✗

But what about a
dense media like ice ?

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

SLAC T-576 Experiment(2020)
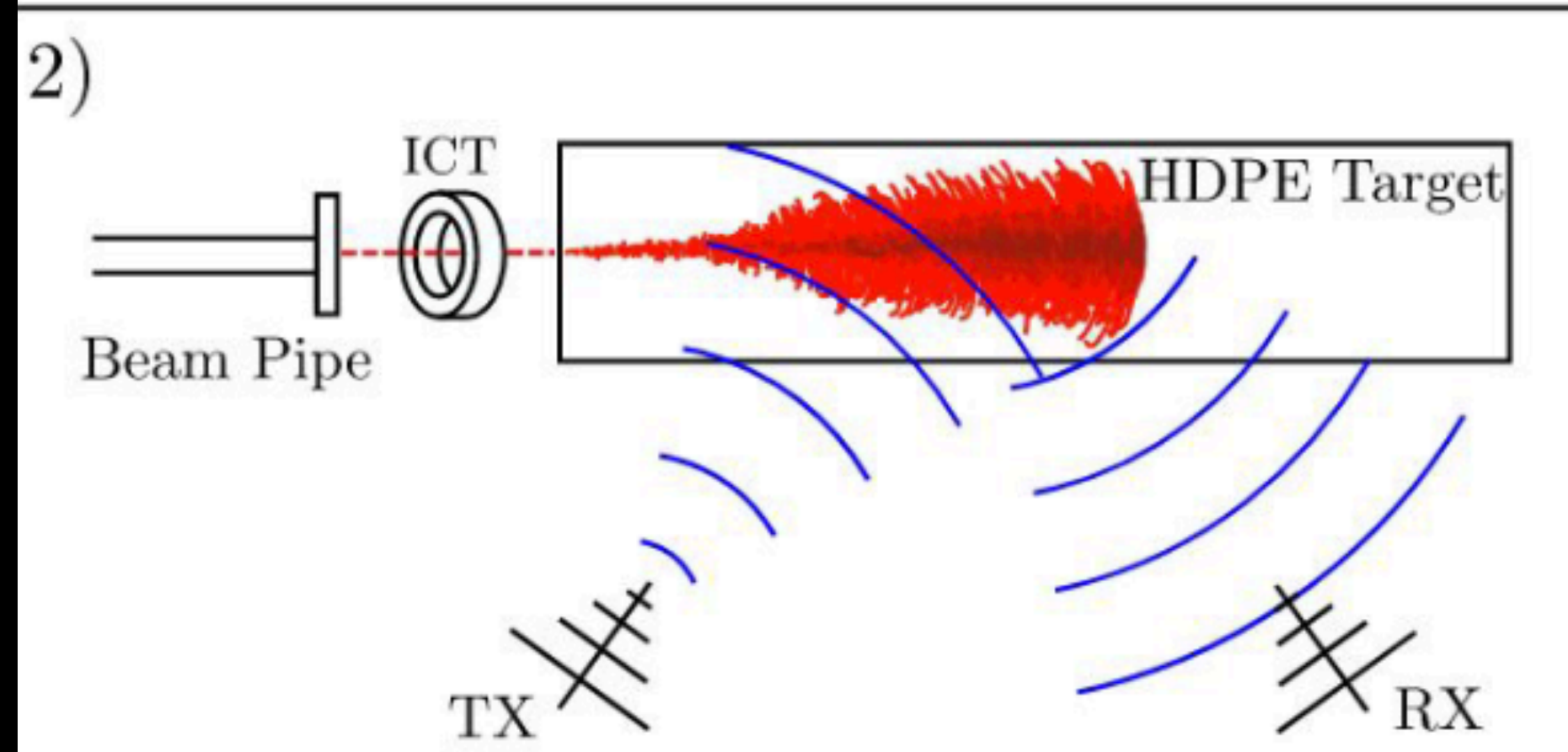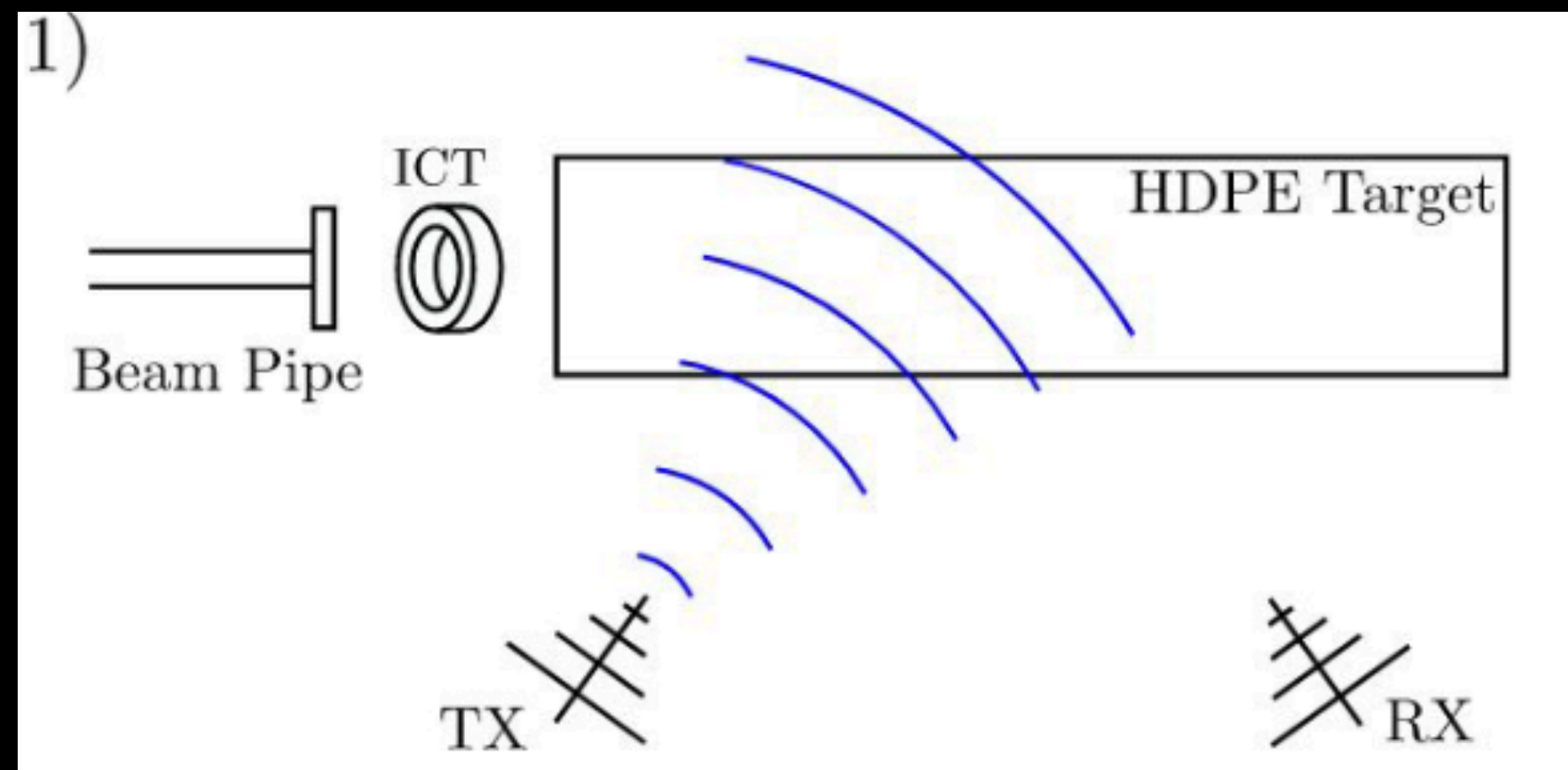
The density of the particle cascade was similar to that of a greater than 10^{17} eV neutrino induced shower in ice

A successful detection of a radar echo in LAB ✔
A successful detection of a radar echo in nature ?

FIRST EVER DETECTION OF RADAR ECHOES FROM PARTICLE-SHOWER INDUCED CASCADE !

4

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

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

Test Bed Experiment!

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

RET-CR

Cosmic-Ray
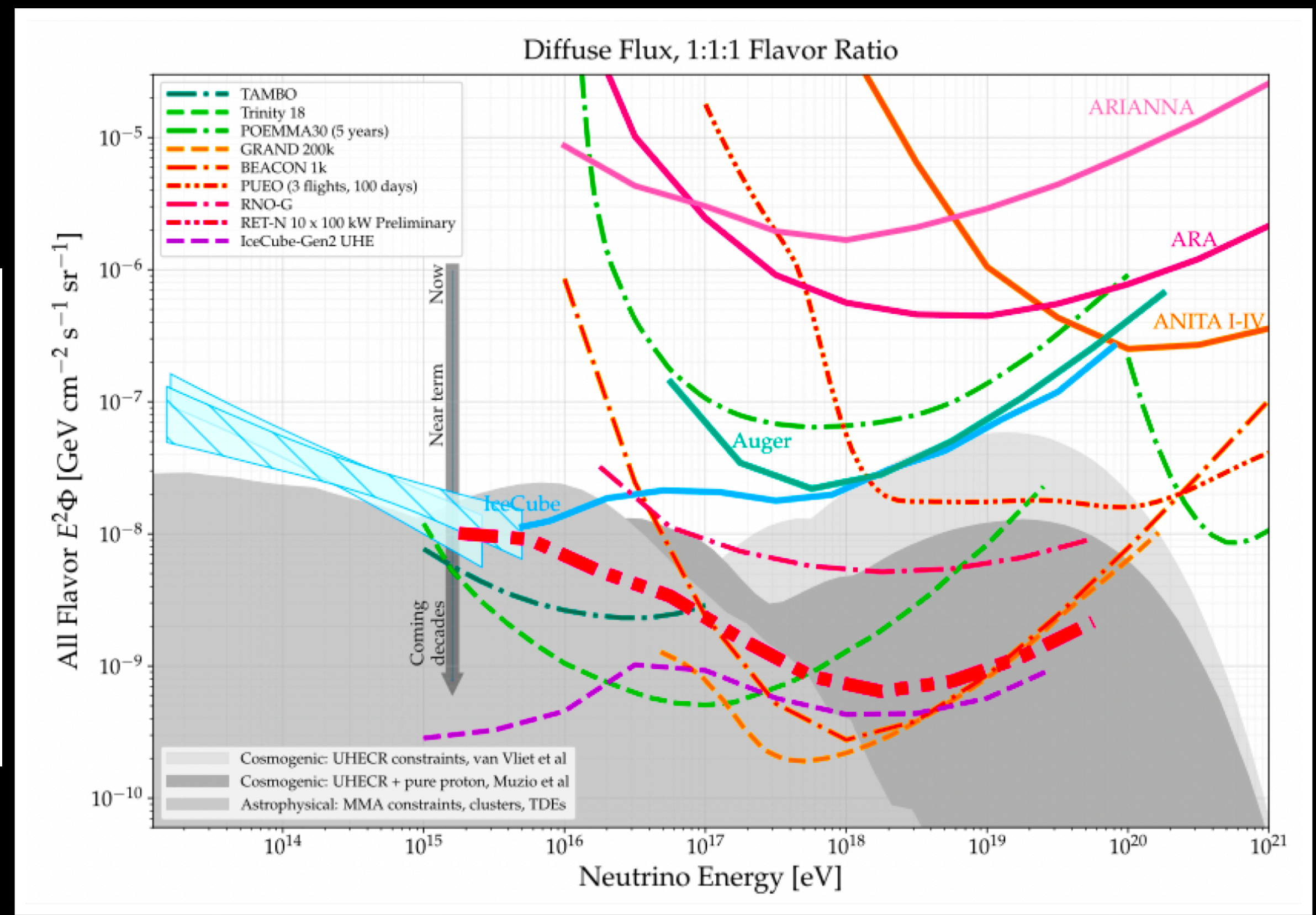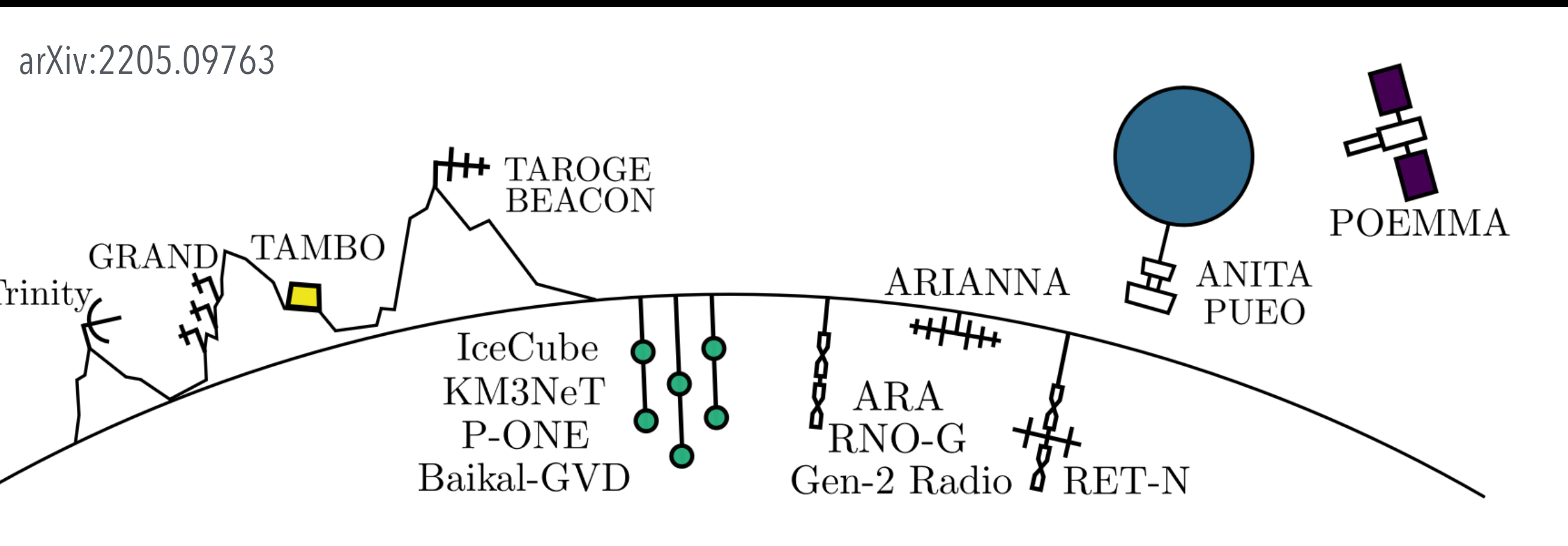Air Shower

Surface
Detectors

DAQ

In-ice
Cascade

TX

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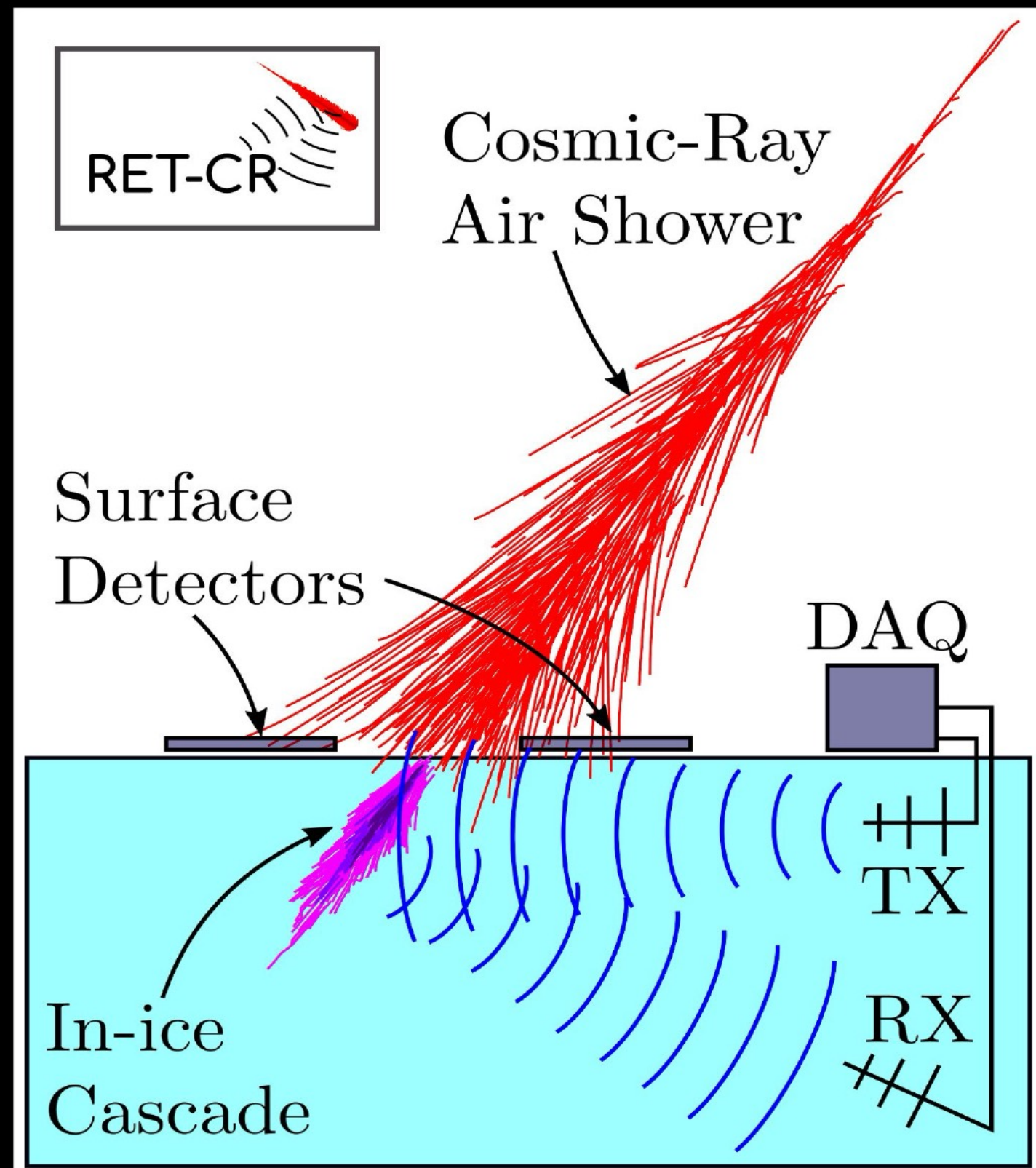
The detection of this in-ice secondary
cascade by cosmic ray air shower with
the radar method!

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

Neutrinos !

ν
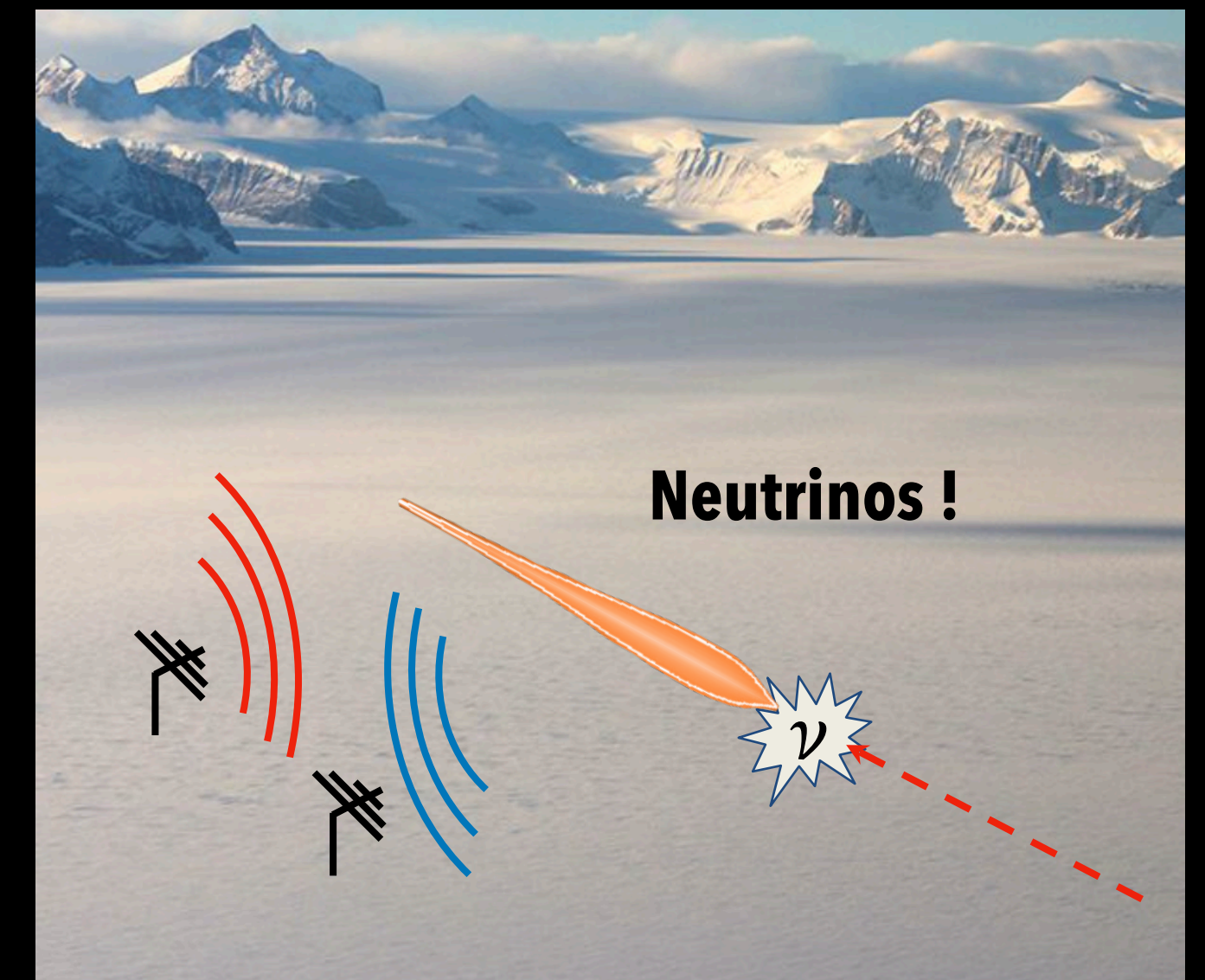
Current Neutrino detection Experiments

arXiv:2205.09763

Experimental Set-Up of RET-CR

RET-CR Site Map (GNSS Survey 15th & 19th May, 2024)
TX at (lat=72.605928 N, lon=-38.35038826 E)
alt = 3264.844 m (a.s.l)
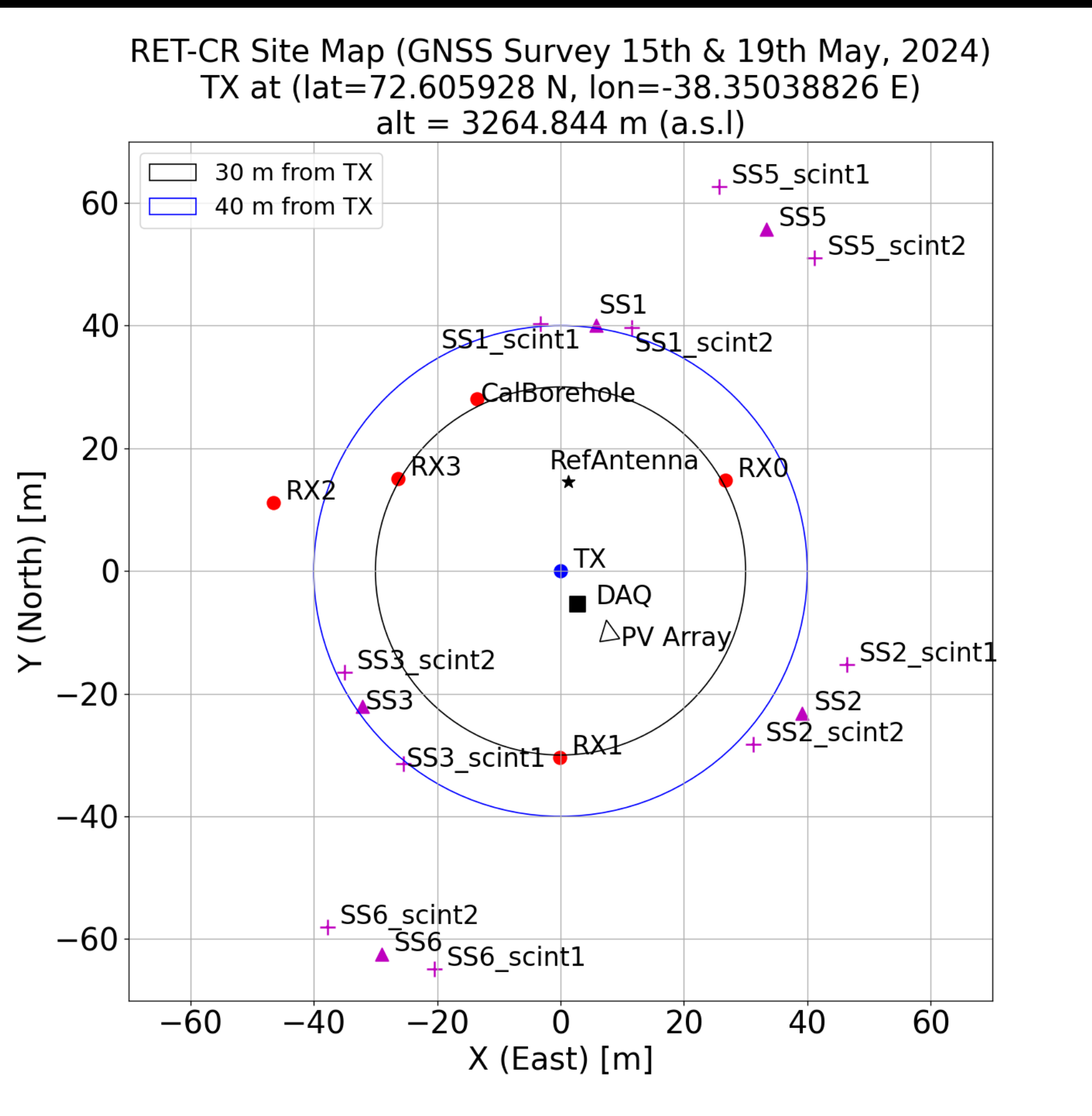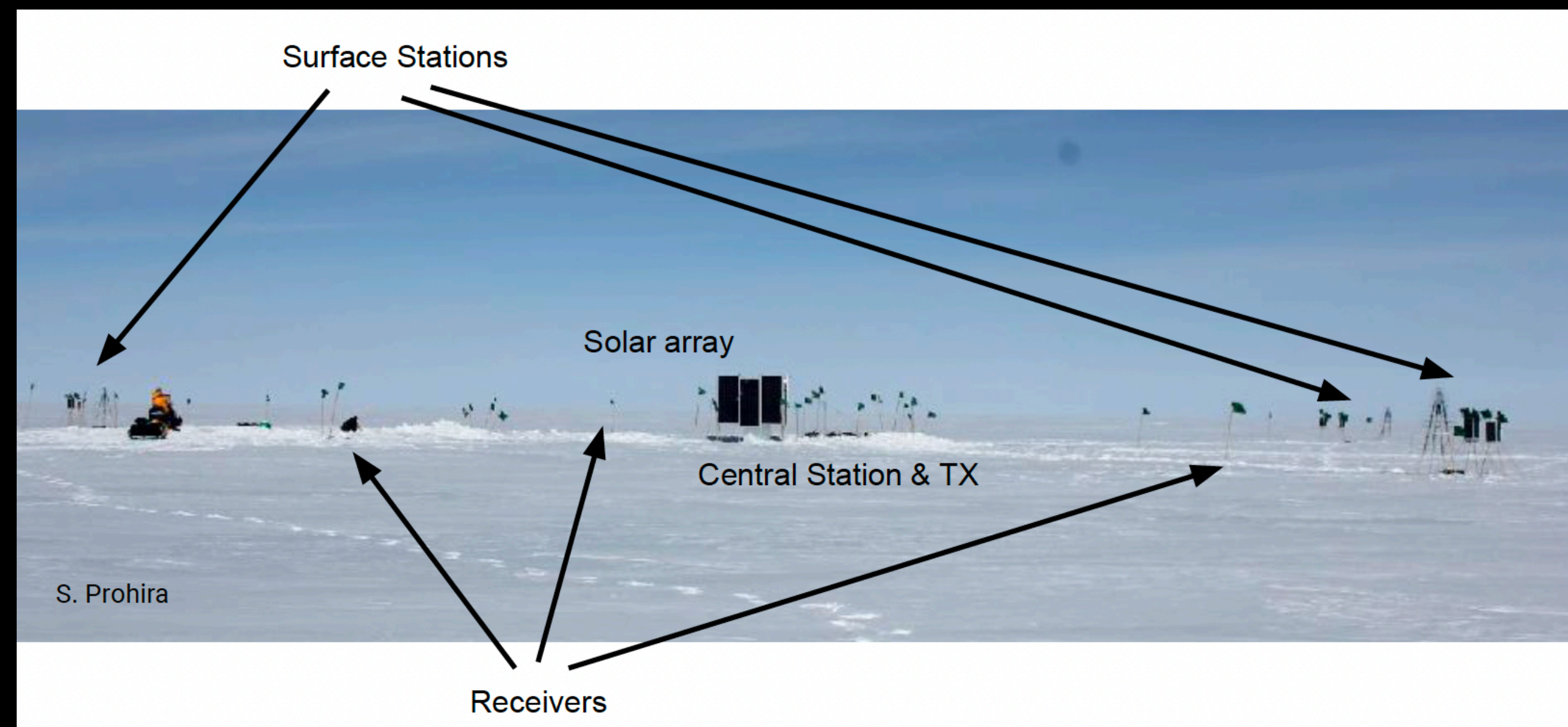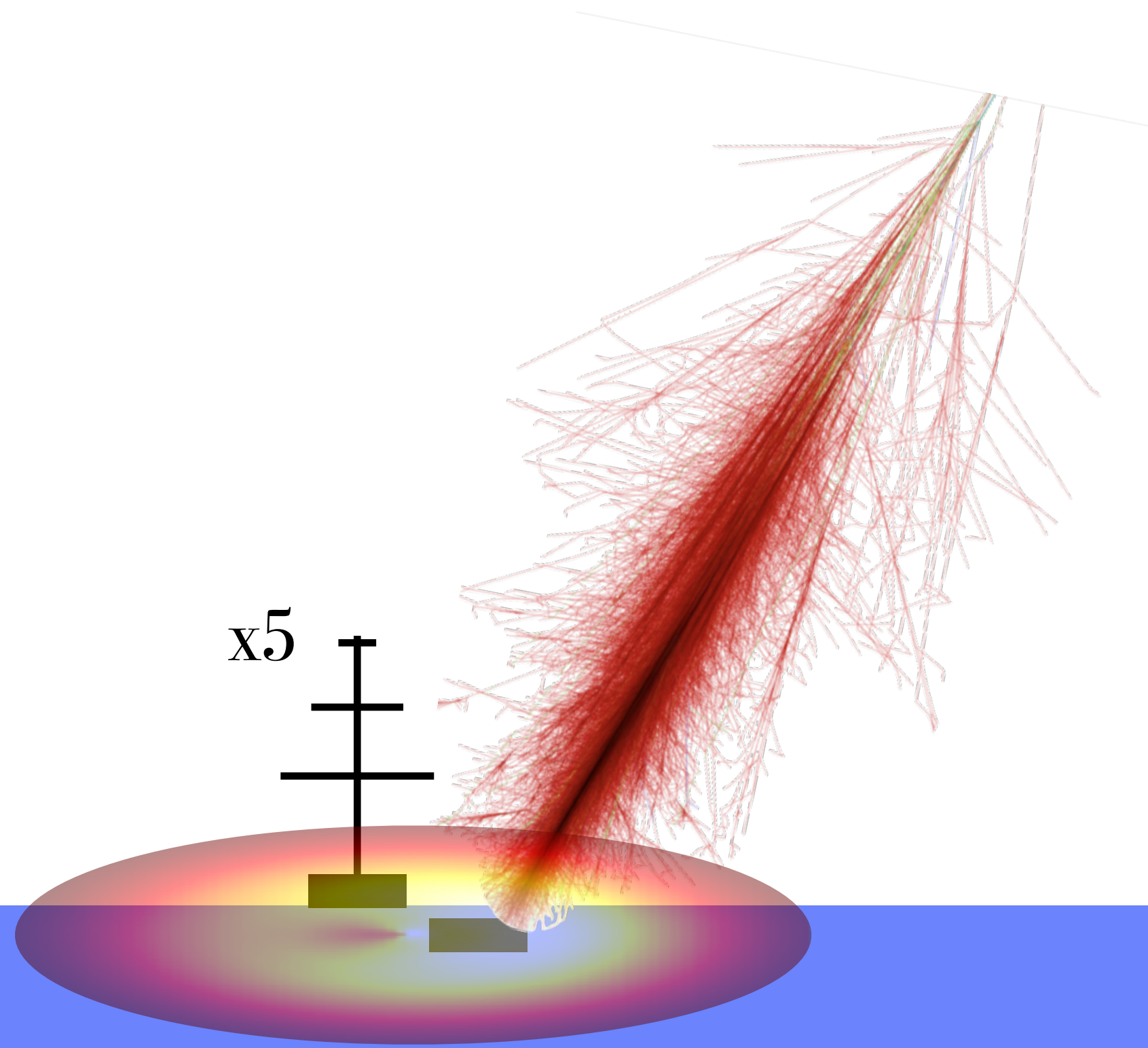
Surface stations trigger on an incoming high energy cosmic ray air shower
- Its own independent reconstruction strategy

The Radar system - detects the in-ice cascade and reconstructs the properties in compliment to the surface stations
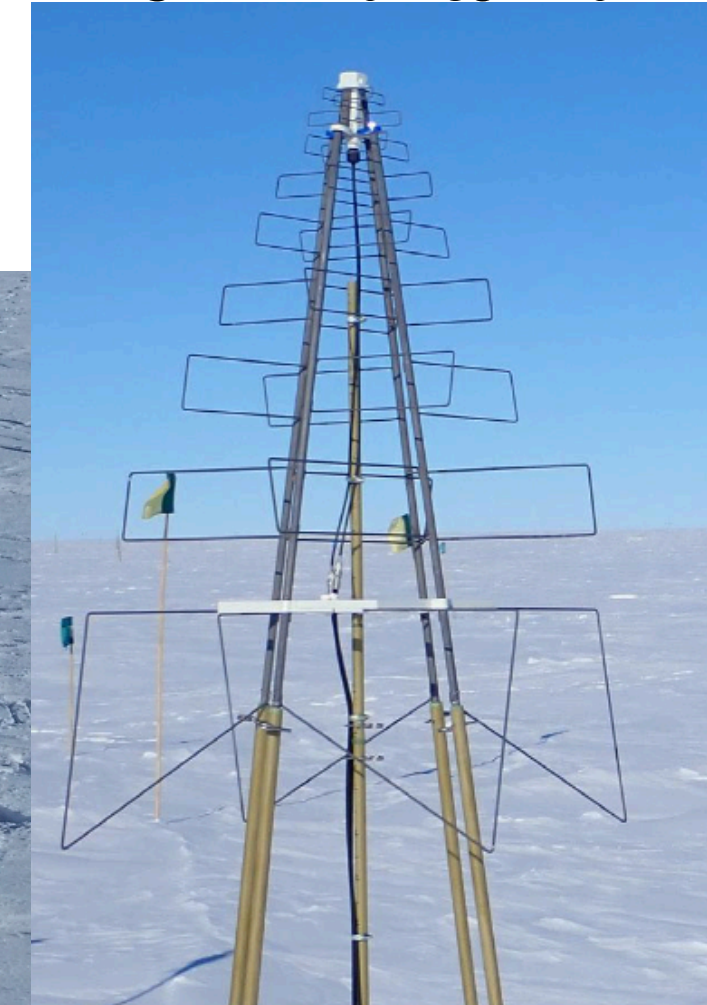
In-air cosmic ray shower

x5
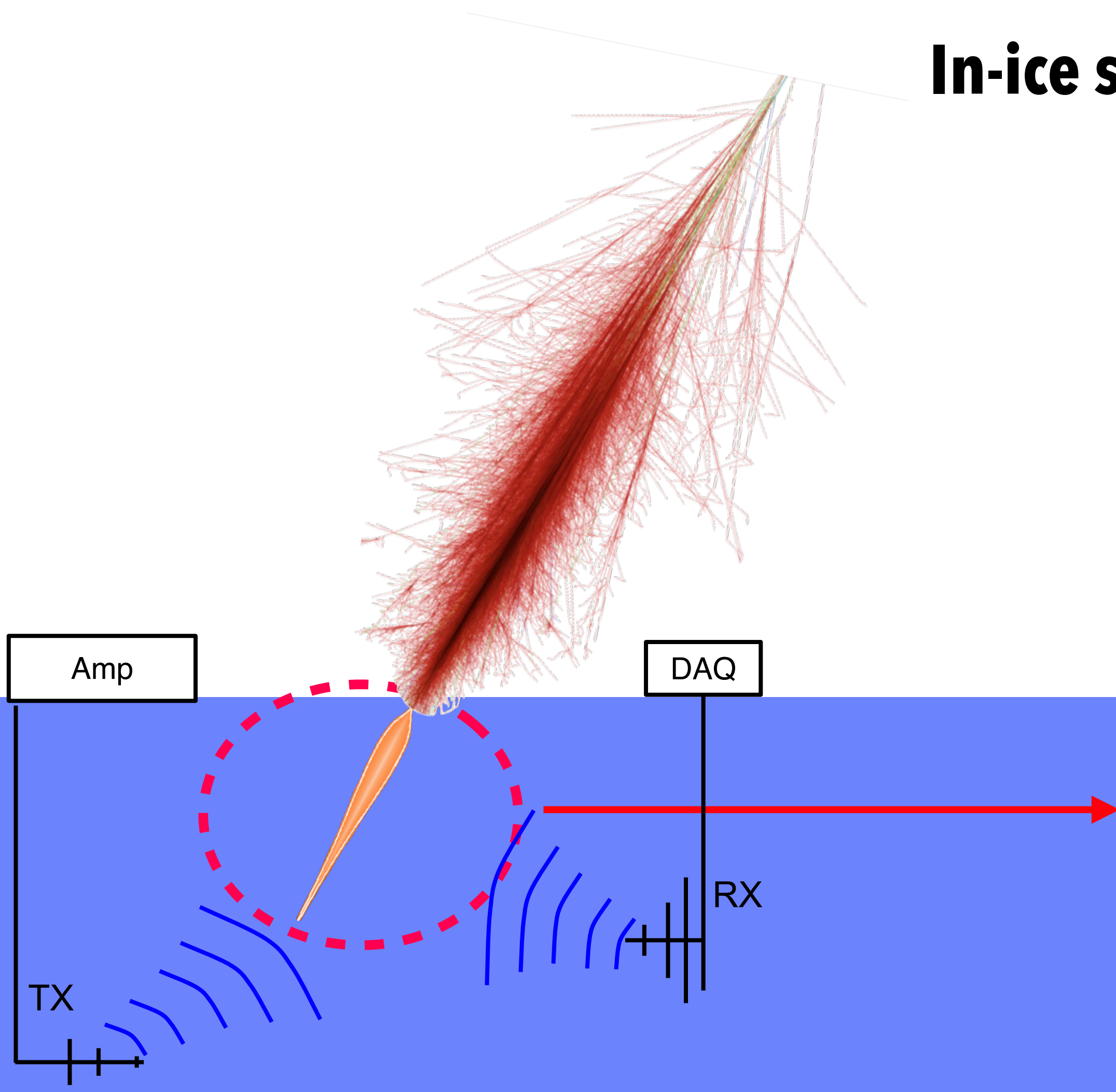
2 x IceTop scintillator

SKALA antenna

INDEPENDANT RECONSTRUCTION

◆ Arrival Direction

◆ Energy of the primary particle

◆ Core position reconstruction

◆ X_{max} reconstruction

In-ice secondary cascade

Amp

DAQ

TX

RX

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

In-ice secondary cascade

Amp

DAQ

RX

TX

100MHz

height-2350 [m]

10^4

10^3

10^2

— 10^{19} eV
— 10^{18} eV
— 10^{17} eV
— 10^{16} eV

Air

Ice

RET-CR

10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1

f_p [GHz]
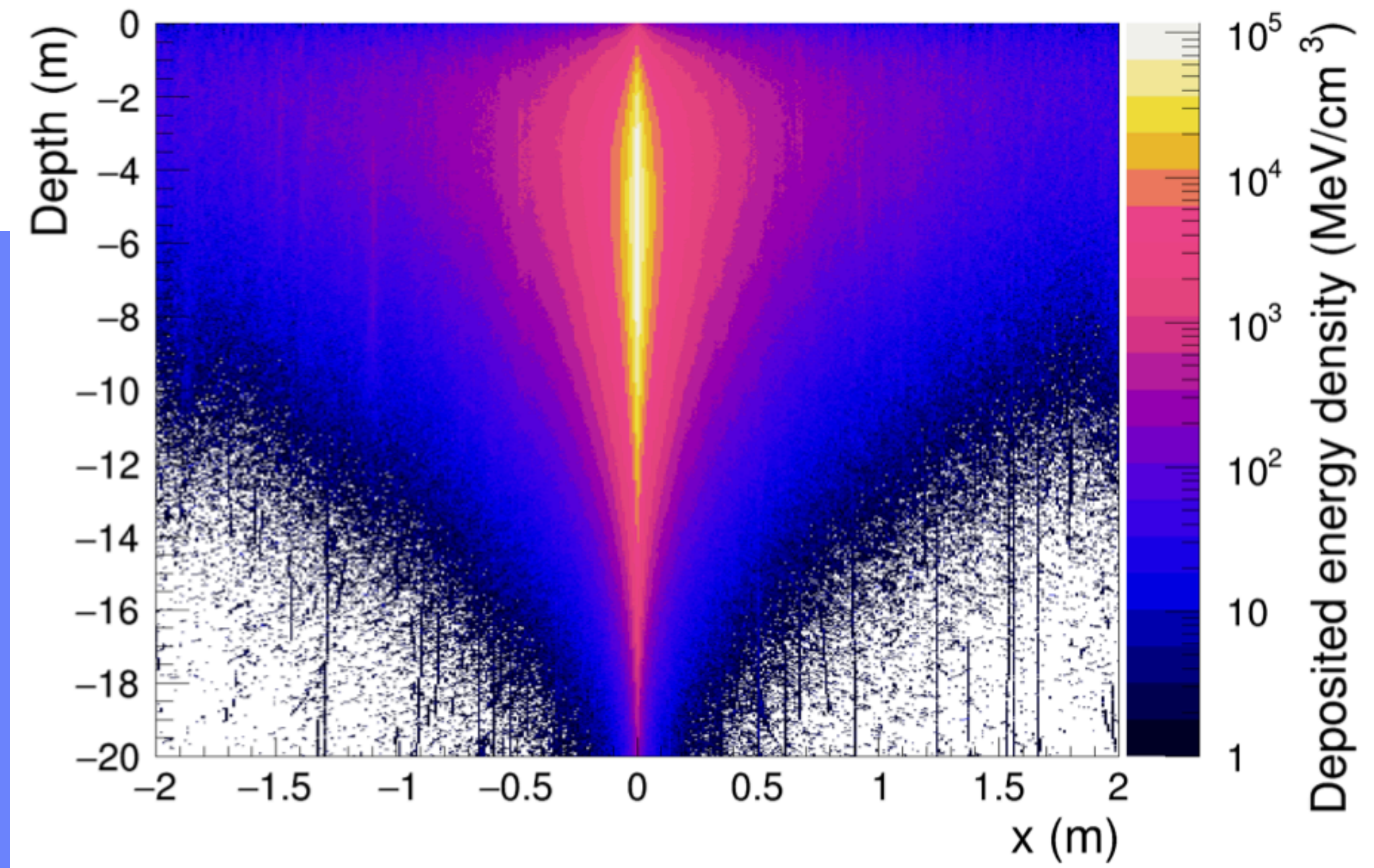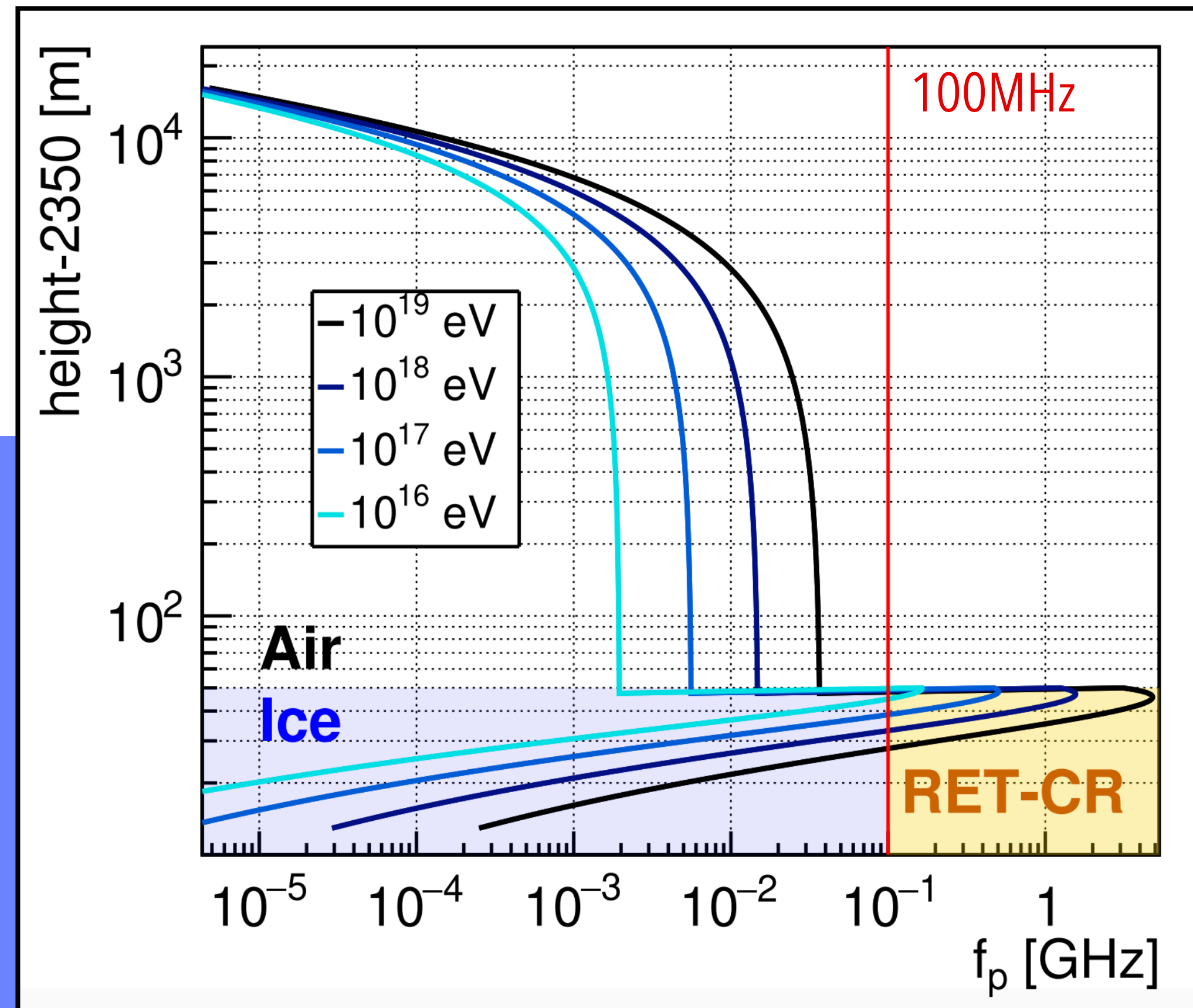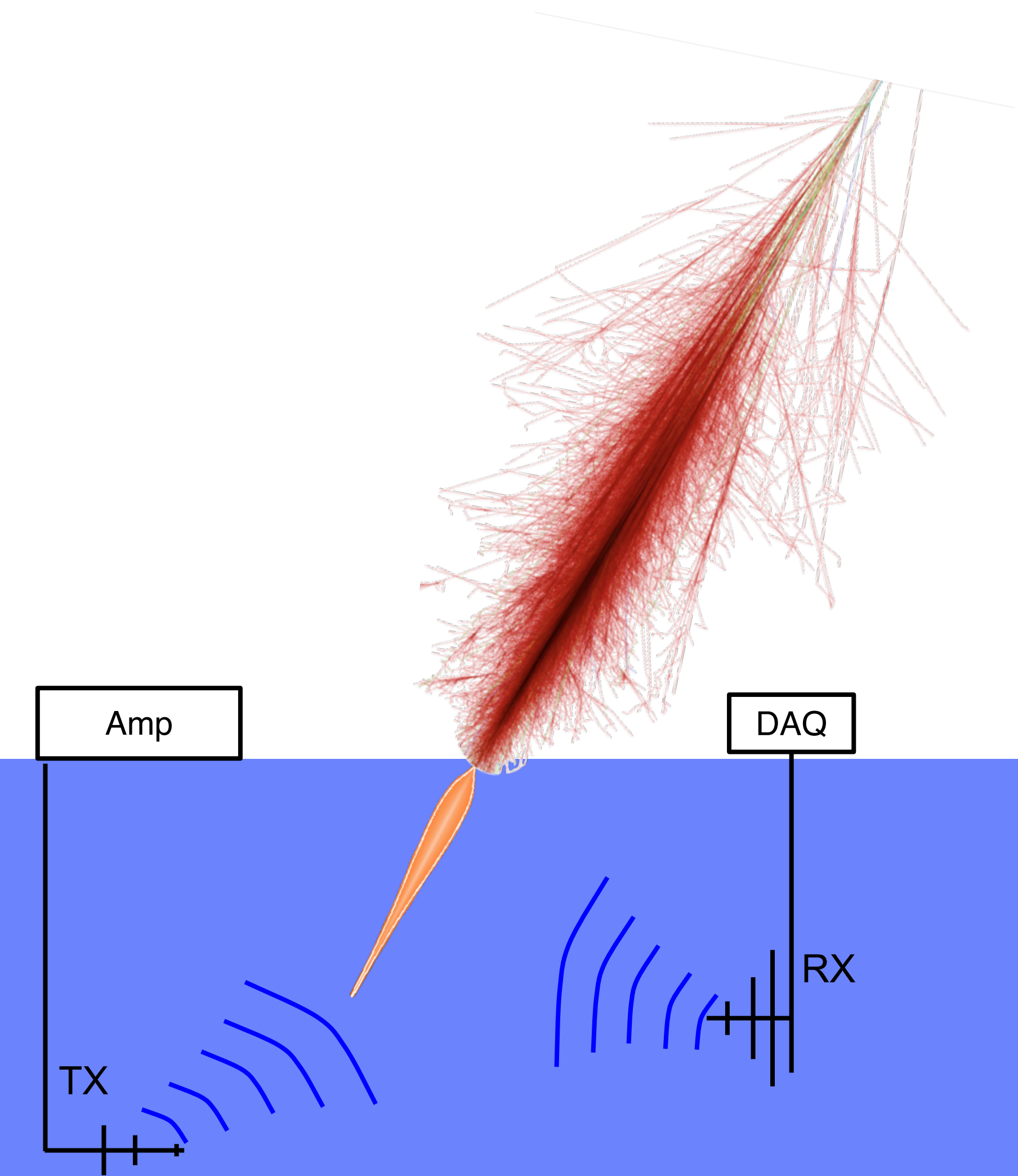
Detectable via radar -
$$E = 10^{16}\text{eV}$$

In-ice secondary cascade

Radar detection depends on :

- Medium: density of ionization plasma

- Plasma lifetime: function of medium temperature and conductivity (10 ns)

- Probing frequency (we can control)

- Cascade properties : energy, direction
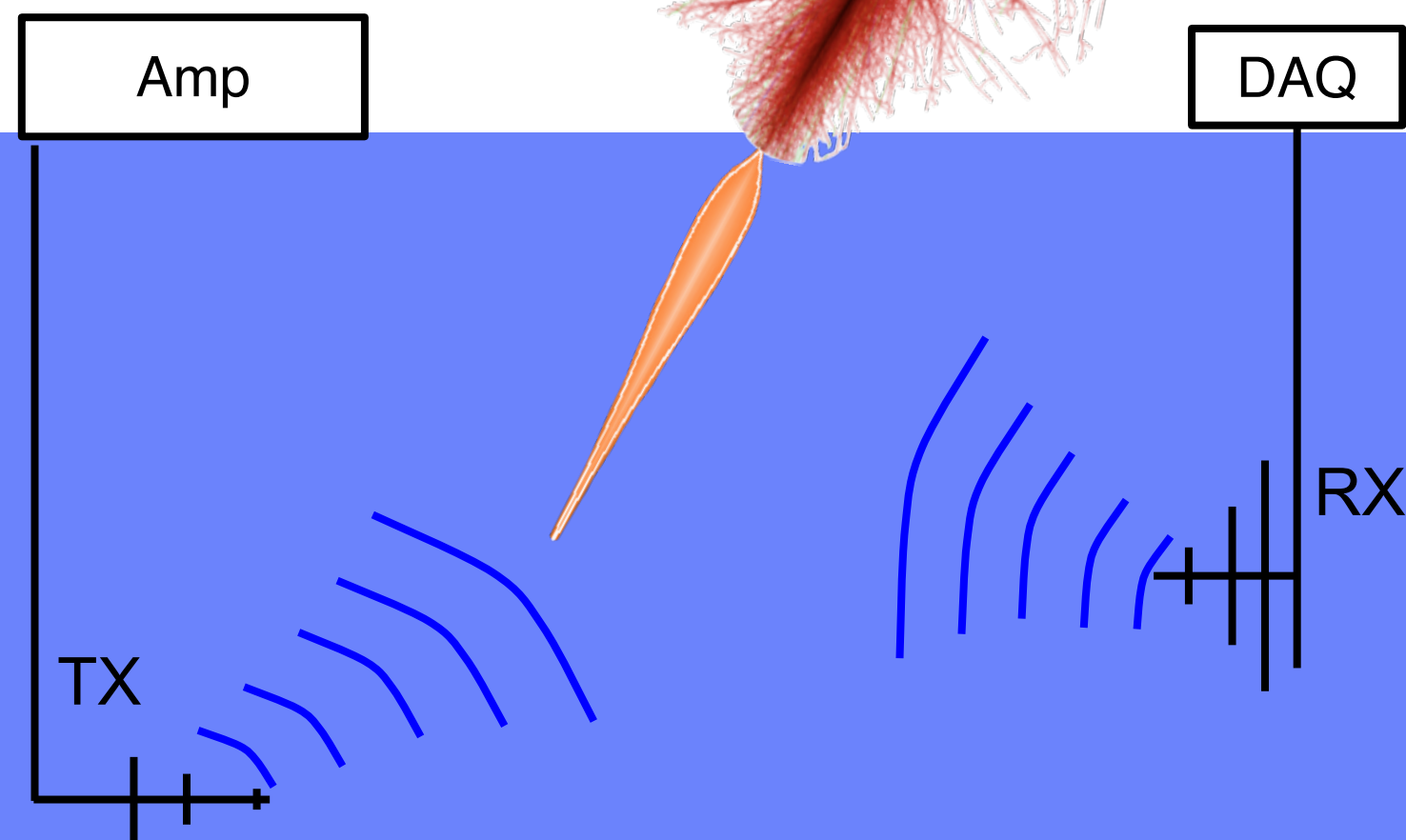
- Signal strength scales with energy

- Signal arrival time gives vertex position
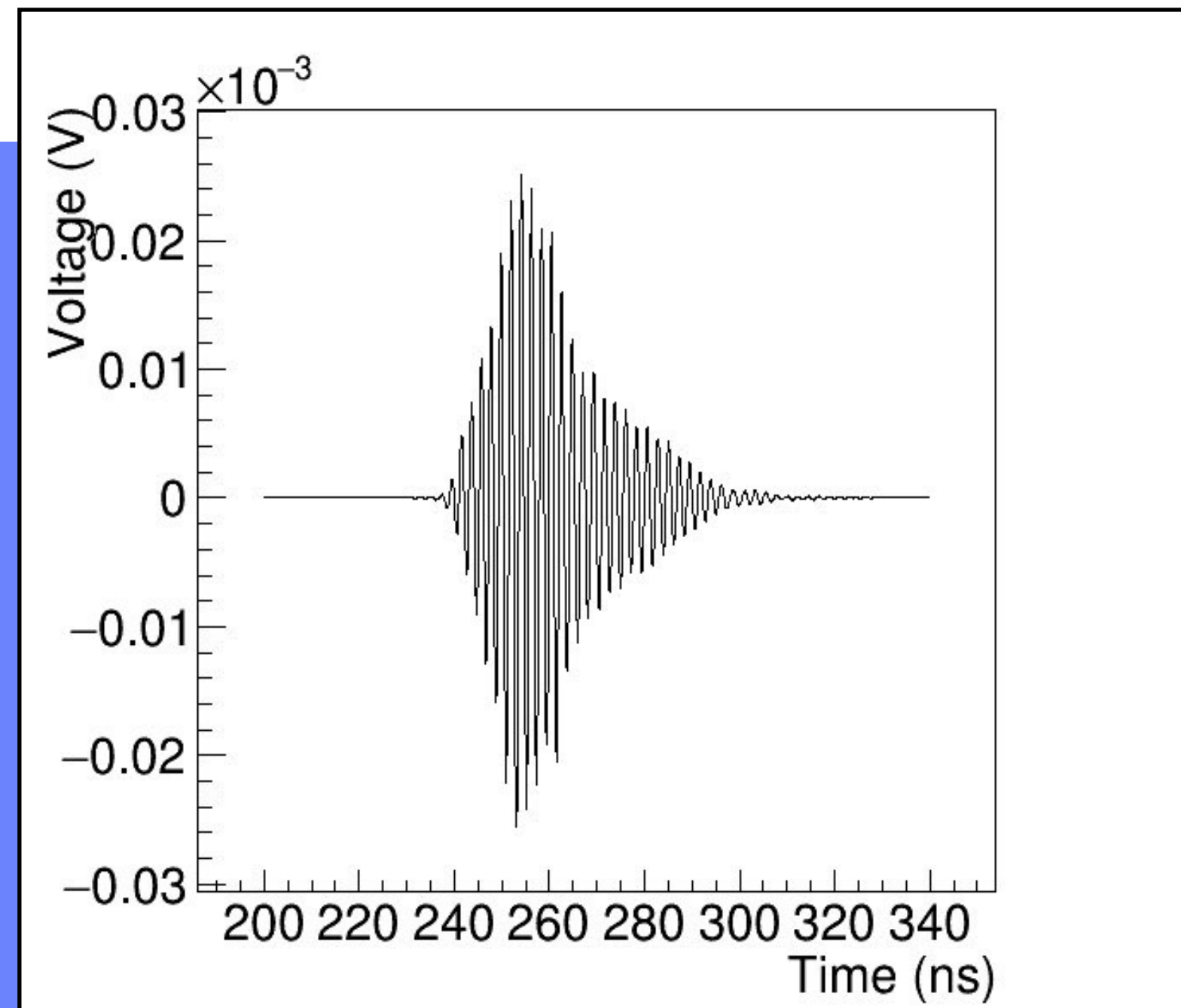
- Frequency content gives arrival direction

Into the future

2023   2024   2025   2026   2027
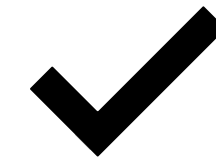
RET-CR Data taking ✓

Into the future

2023	2024	2025	2026	2027

RET-CR Data taking ✔

Full data taking run in 2024 summer

Into the future
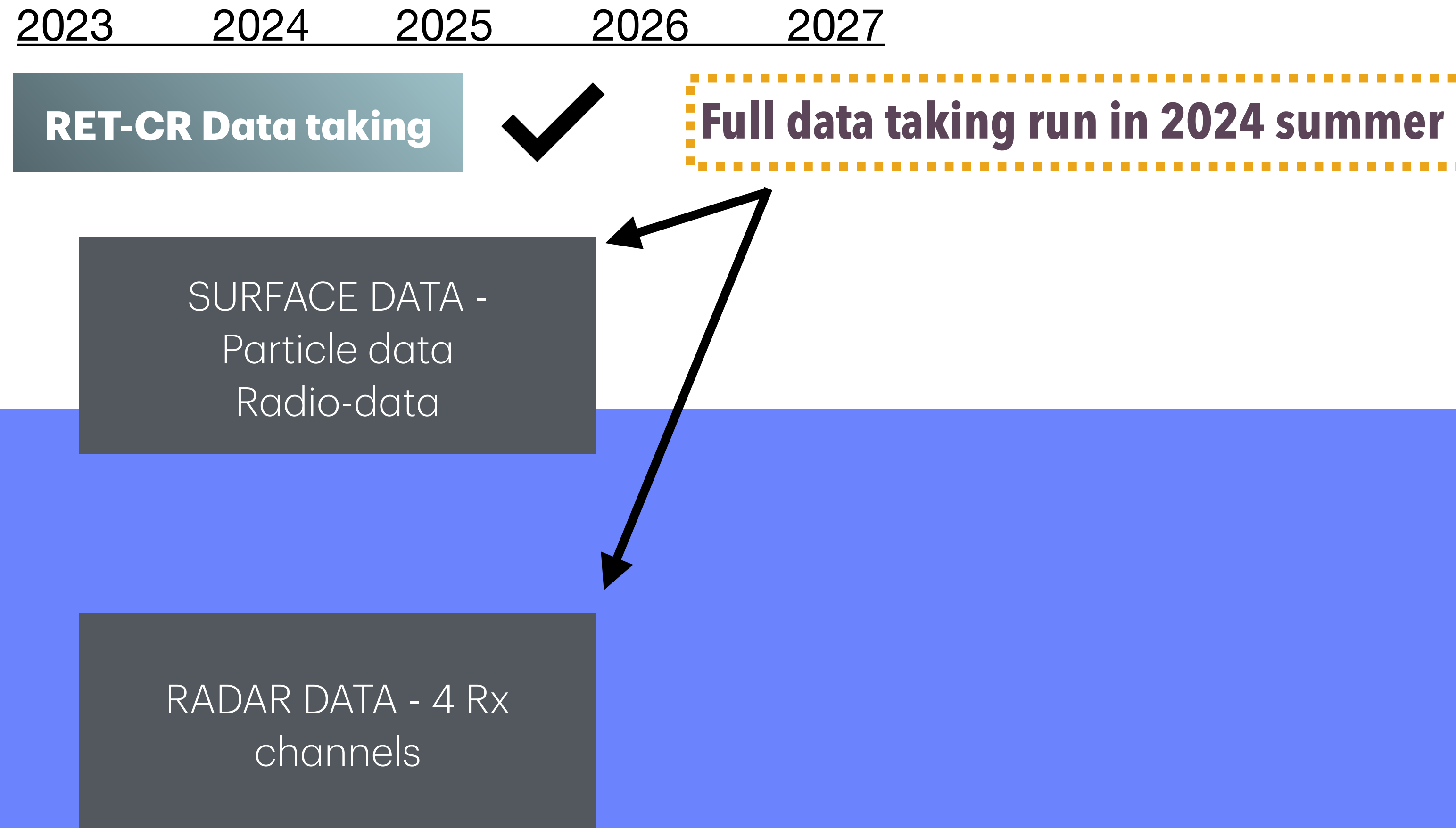
2023   2024   2025   2026   2027

RET-CR Data taking ✓

Full data taking run in 2024 summer

SURFACE DATA -
Particle data
Radio-data

Into the future

2023   2024   2025   2026   2027

RET-CR Data taking ✓

Full data taking run in 2024 summer

SURFACE DATA -
Particle data
Radio-data

RADAR DATA - 4 Rx
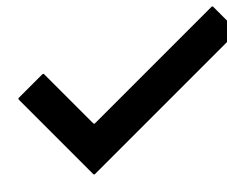channels

Into the future

2023   2024   2025   2026   2027
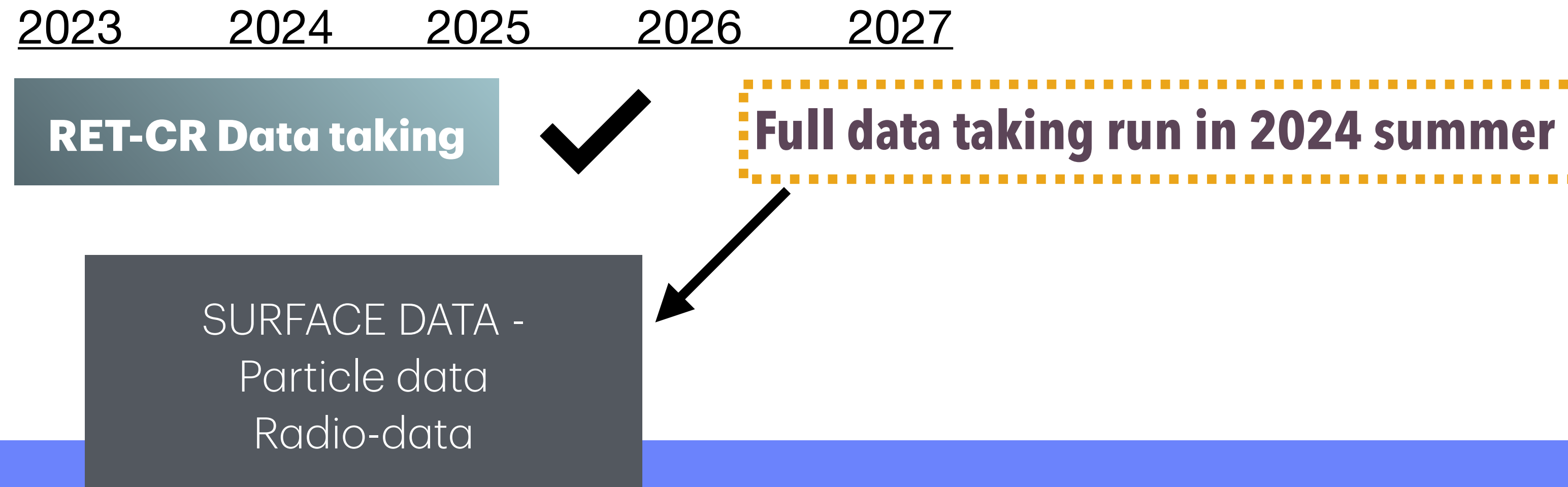
RET-CR Data taking ✓

Full data taking run in 2024 summer

SURFACE DATA -
Particle data
Radio-data

Reconstructions:
- Arrival Direction
- Energy of the primary particle
- Core position reconstruction

What I currently work on?

RADAR DATA - 4 Rx
channels

The combined askaryan - radar signals

Into the future

2023   2024   2025   2026   2027

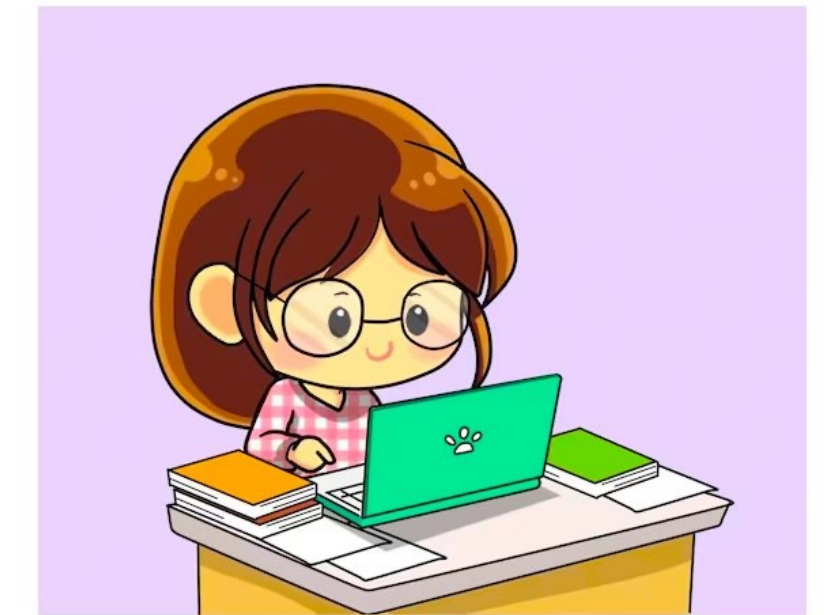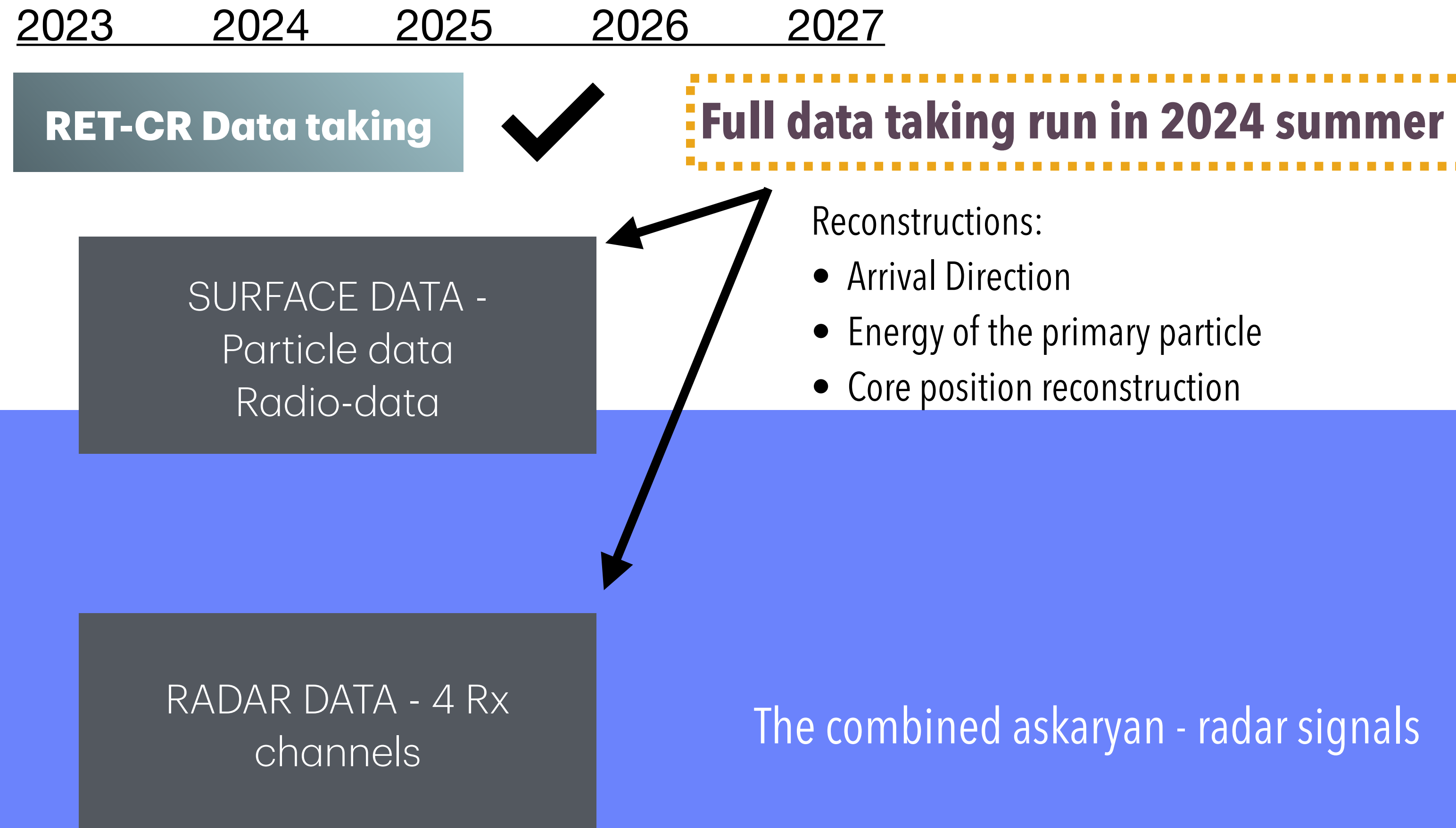**RET-CR Data taking** ✓

Full data taking run in 2024 summer

SURFACE DATA -
Particle data
Radio-data

Denoising - Singular value decomposition (SVD) method
Any questions: Curtis McLennan (In this room)
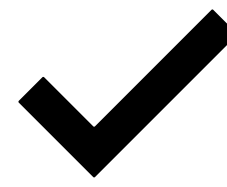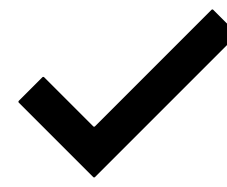
RADAR DATA - 4 Rx
channels

Into the future

2023   2024   2025   2026   2027

RET-CR Data taking   ✓   **Full data taking run in 2024 summer**

SURFACE DATA -
Particle data
Radio-data

Denoising - Singular value decomposition (SVD) method
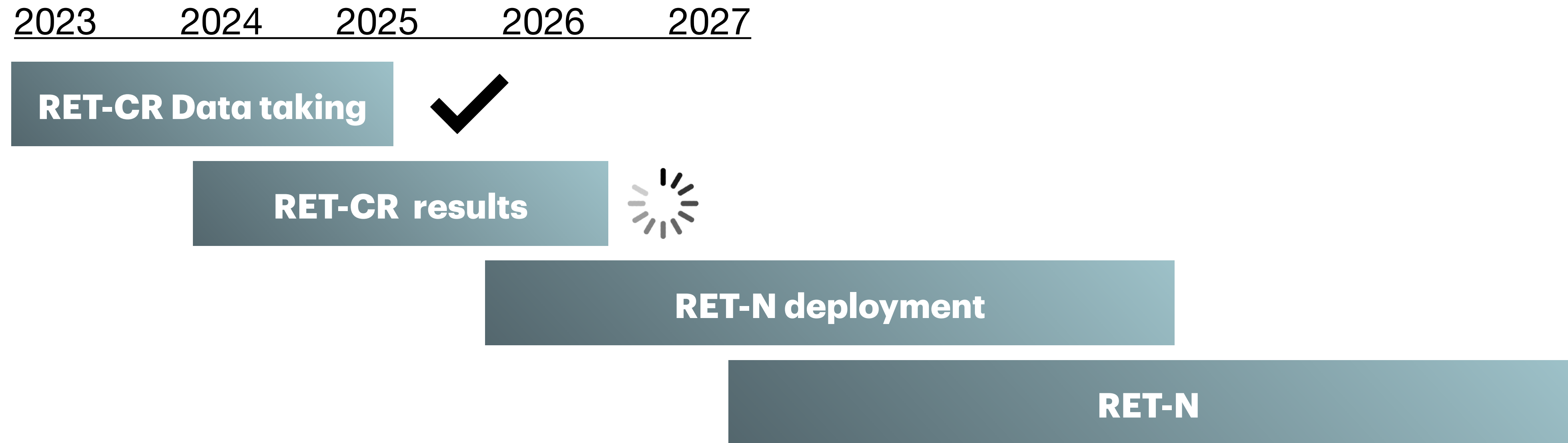Any questions: Curtis McLennan (In this room)
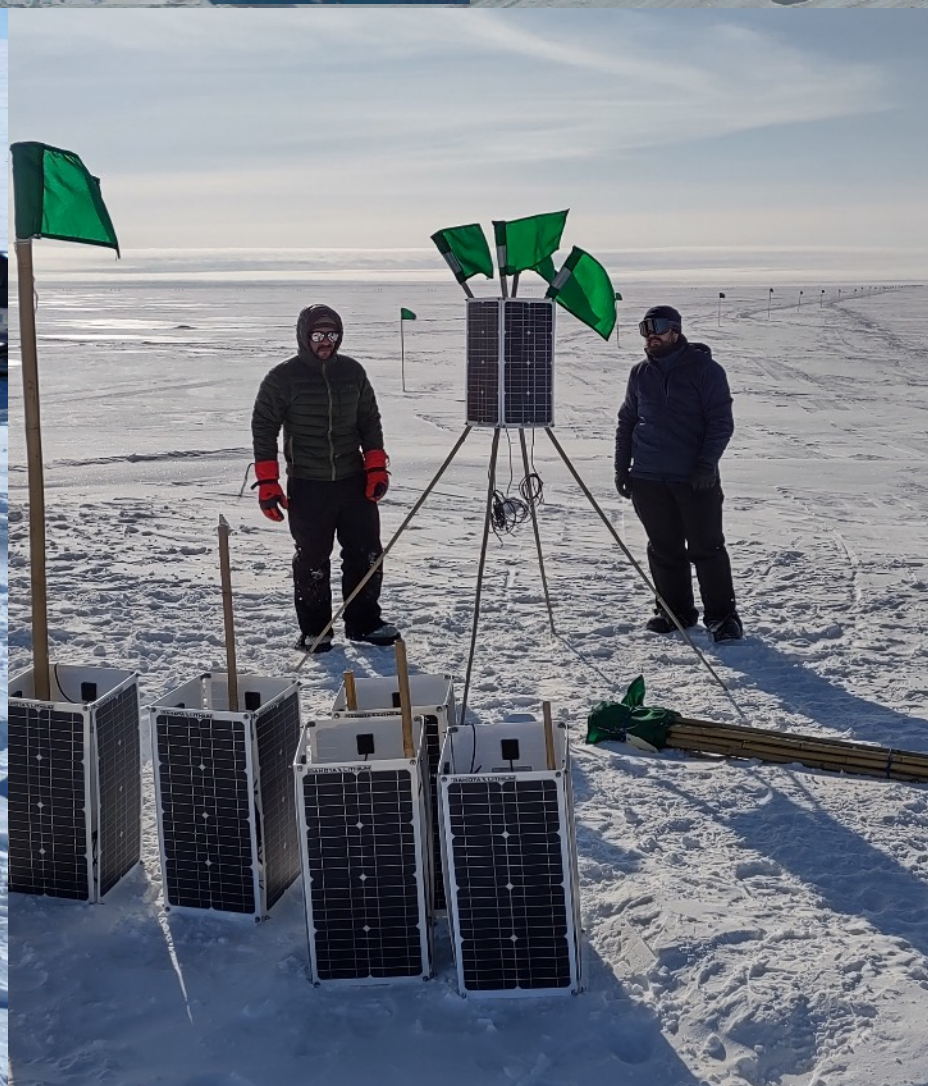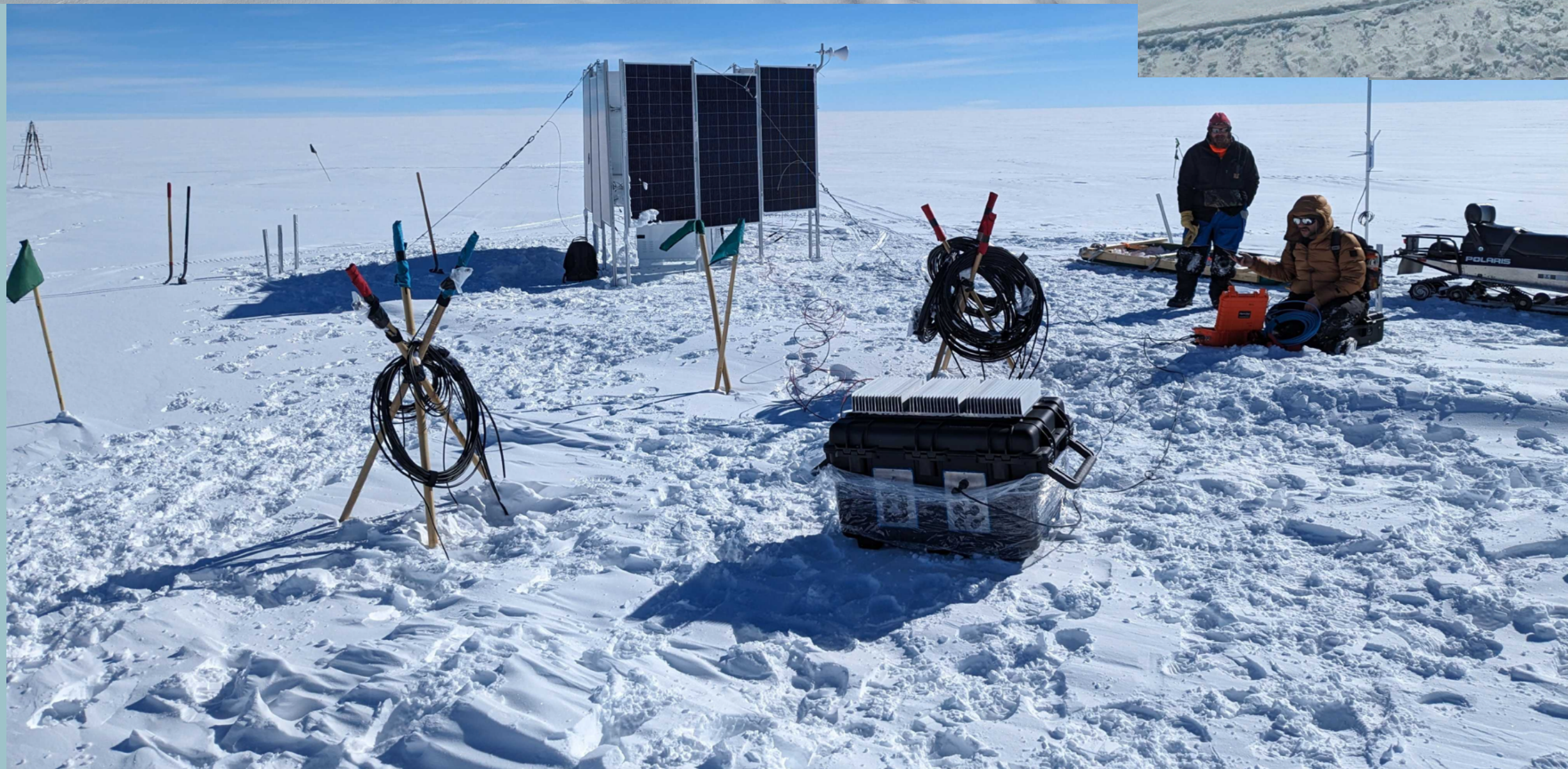
RADAR DATA - 4 Rx
channels

Understanding the combined askaryan and radar signals
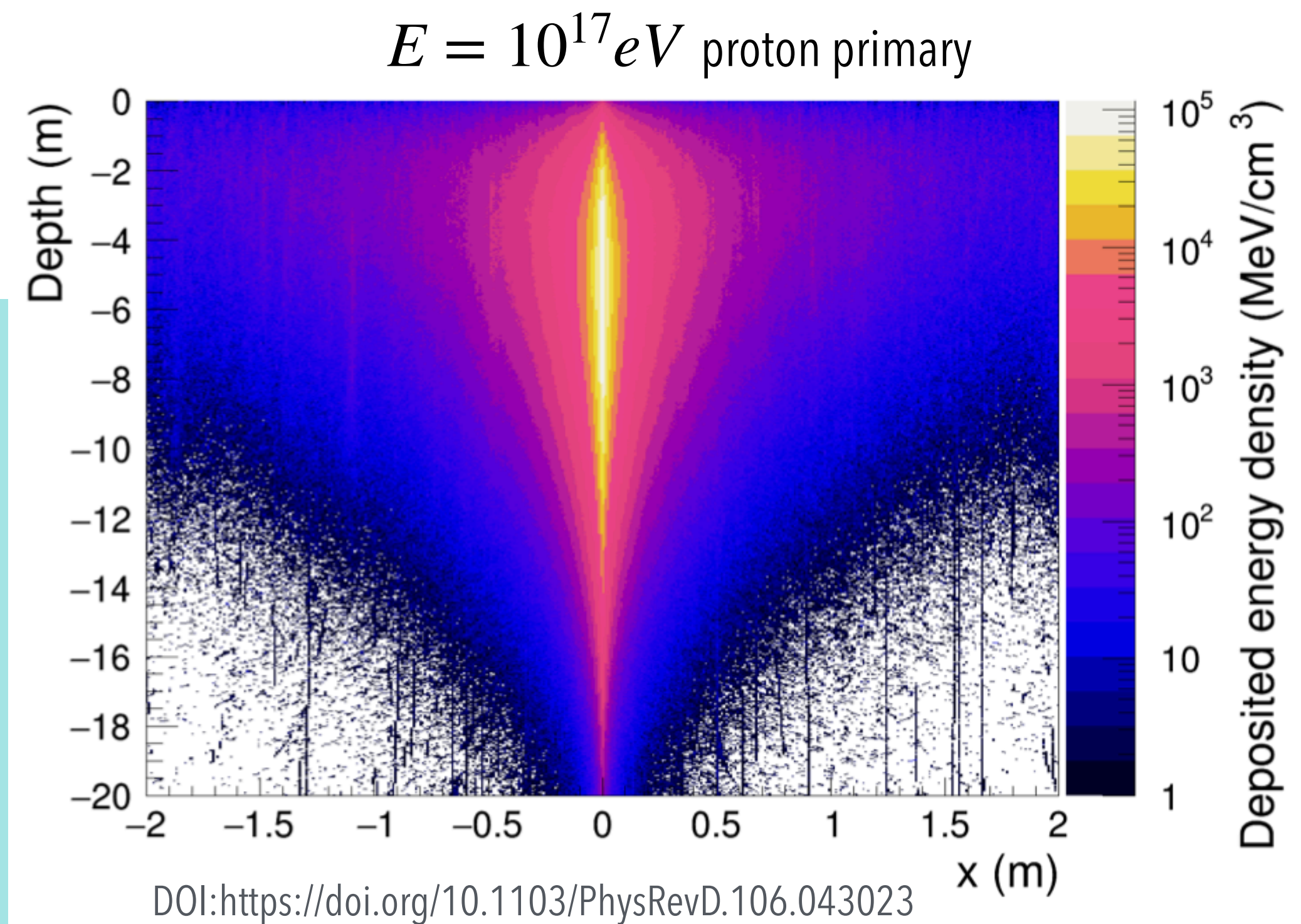
Exploring the possibility of using Machine learning methods for denoising the data

Into the future

2023   2024   2025   2026   2027

RET-CR Data taking ✓

RET-CR results

RET-N deployment

RET-N

Thank you!! ♡

BACK UP SLIDES

In-ice secondary cascade

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

Amp

DAQ

RX

TX
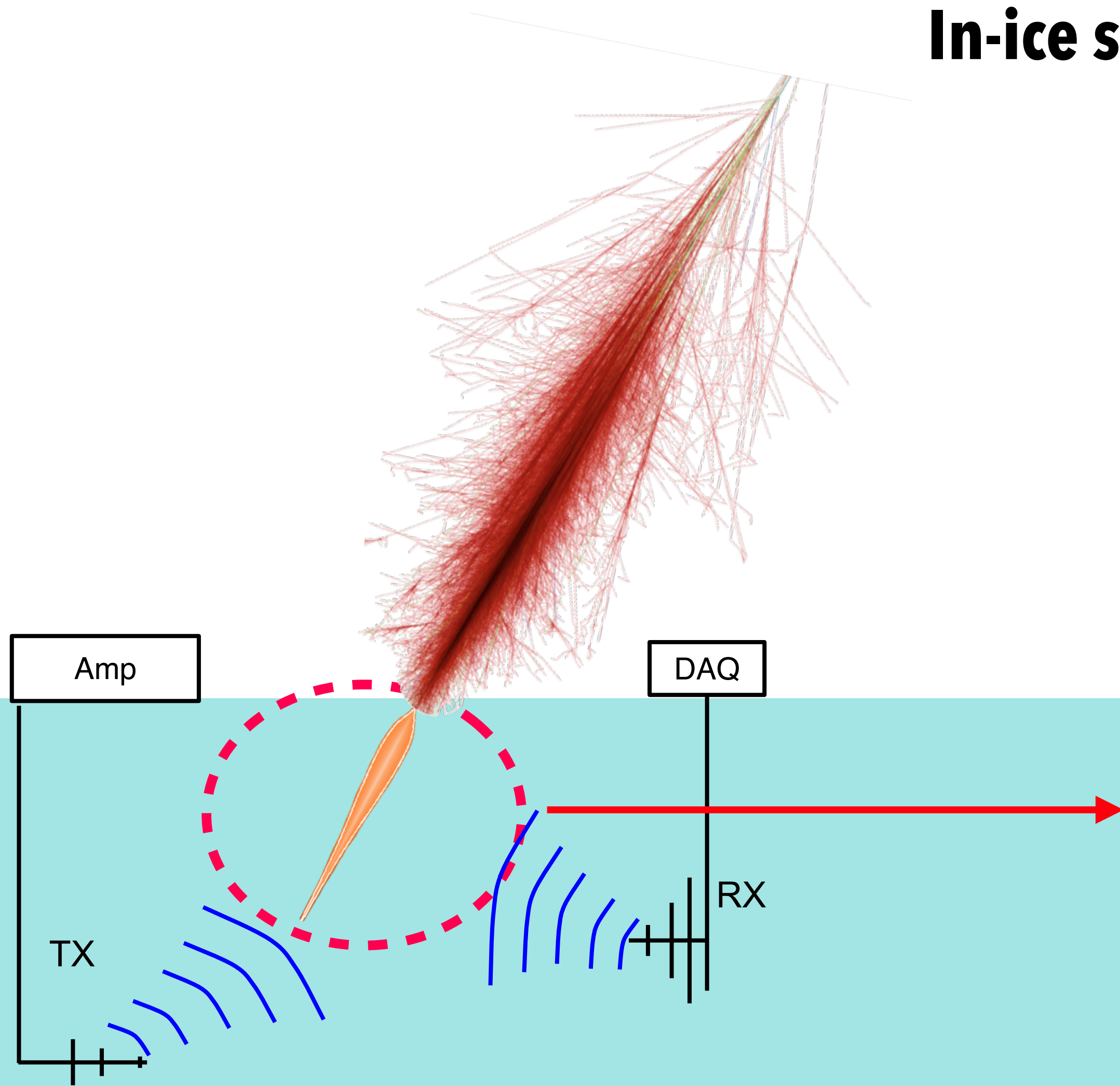
Energy and Core position Reconstructions

Fluence Interpolation profile
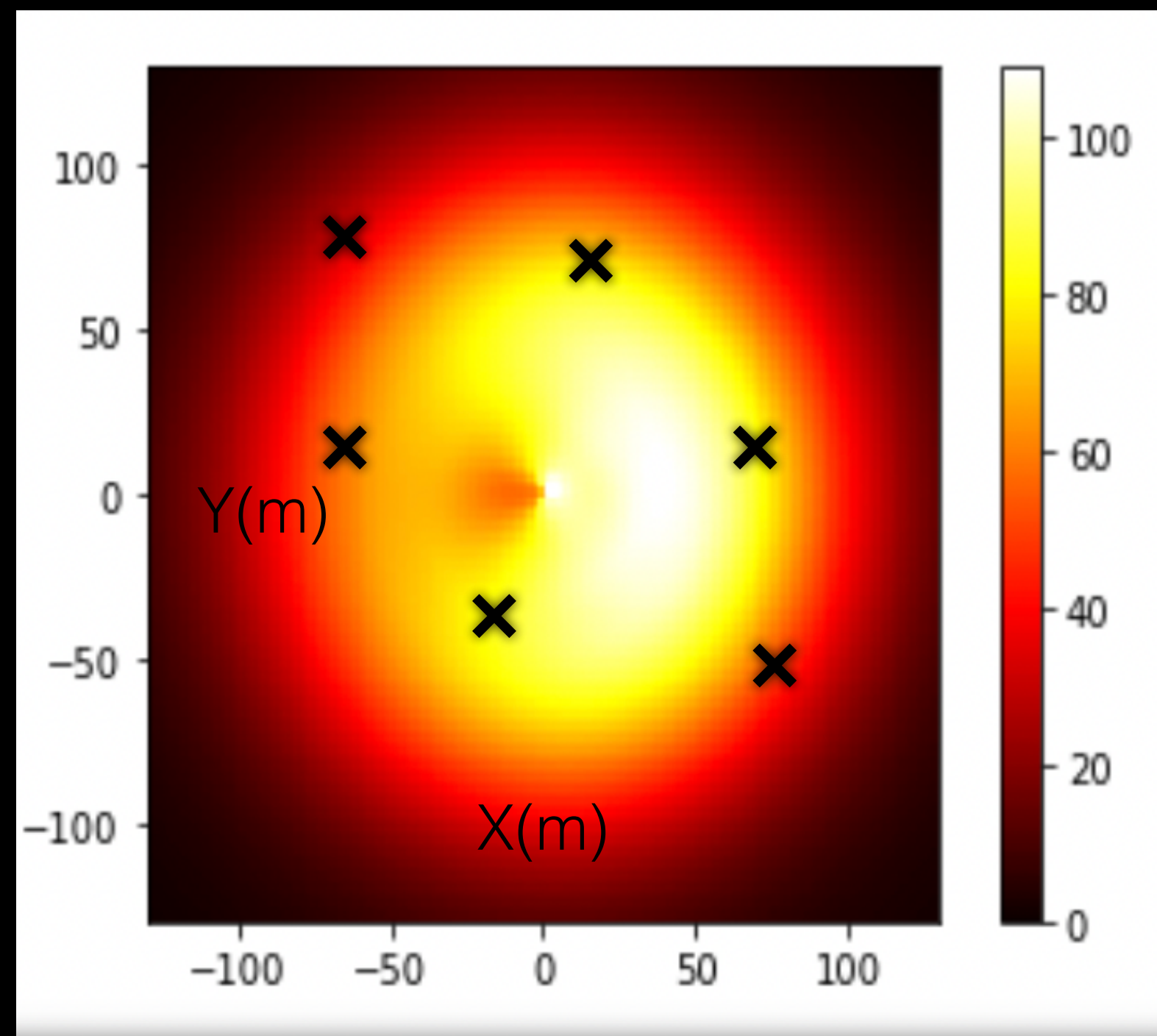
Linear Slope(mf) Interpolation profile

23

In-ice secondary cascade
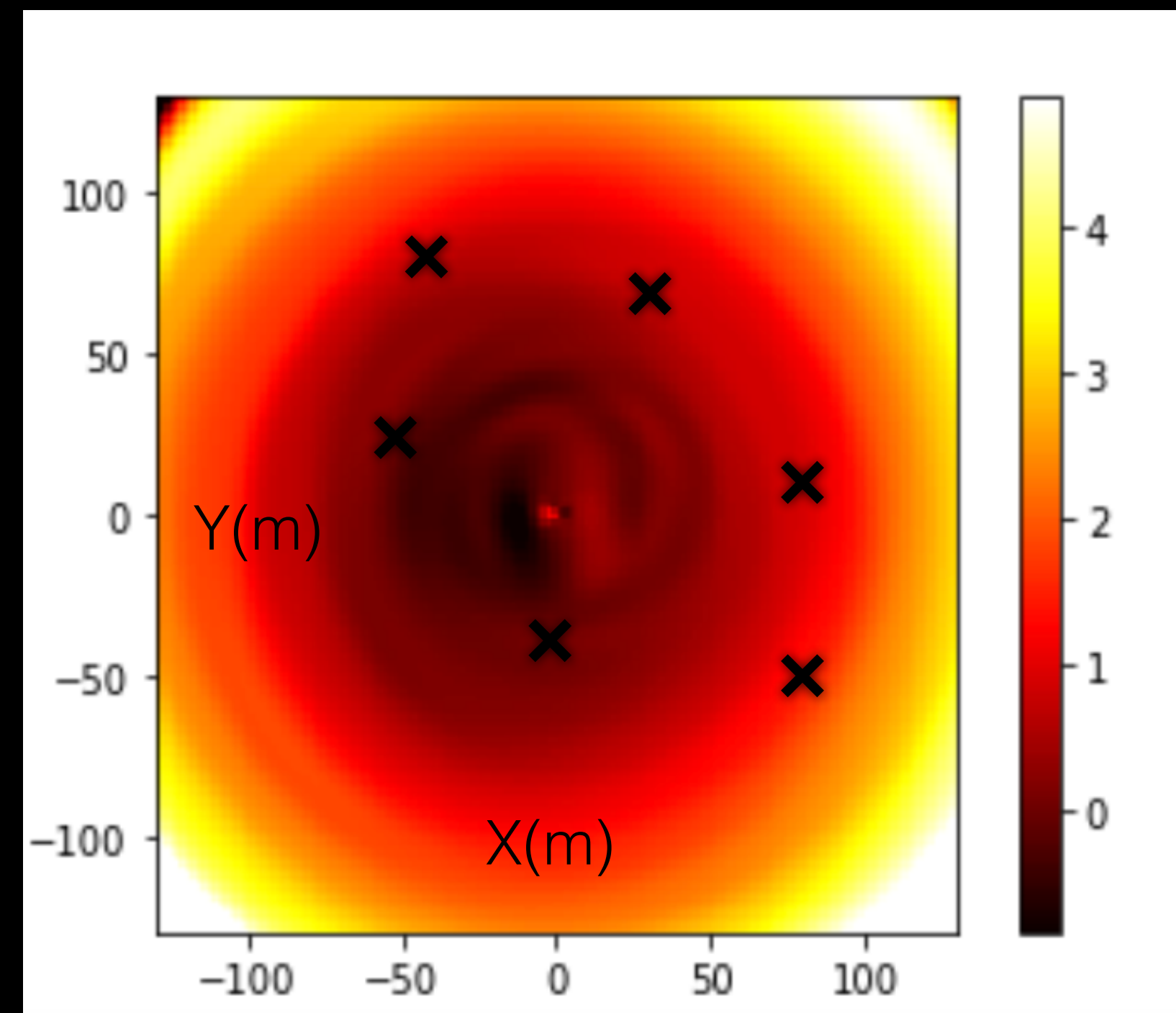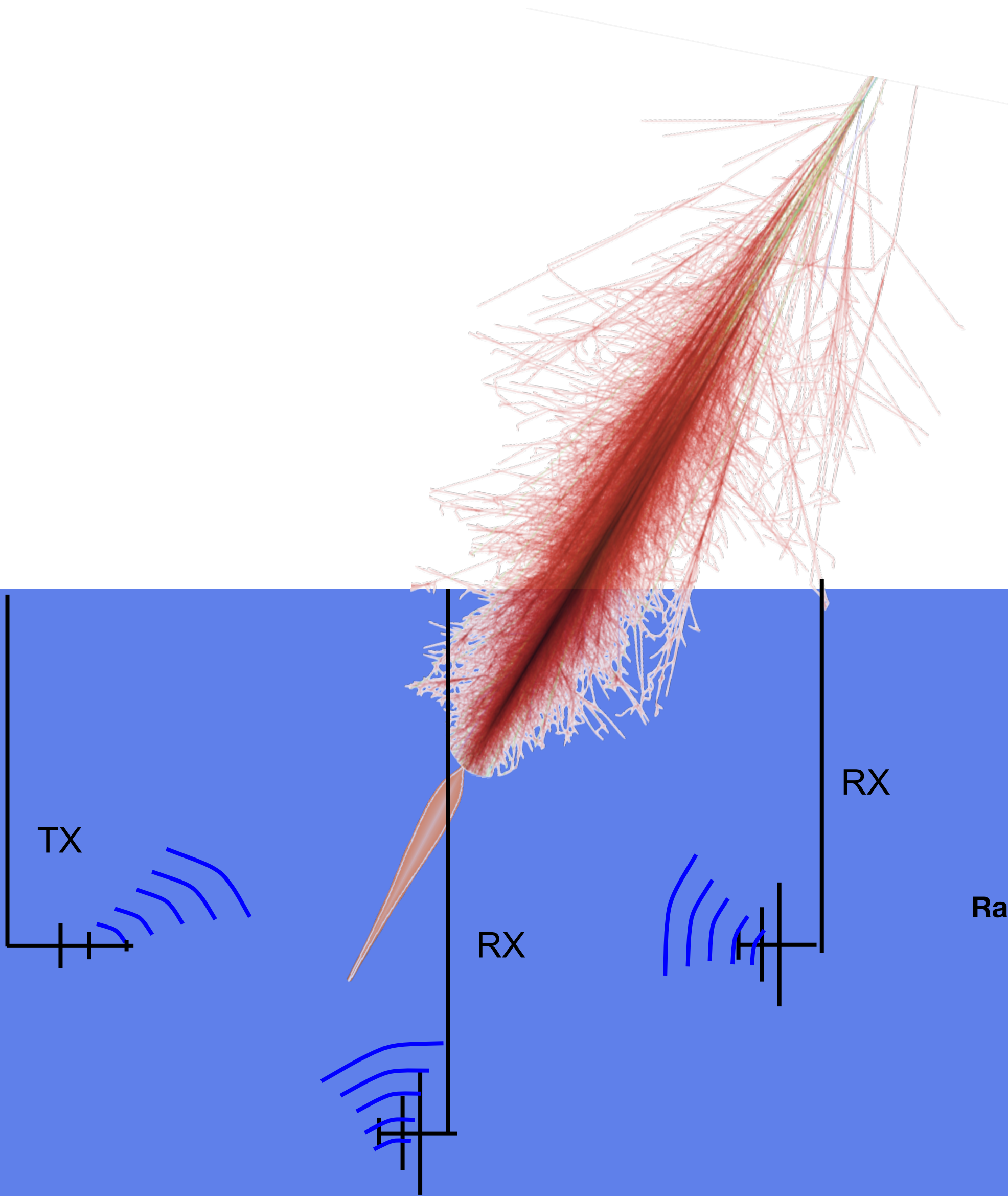

- Three phases of a RET event:
  - **Cascade development**
  - **Cascade as a static reflector**
  - **Recombination/Attachment**

TX

RX

RX

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

RadioScatter

D. Frykken

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

In-ice secondary cascade

Amp

DAQ

TX

RX

height-2350 [m]

10^4

10^3

10^2

100MHz

— 10^{19} eV
— 10^{18} eV
— 10^{17} eV
— 10^{16} eV

Air

Ice

RET-CR

10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1

f_p [GHz]

Detectable via radar -

$E = 10^{16} \text{eV}$
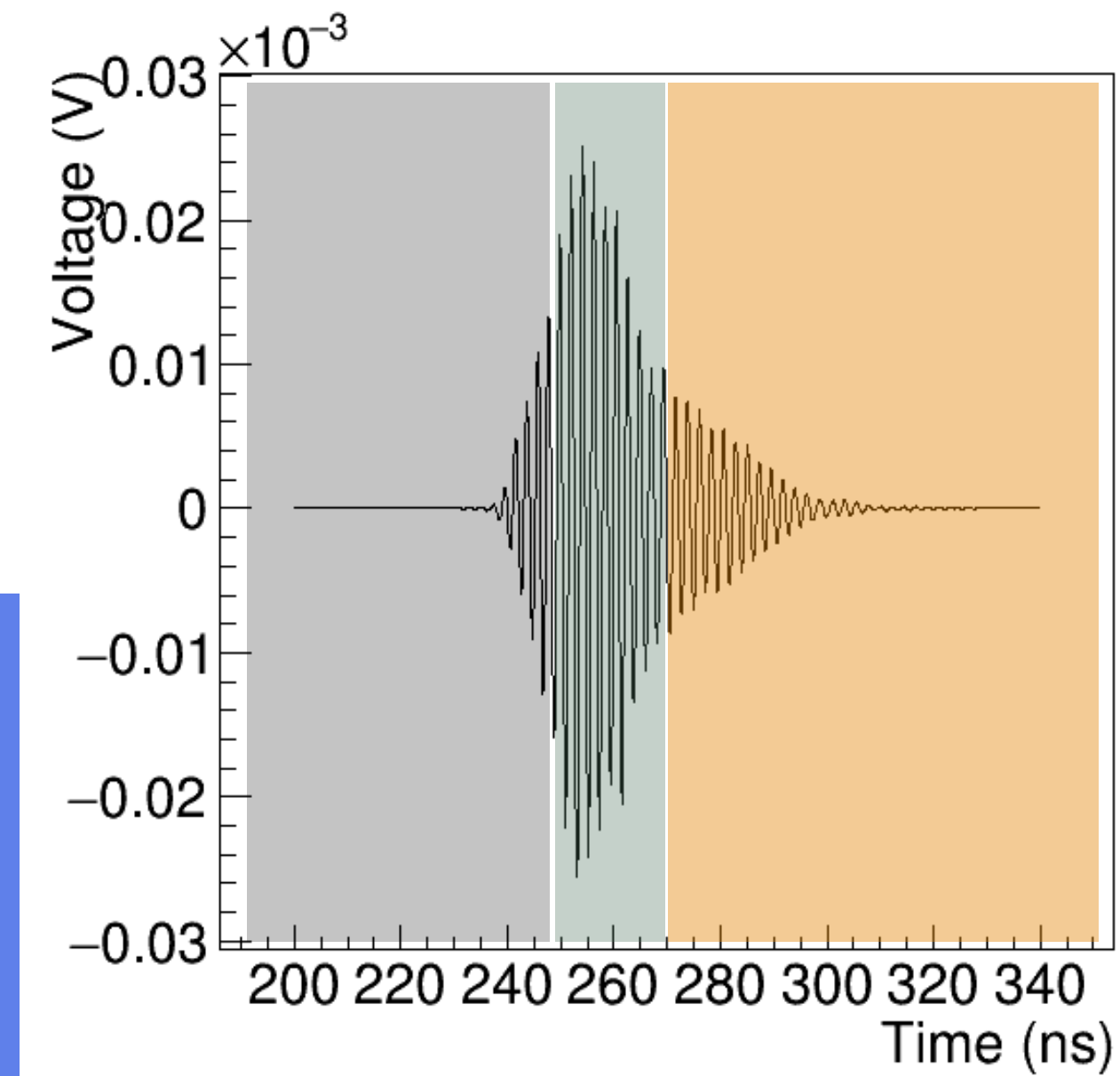
In-ice secondary cascade

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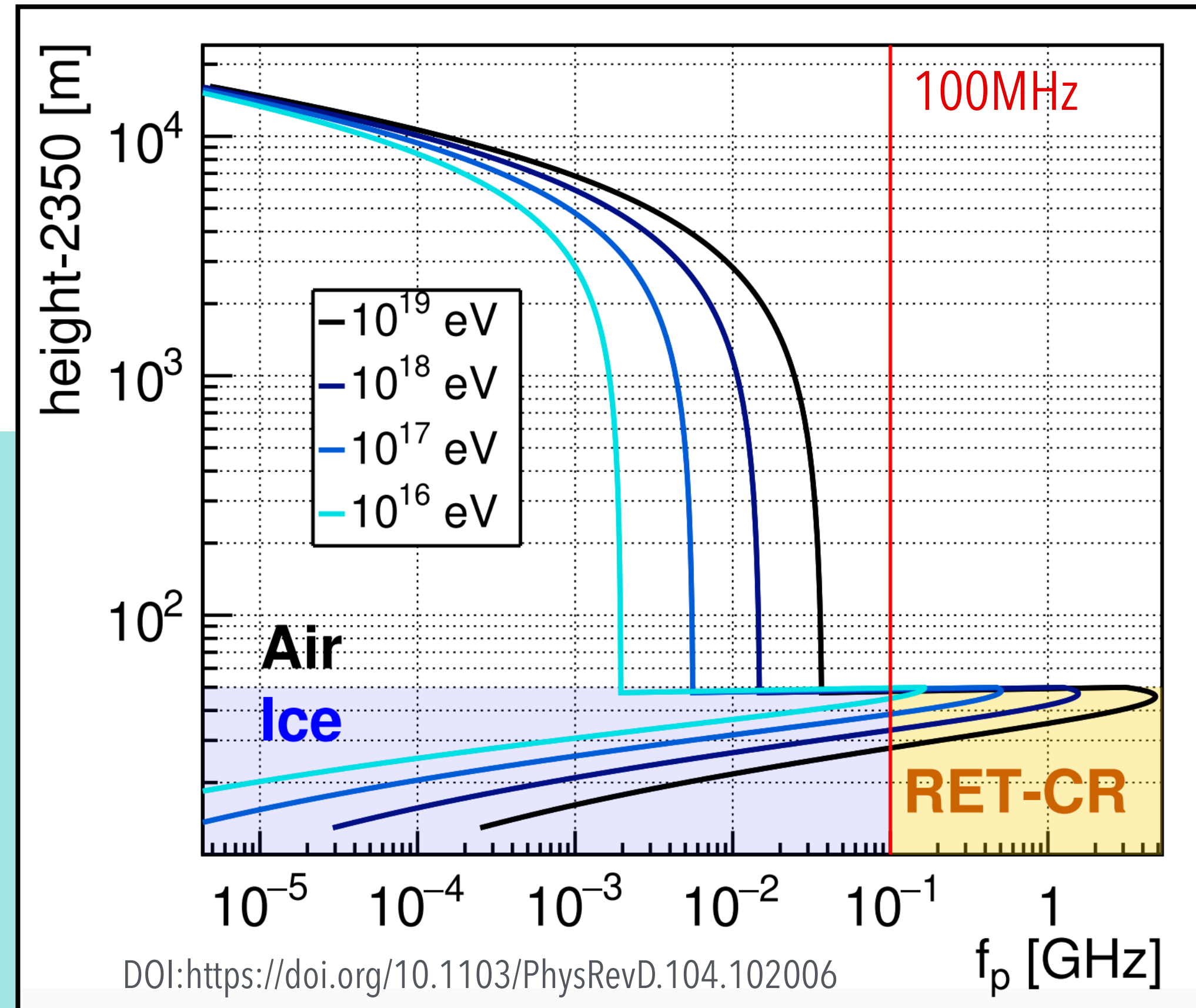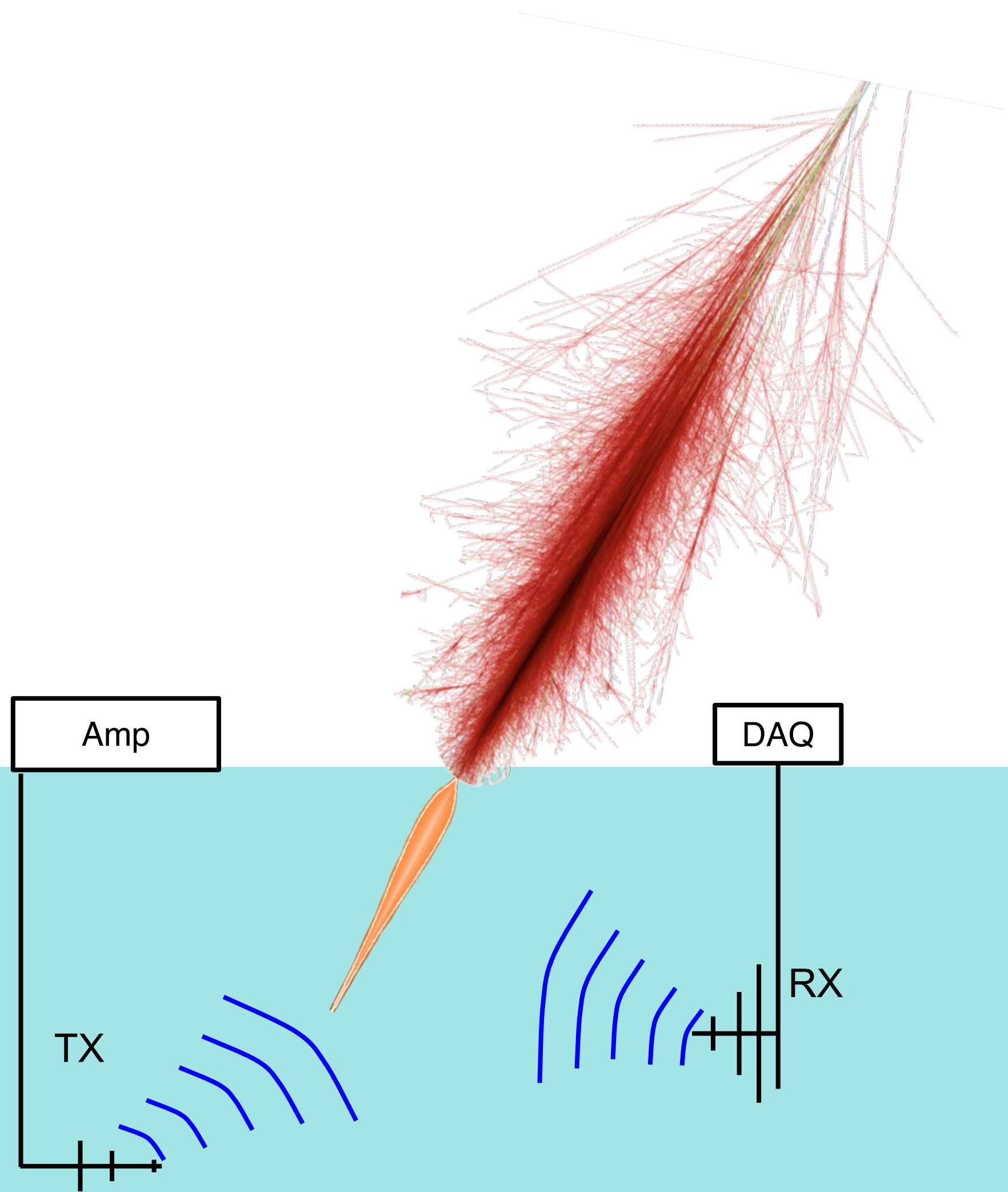 - **Cascade as a static reflector**
  - **Recombination/Attachment**

Amp

DAQ

RX

TX
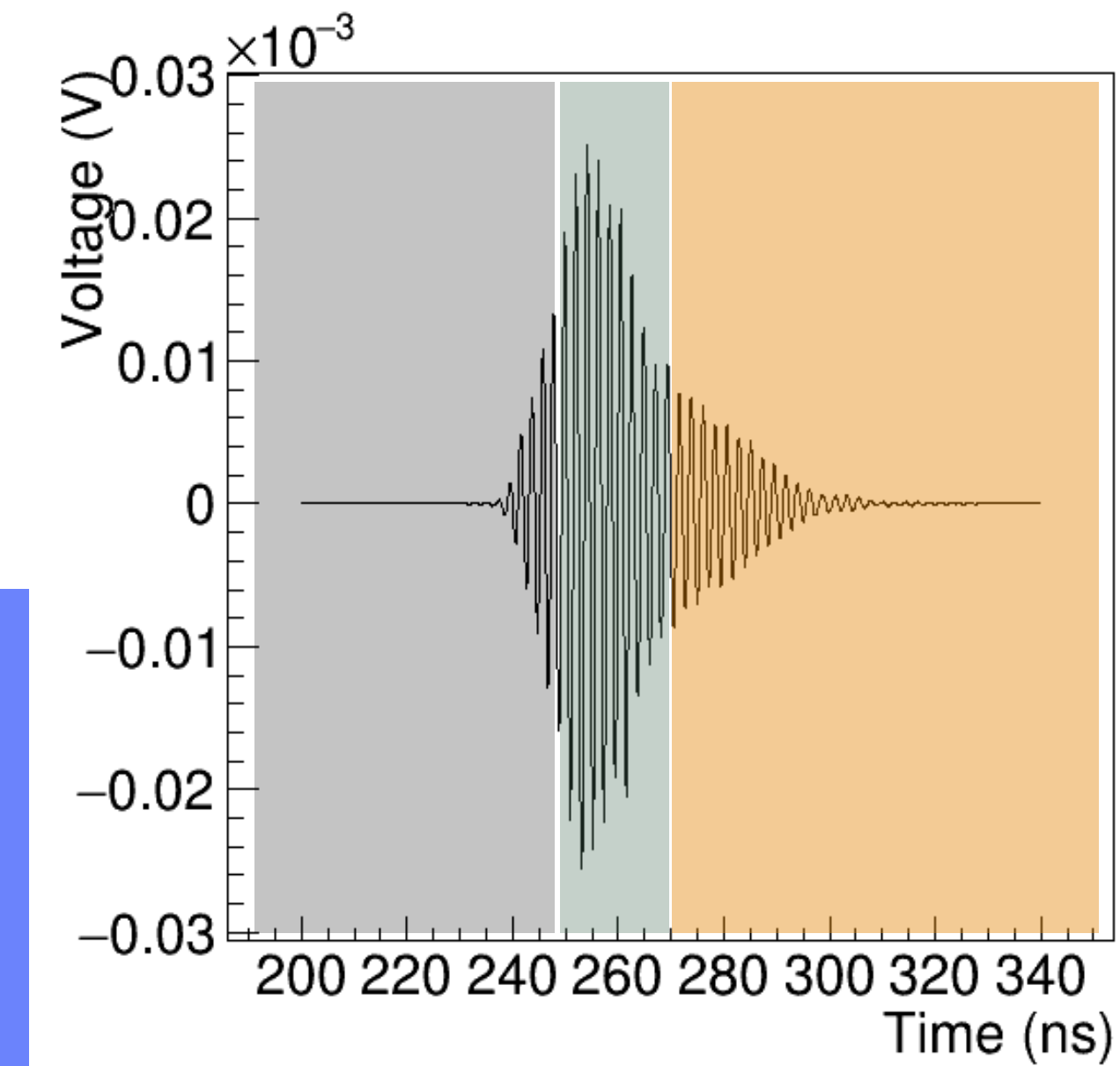
RadioScatter (in-house radar reflection simulation with GEANT4) , Prohira, Besson Nucl.Instrum.Meth.A 922 (2019)
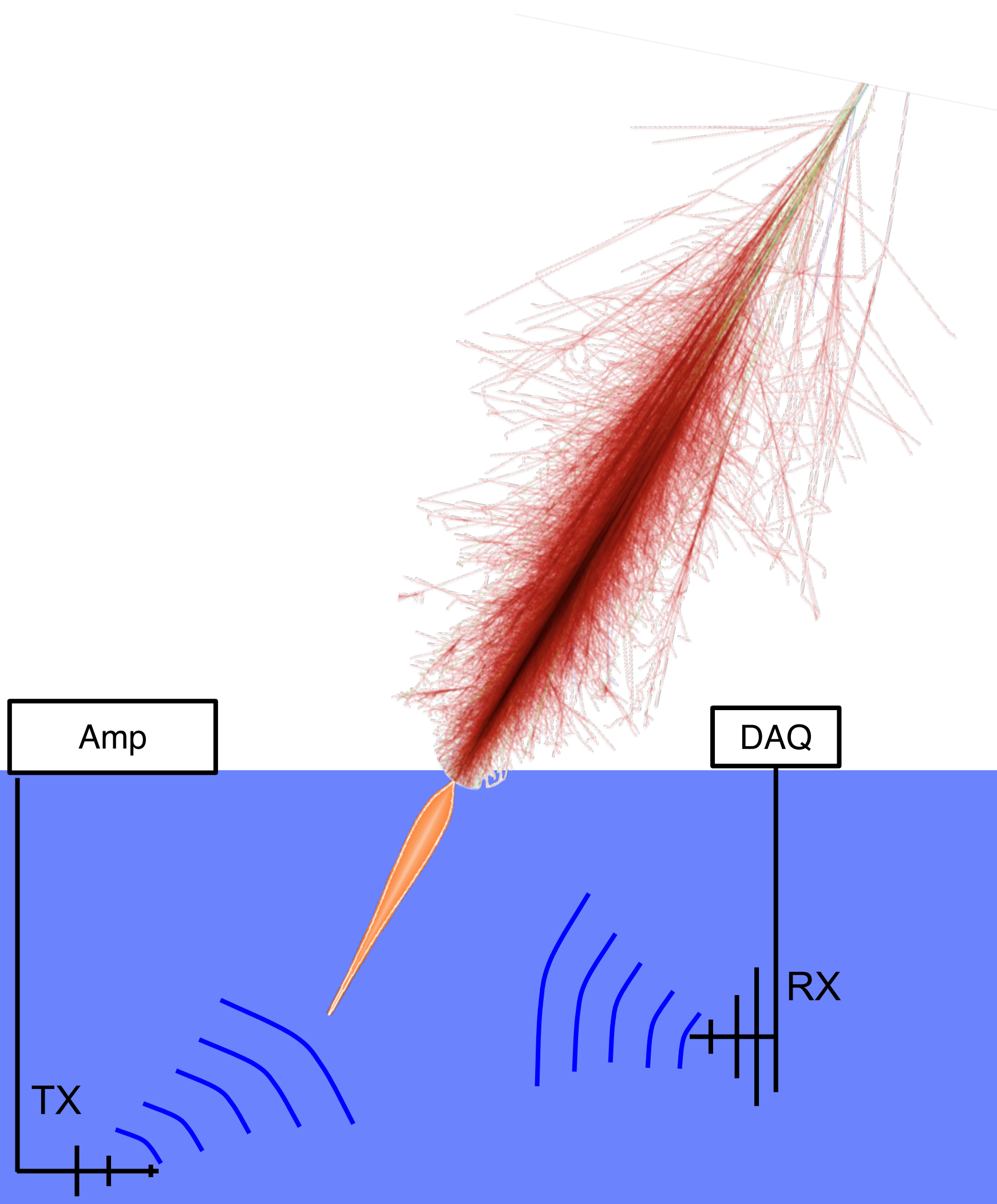*MARES: Macroscopic Approach to the Radar Echo Scatter , E. Huesca Santiago, et al. 2024, arXiv:2310.06731*
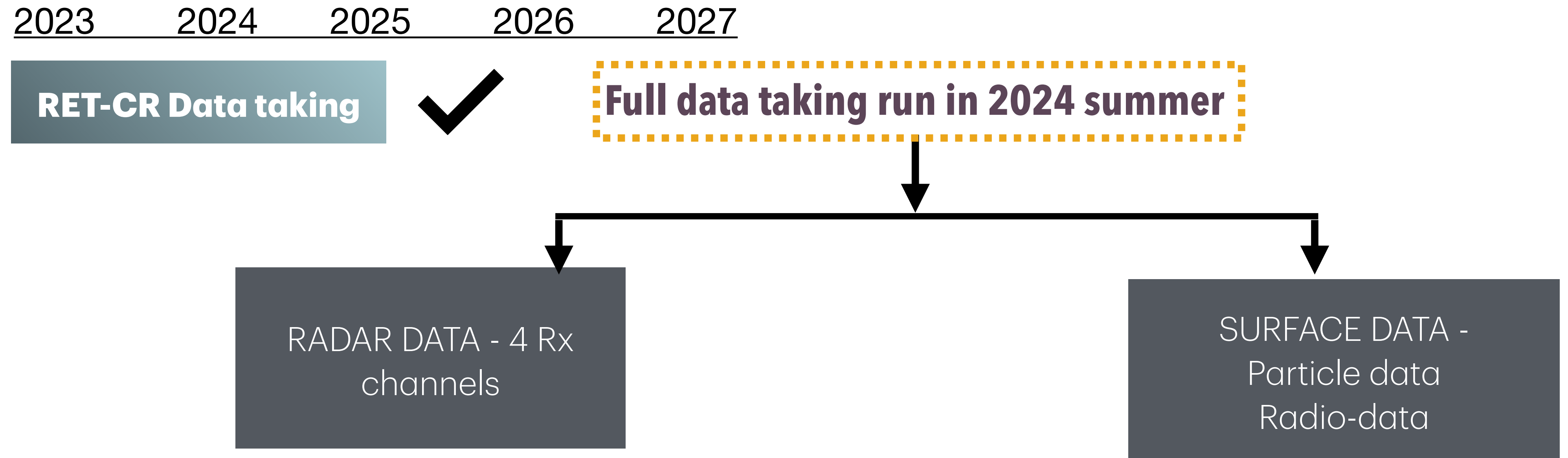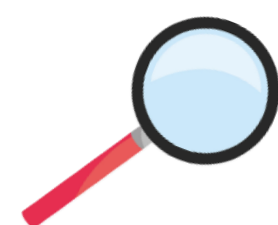
Into the future

2023   2024   2025   2026   2027

RET-CR Data taking ✓ **Full data taking run in 2024 summer**

RADAR DATA - 4 Rx channels

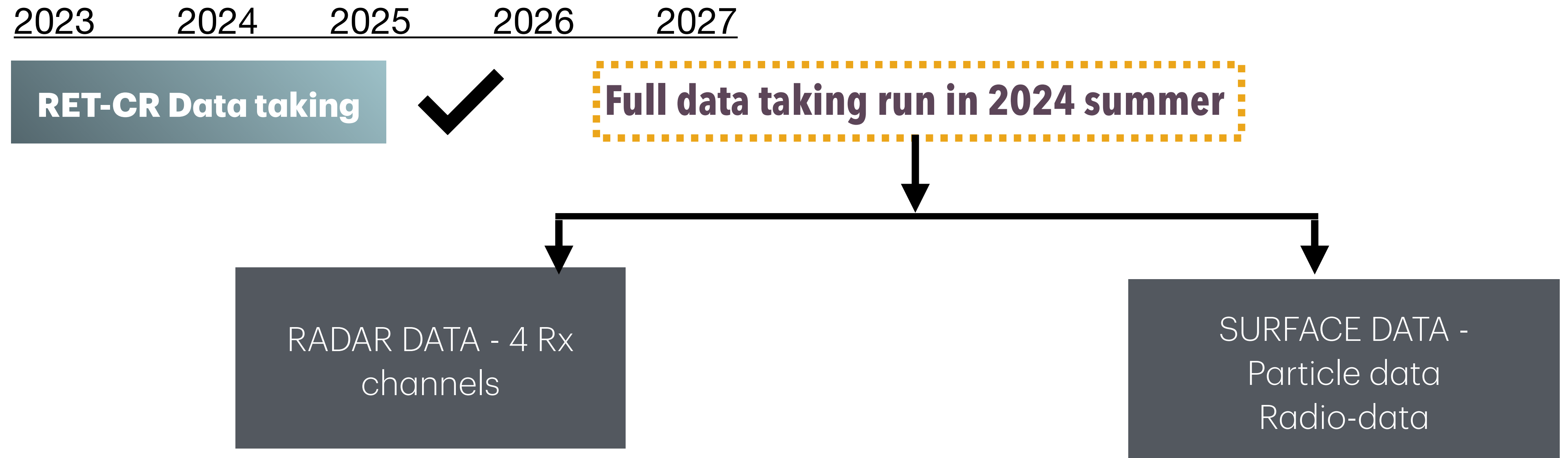SURFACE DATA - Particle data Radio-data

Denoising - Single value decomposition (SVD)

Any questions: Curtis McLennan (In this room)

Exploring the possibility of using Machine learning methods for denoising the data

Into the future

2023   2024   2025   2026   2027

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Full data taking run in 2024 summer

RADAR DATA - 4 Rx channels

SURFACE DATA - Particle data Radio-data

Into the future

2023   2024   2025   2026   2027

RET-CR Data taking ✔

Full data taking run in 2024 summer

RADAR DATA - 4 Rx channels

SURFACE DATA -
Particle data
Radio-data

Into the future

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