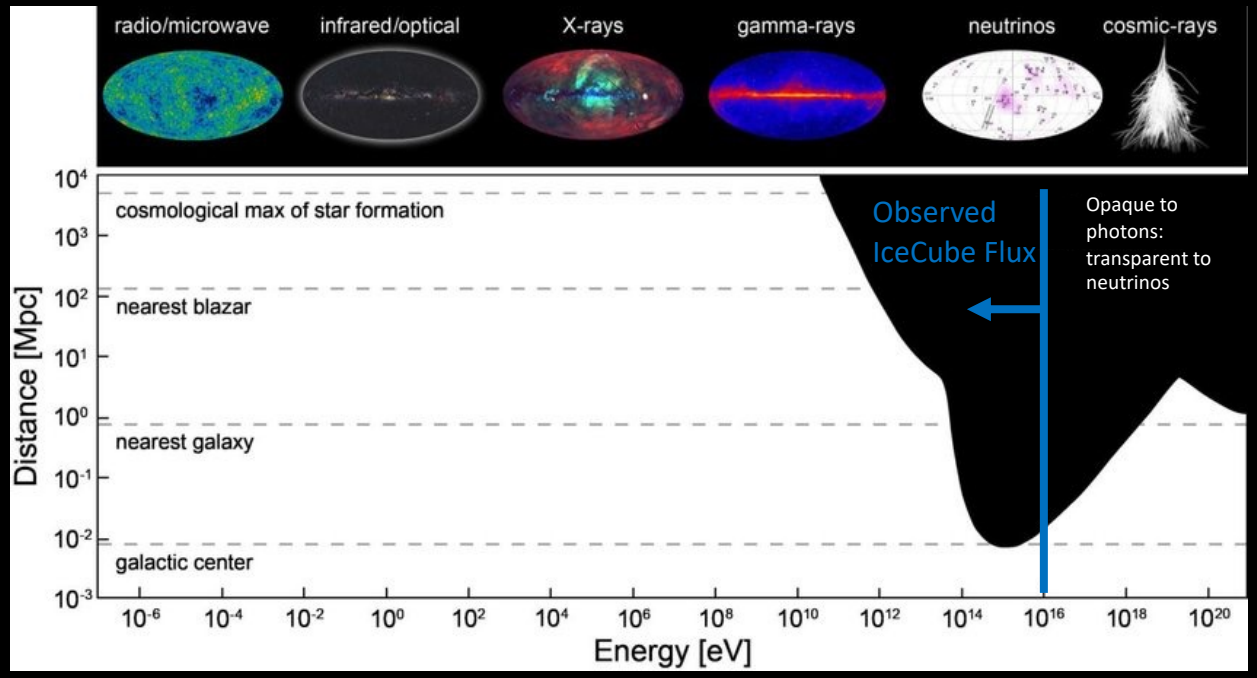
Radio Detection of Neutrinos

Abby Bishop – For Bootcamp 2021

11 June 2021

Why High Energy Neutrinos?

- Ultra High Energy neutrino observatories focus on observing neutrinos from 10^{15} eV to the GZK cutoff at 10^{20} eV

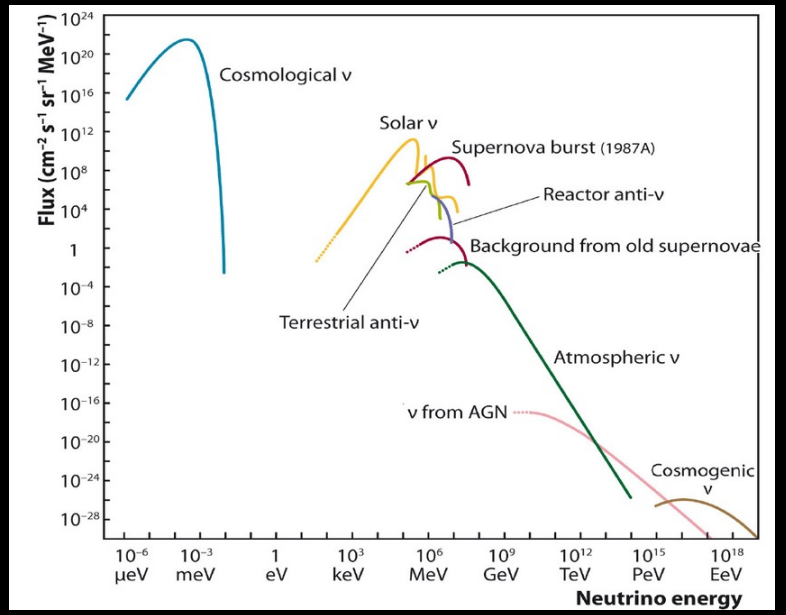


https://www.researchgate.net/publication/334858493_Panorama_of_Multi-messenger_Astronomy

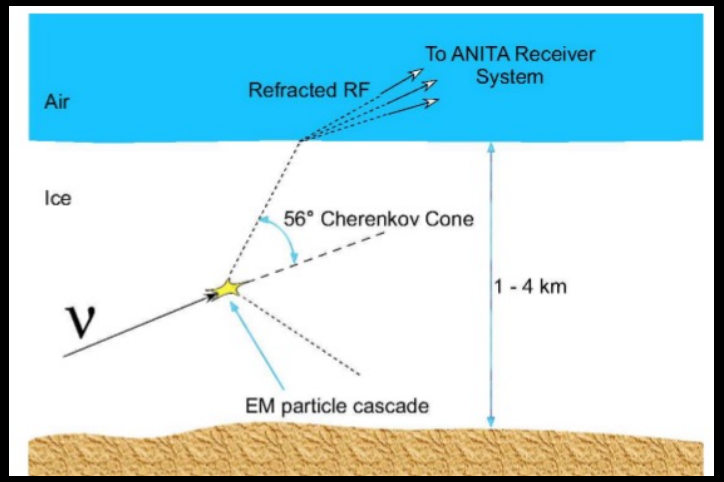
- These neutrinos are produced via
  - Astrophysical methods: hadronic interactions that yield neutrinos
  - Cosmogenic methods: CMB photons interacting with hadrons via the GZK mechanism

Detector Logistics

- Neutrinos have less flux as their energy increases, so you need more material for them to interact with
  - Can use dense material
  - Or large volumes of material
- Neutrinos can be observed via
  - Askaryan Radiation in media like ice

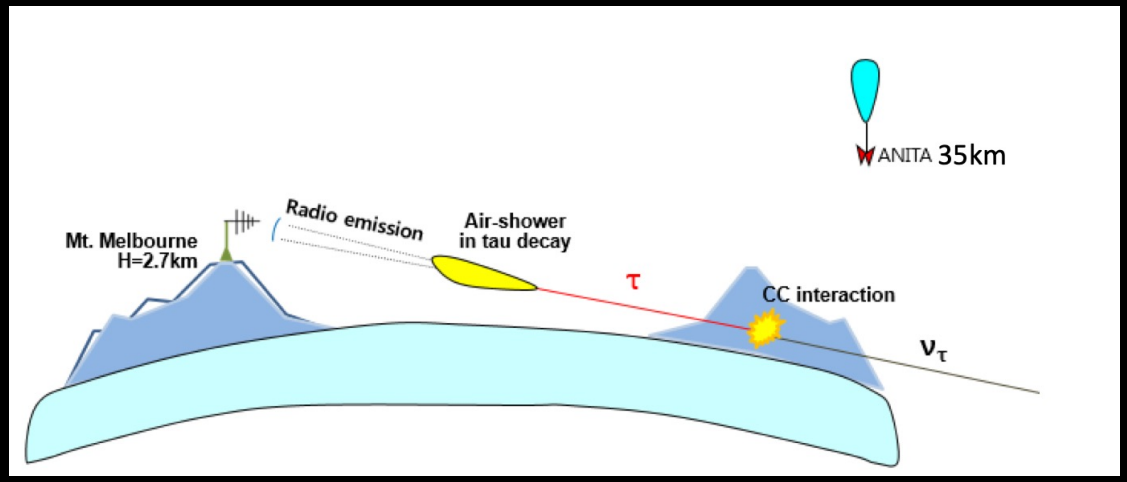


https://www.researchgate.net/publication/329969617_Studies_on_the_Physics_of_Resistive_Plate_Chambers_in_Relation_to_the_INO_Experiment



https://thespectrumofriemannium.wordpress.com/tag/askaryan-radiation/

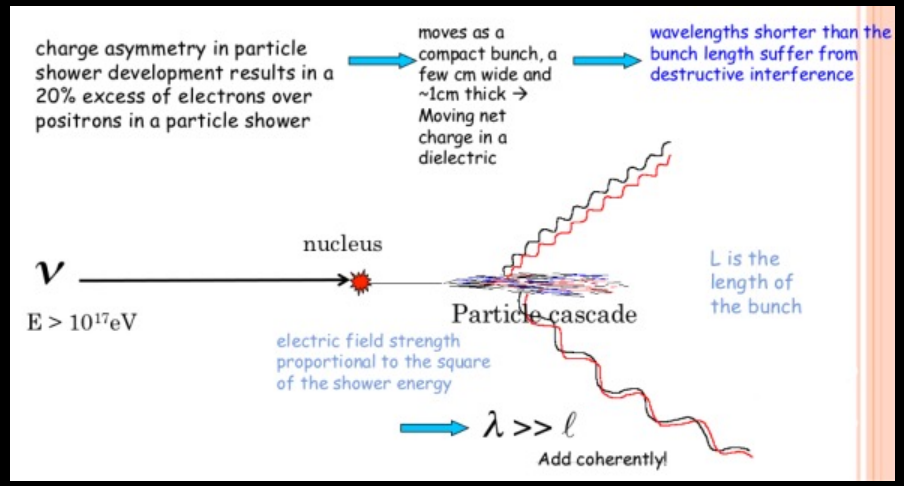
- Tau Neutrino Air Showers



https://www.icrc2019.org/uploads/1/1/9/0/119067782/icrc2019_jiwoo_nam_upload.pdf

Askaryan Radiation

- High energy particle showers in dense dielectric material develop a negative charge asymmetry from Compton scattering and positron annihilation
- If the high energy charged particles are traveling faster than the speed of light in the dielectric, they will shed energy in the form of radio radiation
- When the wavelength is <10 cm, radiation destructively interferes. When the wavelength of radiation is >10 cm, radiation is coherent and the shower appears as a point charge traveling through the medium



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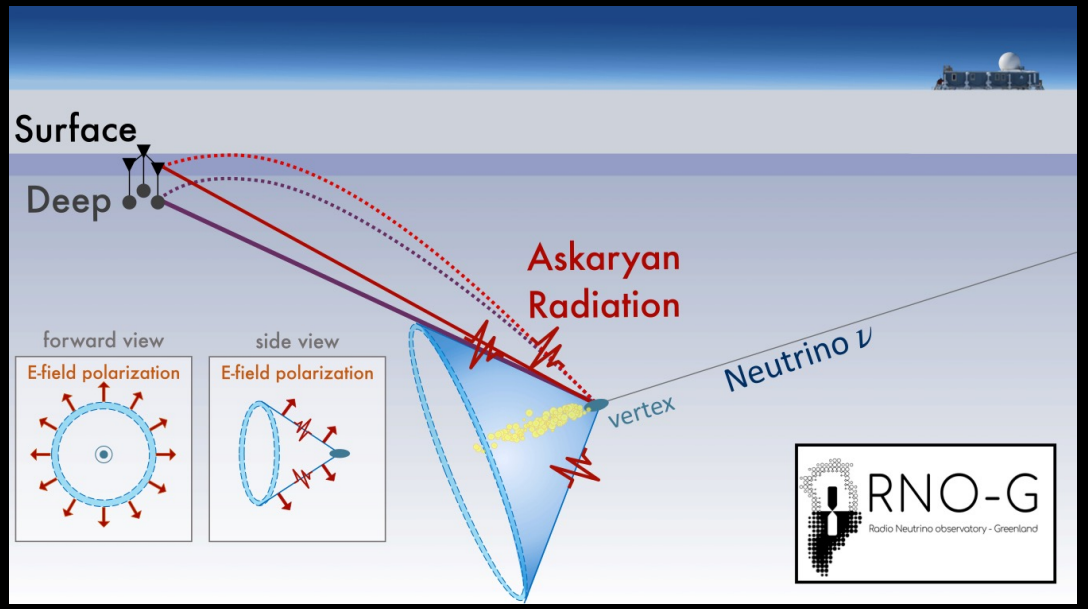
Askaryan Radiation

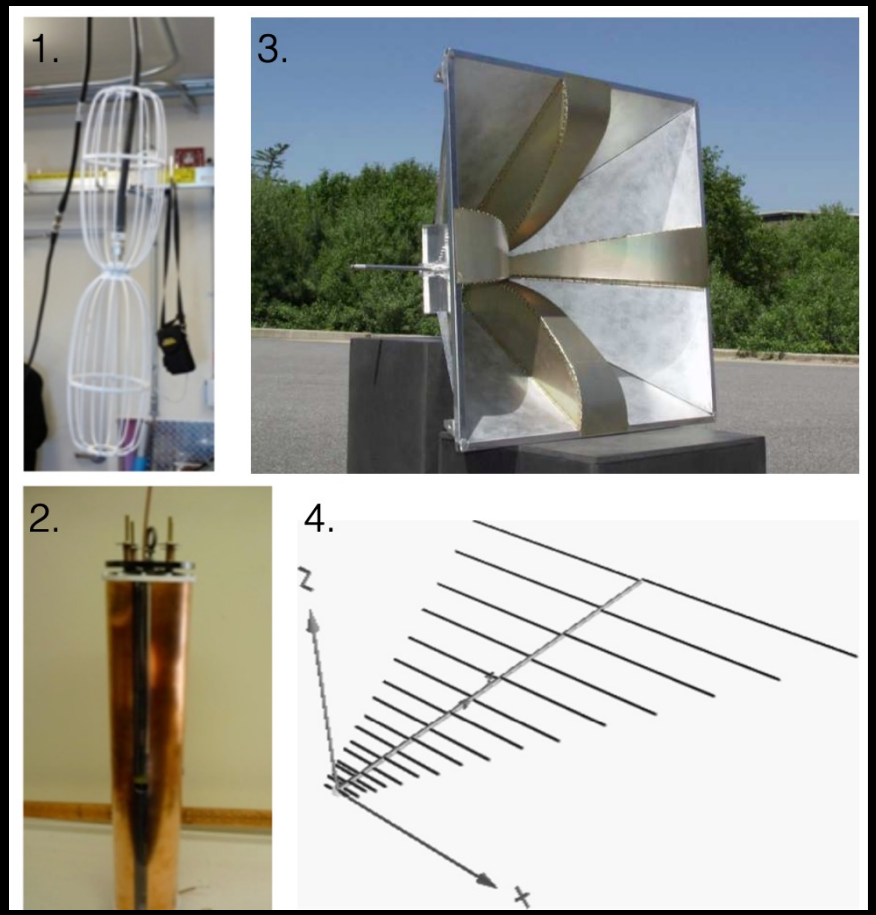
- It's similar to Cherenkov Radiation and follows same equation: $\theta = \cos\left(\frac{1}{n\beta}\right)$
  - Best when observed within 5° of the cone
- Scales with square of electric field
- Detectable signals have a peak frequency ~ 1 GHz



https://arxiv.org/pdf/2010.12279.pdf

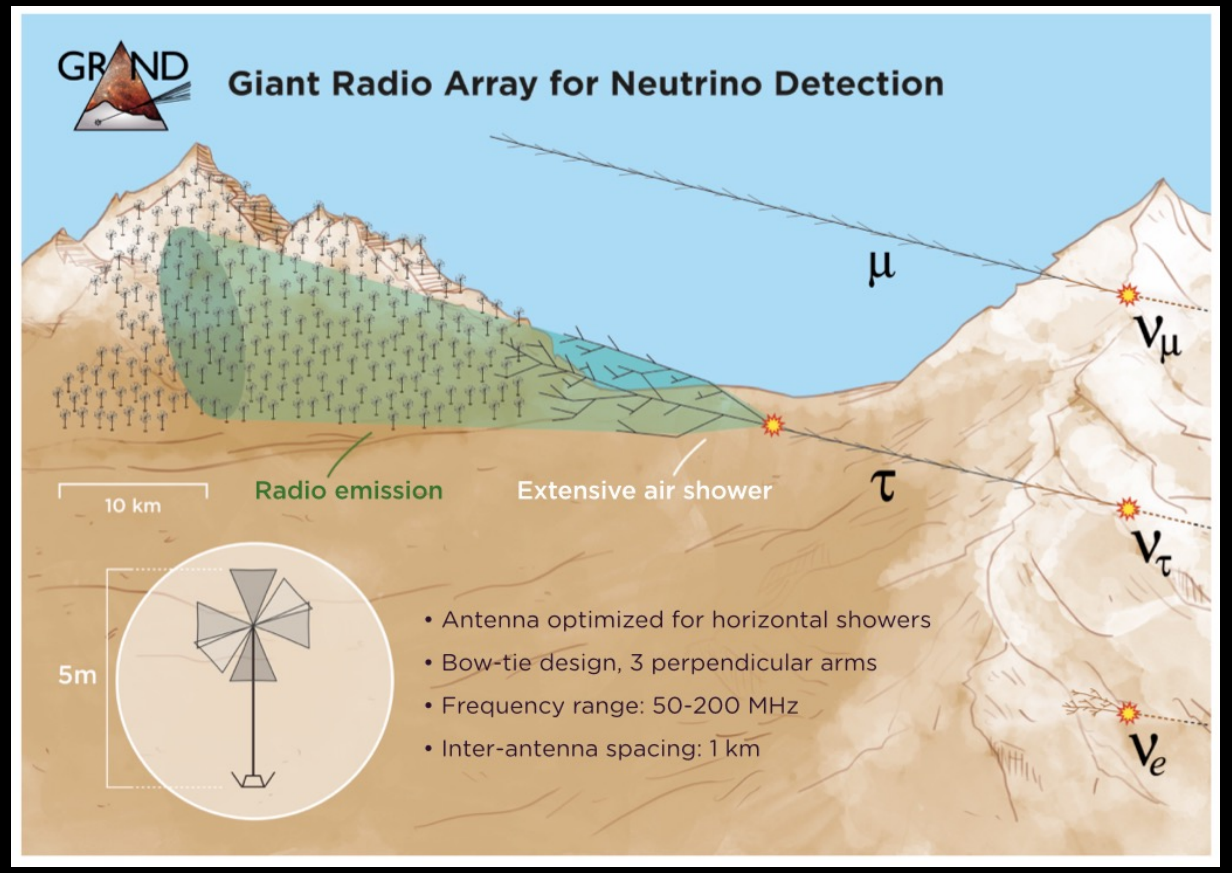
Antennas (From Ben Hokanson-Fasig's X-Meeting talk on 9 February 2021)

1. Bicone – narrow, vertically polarized
2. Slotted Cylinder – narrow, horizontally polarized
3. Horn – Highly directional, dually polarized
4. LPDA – wide, high gain, directionally polarized



BEACON and GRAND

- Giant Radio Array for Neutrino Detection (GRAND)
  - Focuses on cosmic rays and tau neutrinos
  - 200,000 antennas spread over 10,000 km^2
  - First sub-array expected in 2025
- Beamforming Elevated Array for COsmic Neutrinos (BEACON)
  - Proposed, will use horizon as target volume for neutrino interaction
  - Will use a beamforming signal technique to improve sensitivity



https://arxiv.org/pdf/2012.05580.pdf

ANITA and PEUO

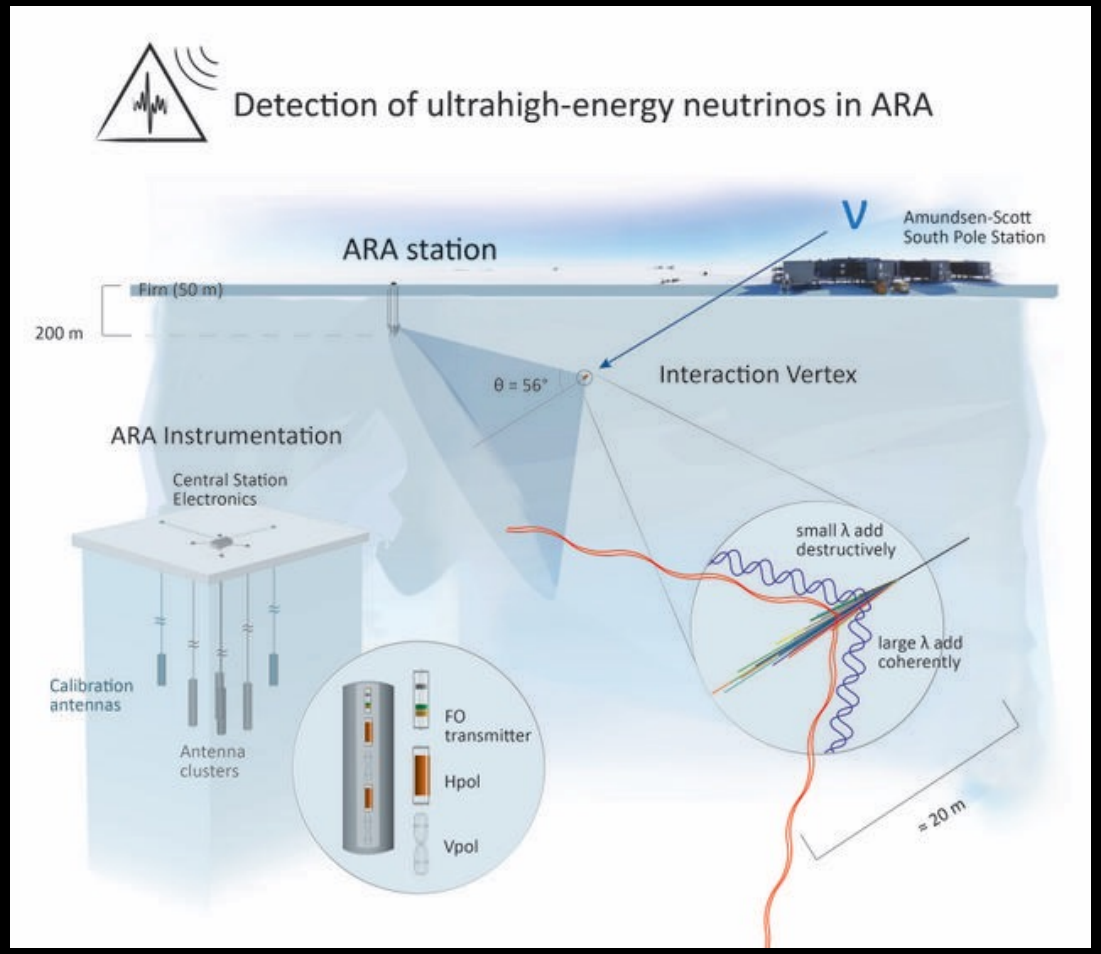
- Antarctic Impulsive Transient Antenna (ANITA)
  - Balloon carried antenna array carried 35 km over the Antarctic Ice
  - Sensitive to Askaryan radiation and Tau air showers
  - Observed interesting candidate events but no confirmed neutrinos

https://www.phys.hawaii.edu/~anita/new/html/instrument.html

- Payload for Ultrahigh Energy Observations (PUEO)
  - Planned to fly in 2024
  - Balloon with more antennas
  - Improved low-frequency antennas provide sensitivity to more air showers
  - 10x more sensitive than ANITA

RICE, ARIANNA, ARA

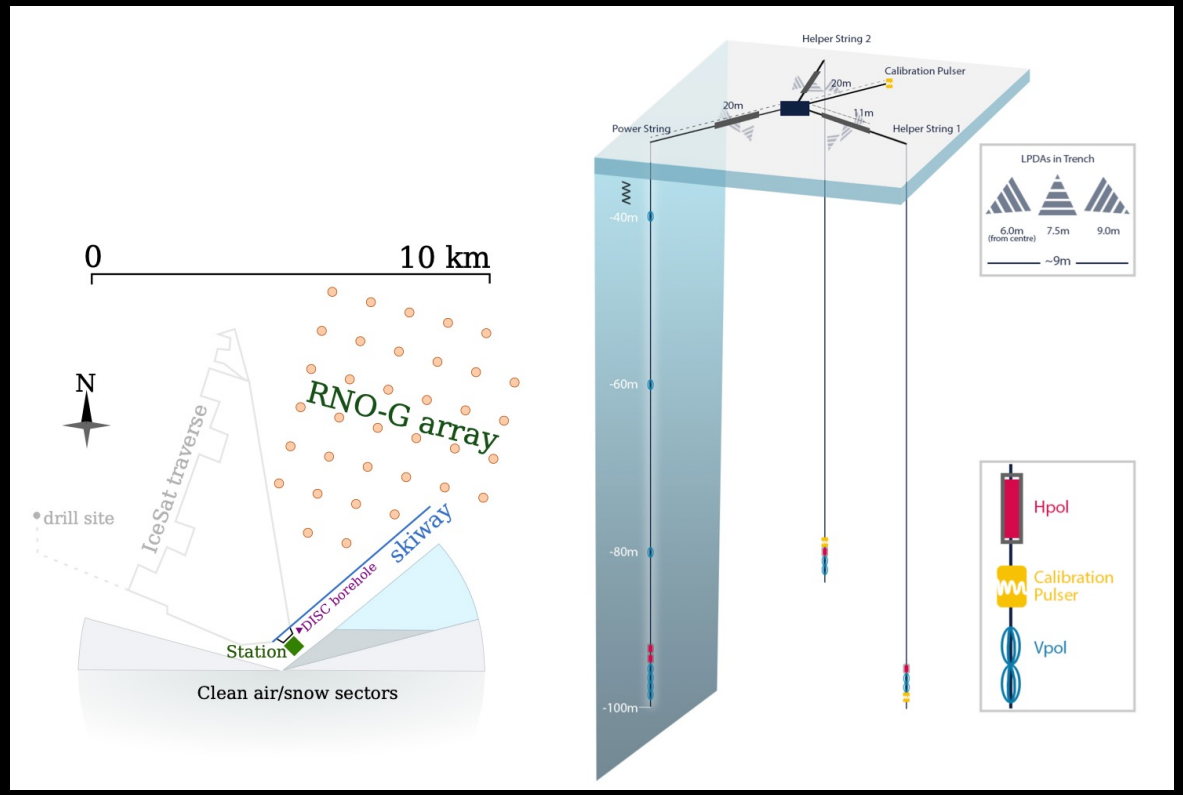
- Radio Ice Cherenkov Experiment (RICE)
  - First radio detector tested in ice, deployed into existing AMANDA holes
- Askaryan Radio Array (ARA) and Antarctic Ross Ice Shelf Antenna Neutrino Array (ARIANNA)
  - Deployed antennas shallow in ice, both have a few stations
  - ARIANNA uses LPDAs and ARA uses the Bicone and Slotted Cylinder antennas



https://ara.wipac.wisc.edu/home

RNO-G, Gen2-Radio

- Radio Neutrino Observatory in Greenland (RNO-G)
  - Deploying now in Greenland
  - Combines Bicone antennas and LPDAs
- Gen2-Radio
  - Similar to RNO-G, in development now



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Thank You!