

Radio Detections of Neutrinos

Abby Bishop
IceCube Summer School 2023
8 June 2022

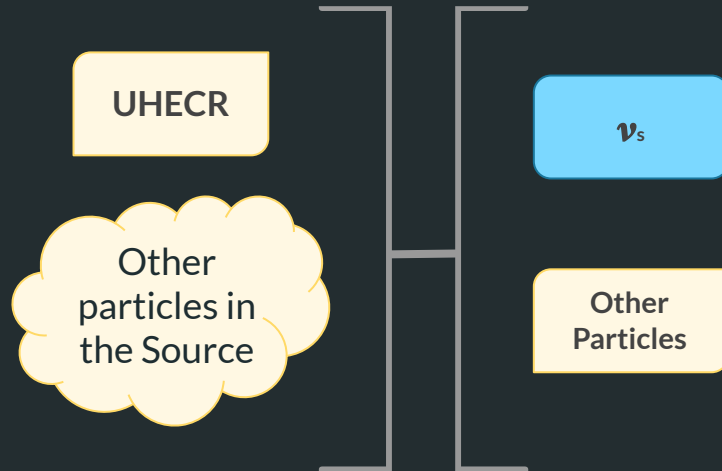
Quick science behind
UHE Neutrinos and
their main progenitor:
UHE Cosmic Rays

UHE (Ultra-High Energy) = Energy $> 10^{17}$ eV

**We think UHE Neutrinos come from
two potential sources:**

Astrophysical Sources

(point sources, pp sources)

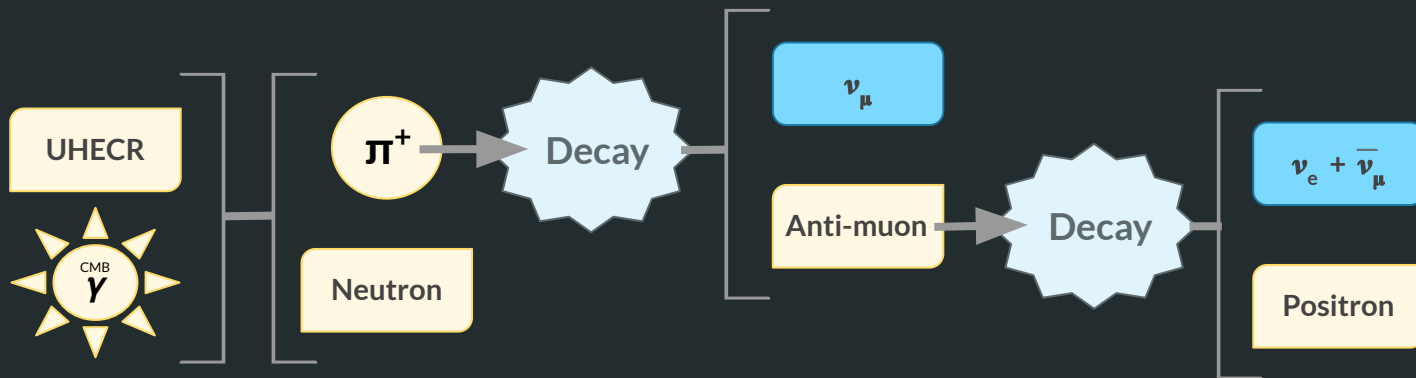


Basically, a really lively astrophysical source or event emits charged particles that interact with each other and result in neutrinos among other things.

Sadly, there aren't a ton of frequent ultra high energy cosmic ray + neutrino producers so this isn't our main source.

Cosmogenic Sources

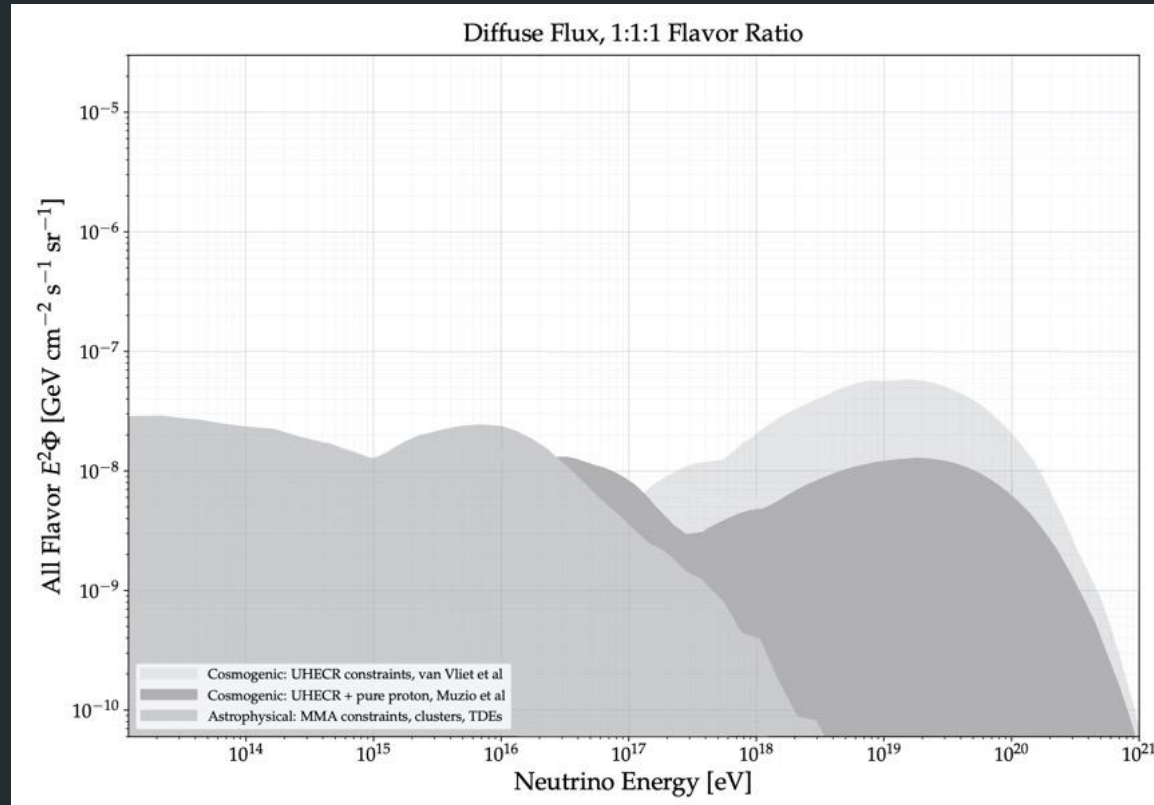
(aka Cosmic Rays smashing into CMB Photons, $p\gamma$ sources)



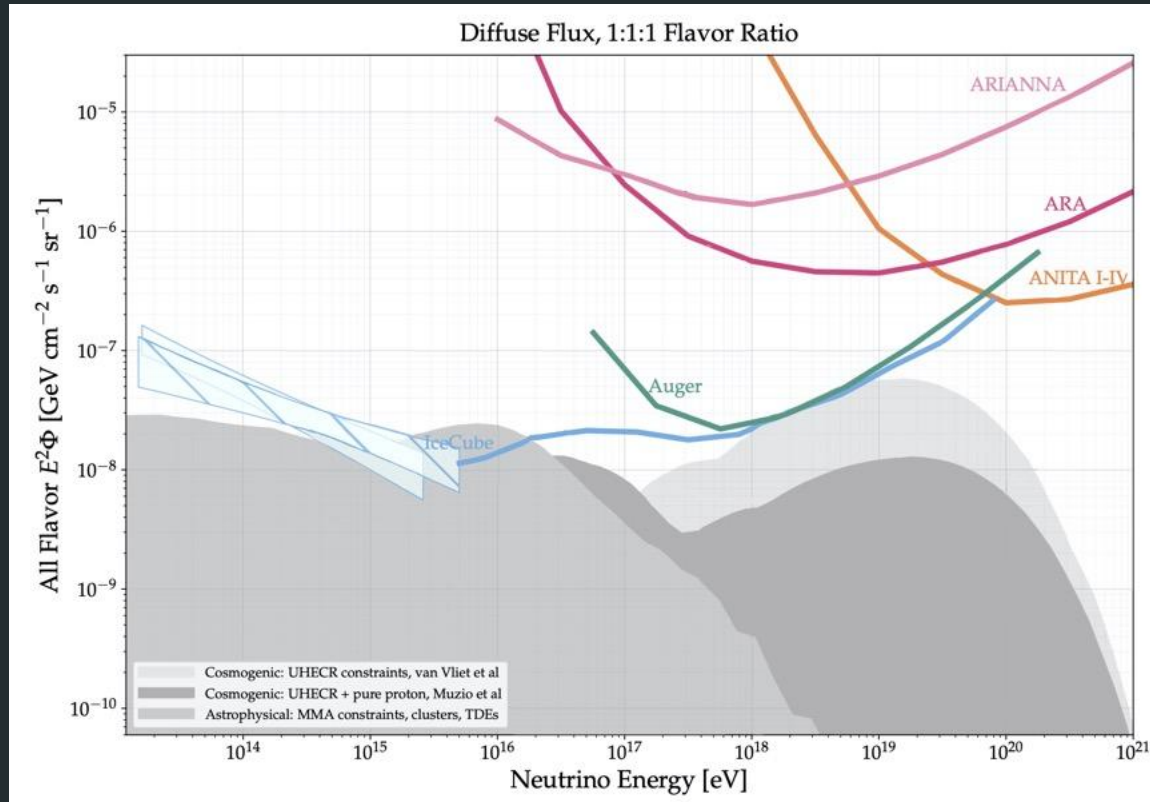
And then the neutrinos oscillate over millions or billions of parsecs until they reach Earth.

This is our main expected source.

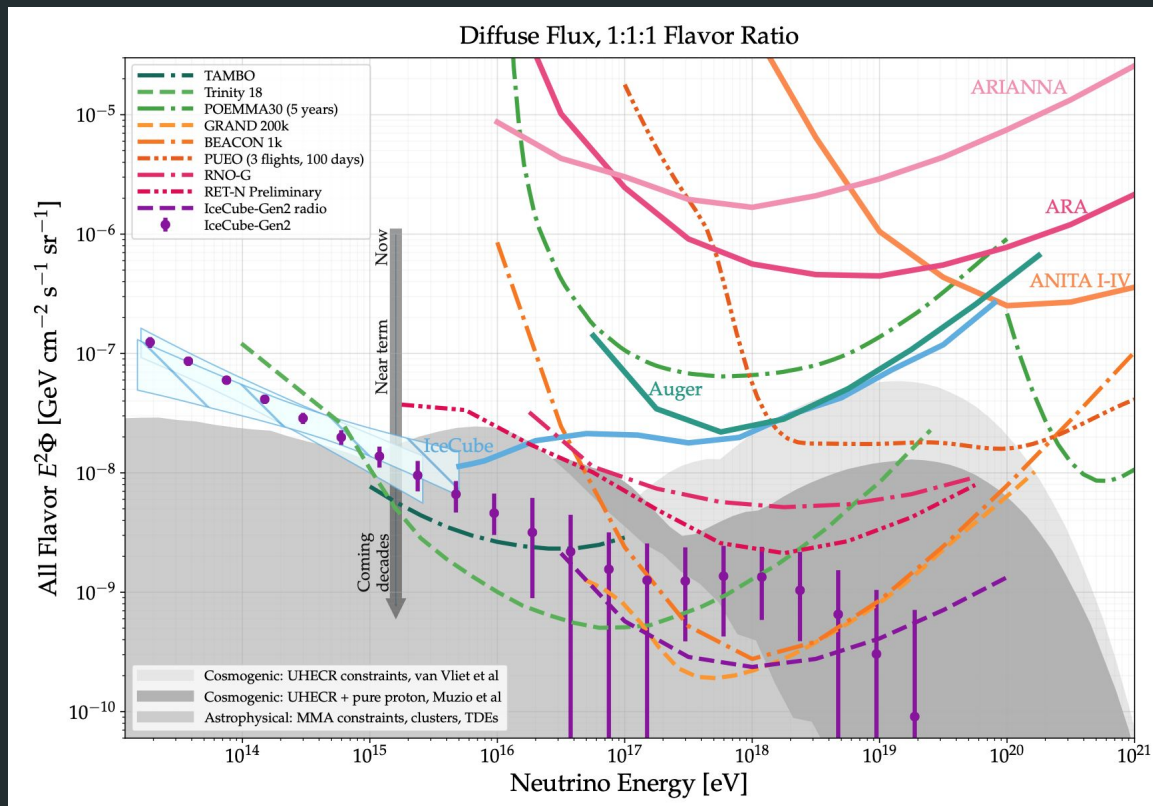
We have models for what neutrino flux we expect



Previous detectors have gotten close



Future detectors are going to probe flux models

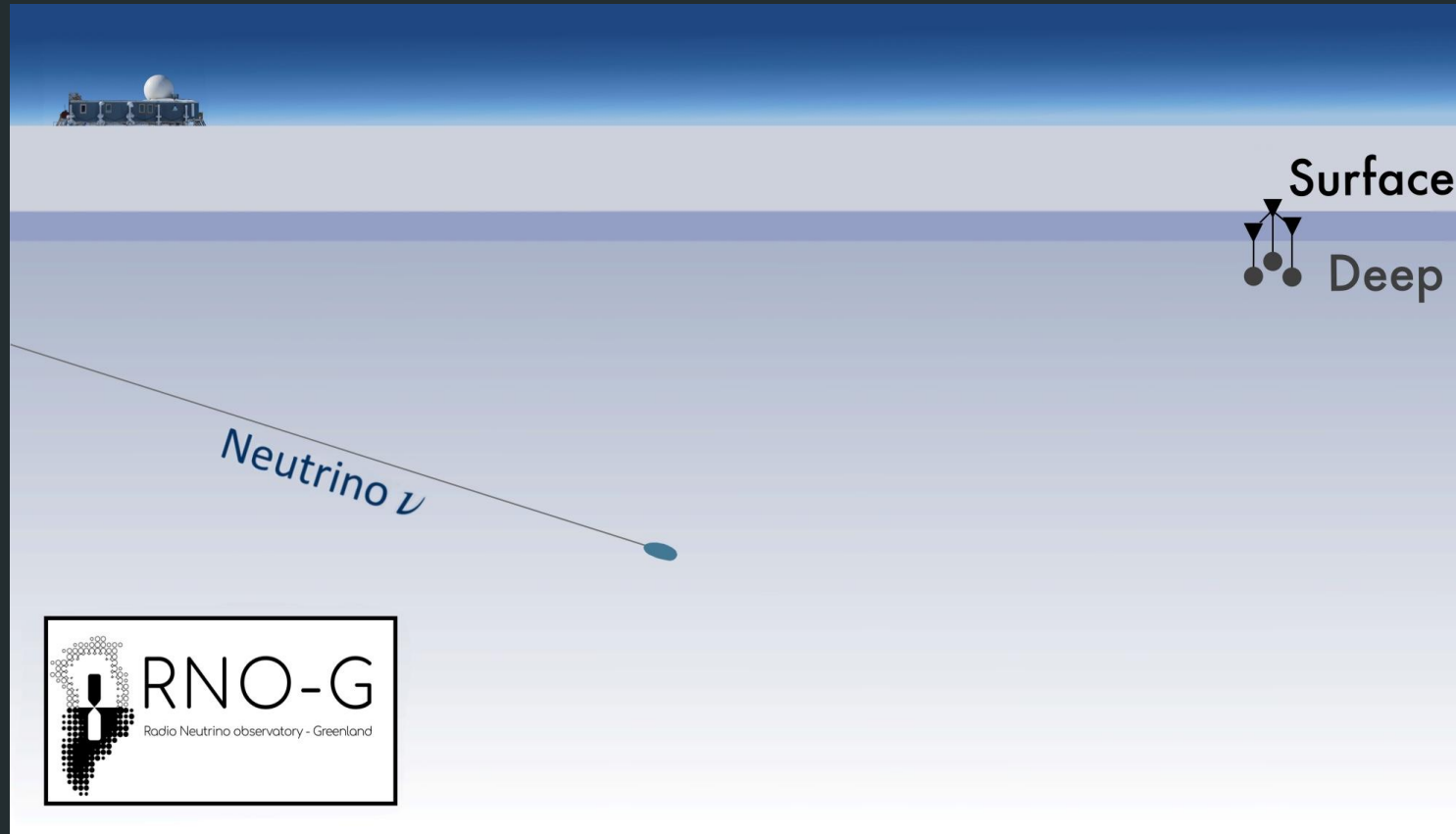


How do we observe
UHE Neutrinos?

Askaryan Radiation Reveals UHE Neutrino Interactions

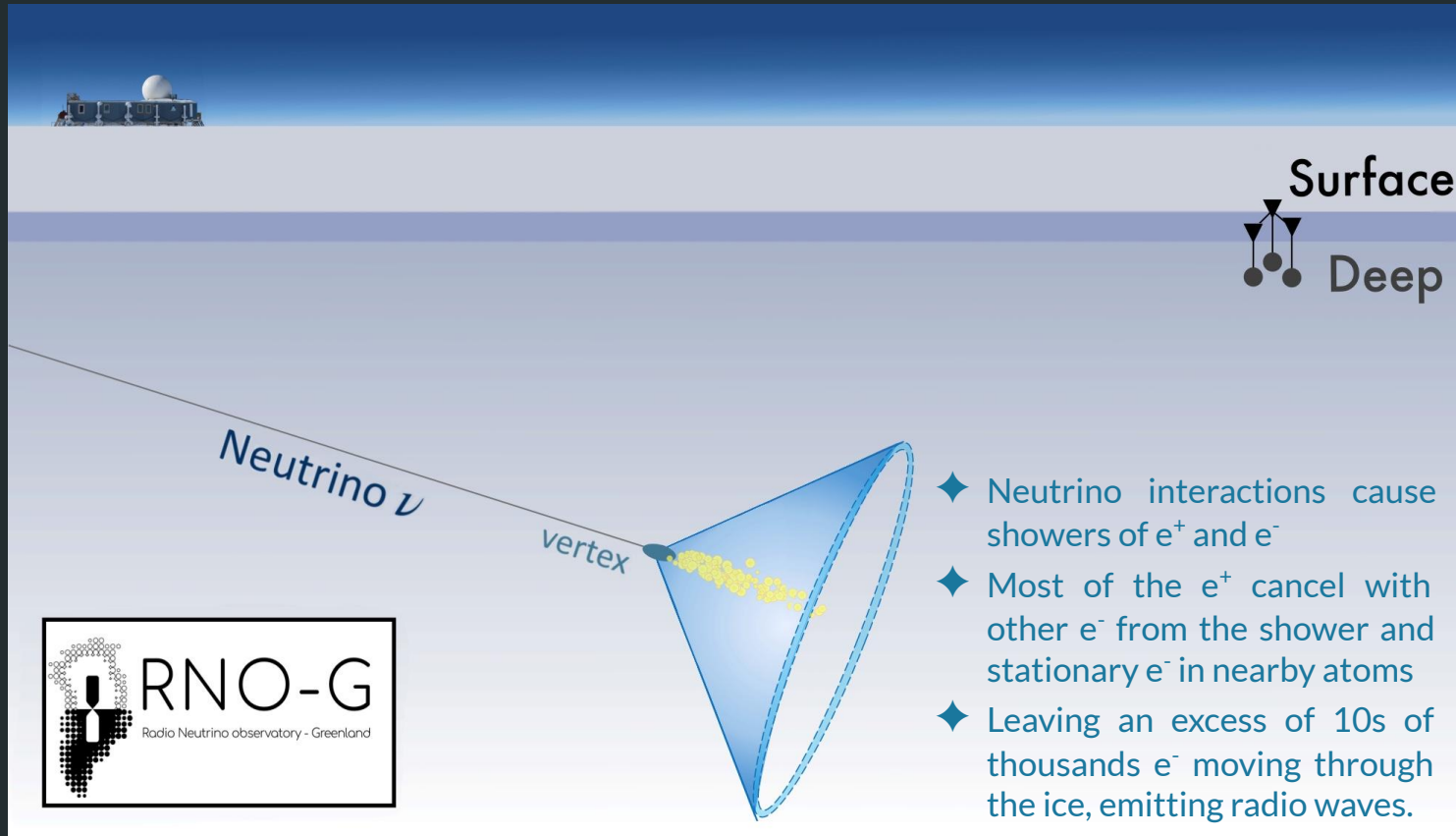


Askaryan Radiation Reveals UHE Neutrino Interactions



<https://arxiv.org/abs/2010.12279>

Askaryan Radiation Reveals UHE Neutrino Interactions




Surface

Deep

Neutrino ν

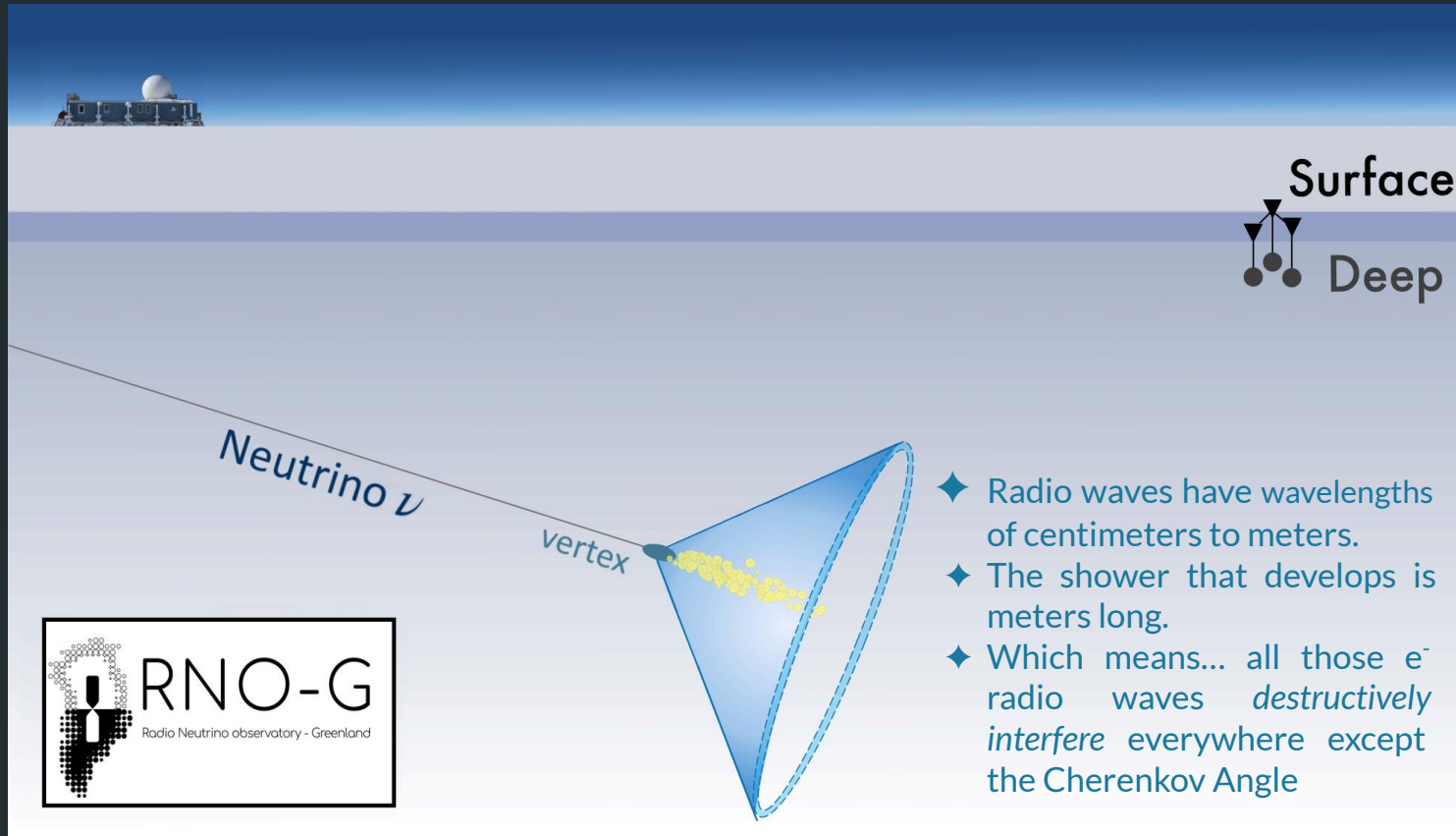
vertex

- ◆ Neutrino interactions cause showers of e^+ and e^-
- ◆ Most of the e^+ cancel with other e^- from the shower and stationary e^- in nearby atoms
- ◆ Leaving an excess of 10s of thousands e^- moving through the ice, emitting radio waves.

 **RNO-G**
Radio Neutrino observatory - Greenland

<https://arxiv.org/abs/2010.12279>

Askaryan Radiation Reveals UHE Neutrino Interactions



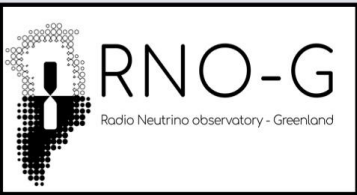
Surface

Deep

Neutrino ν

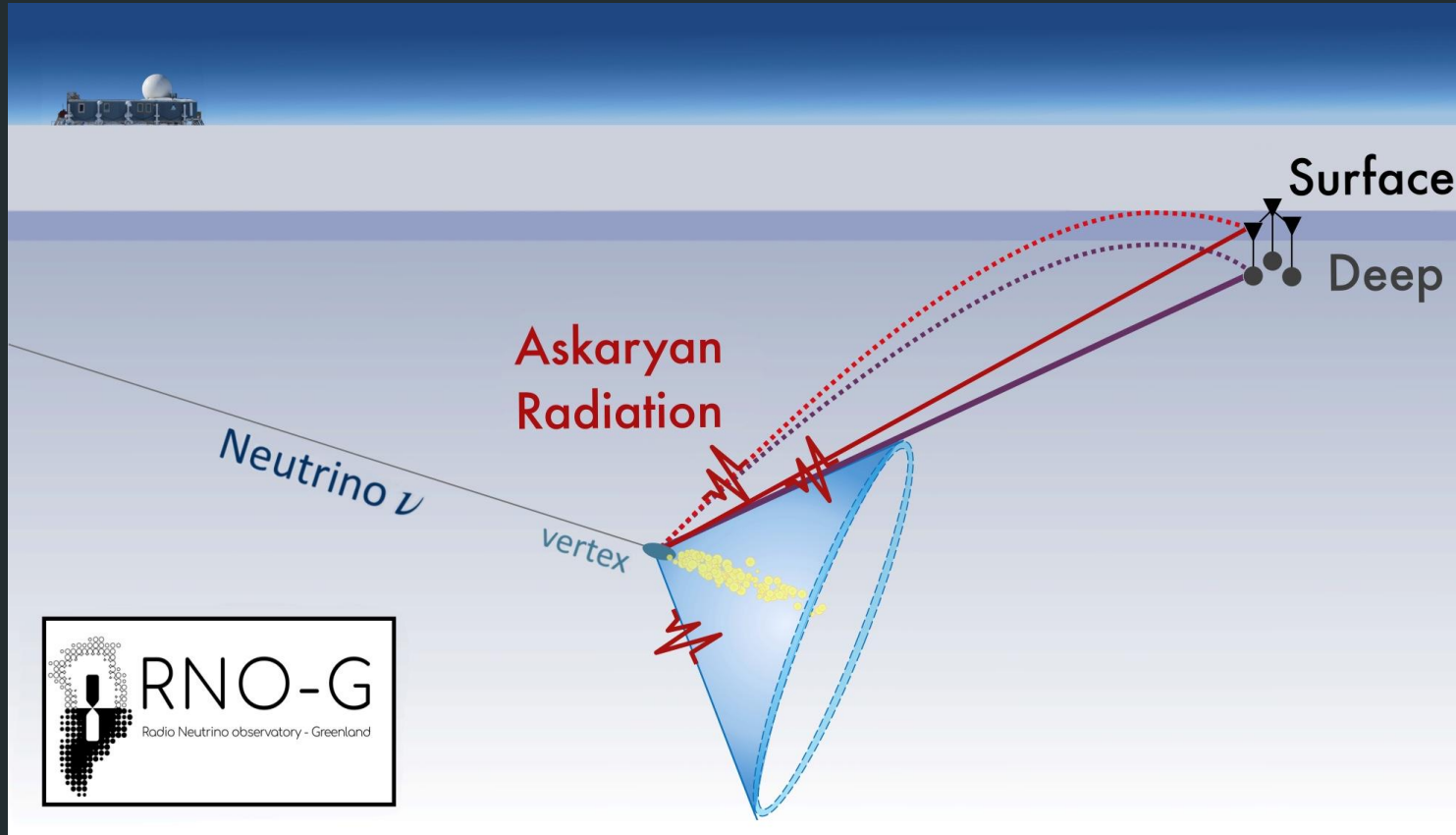
vertex

- ◆ Radio waves have wavelengths of centimeters to meters.
- ◆ The shower that develops is meters long.
- ◆ Which means... all those e⁻ radio waves *destructively interfere* everywhere except the Cherenkov Angle

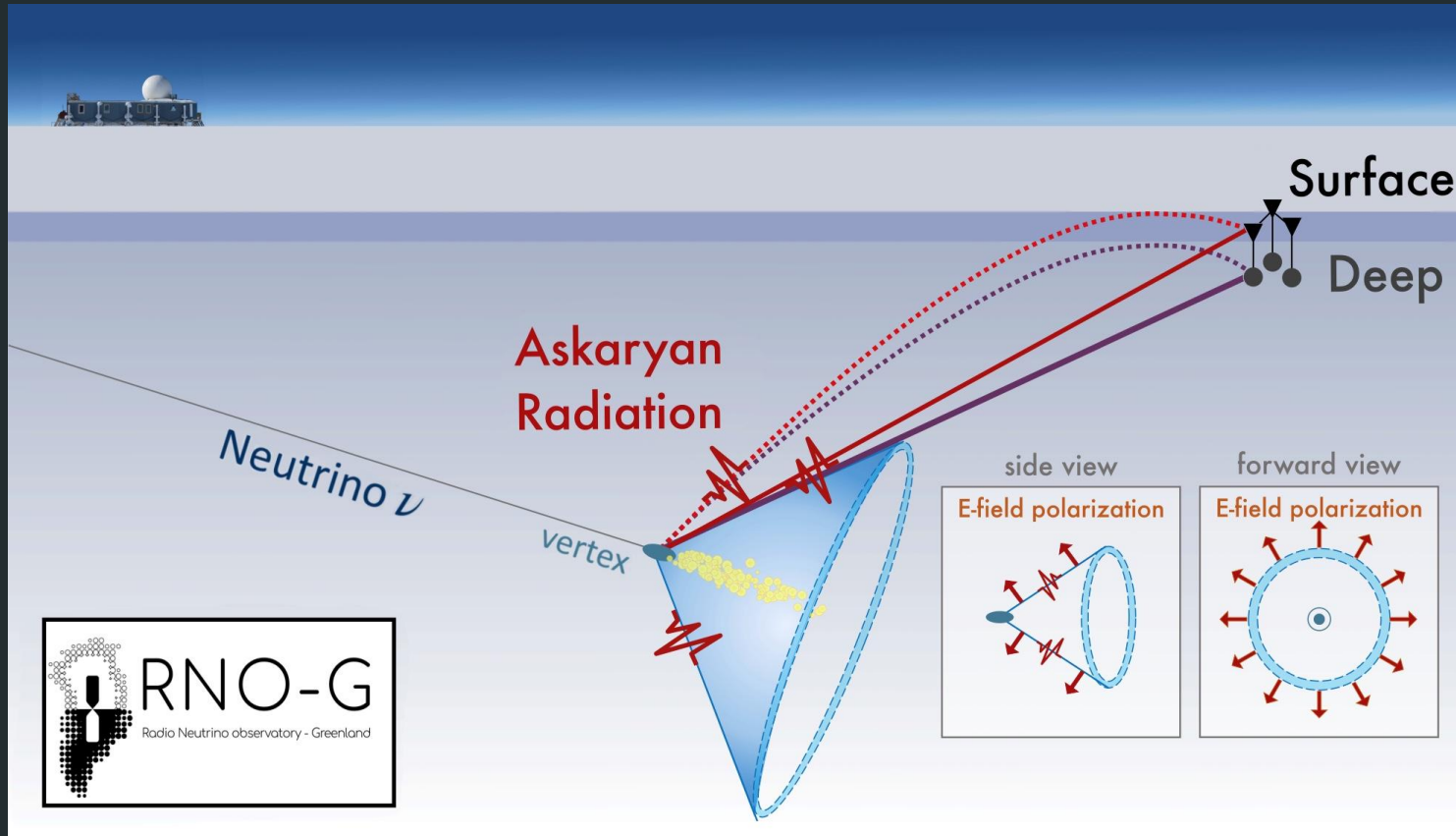


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Askaryan Radiation Reveals UHE Neutrino Interactions



Askaryan Radiation Reveals UHE Neutrino Interactions



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What's the landscape
of UHE neutrino
observatories?

Observing UHE Neutrinos with the 3 Elements

<https://arxiv.org/abs/2203.08096>

Observing UHE Neutrinos with the 3 Elements

	Earth	Ice	The Moon

<https://arxiv.org/abs/2203.08096>

Observing UHE Neutrinos with the 3 Elements

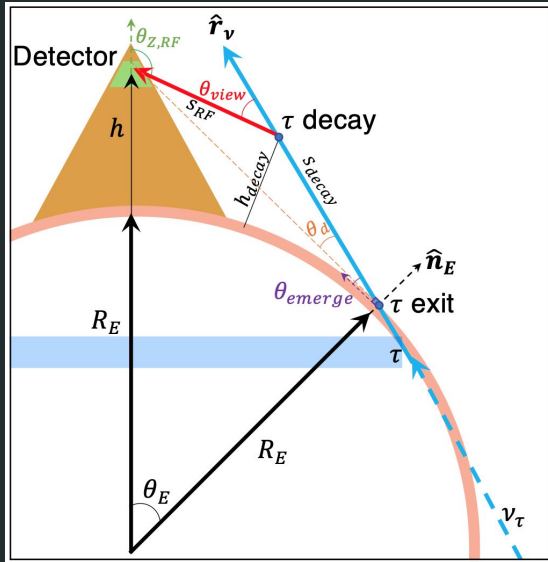
	Earth	Ice	The Moon
Experiments			
Methods			

<https://arxiv.org/abs/2203.08096>

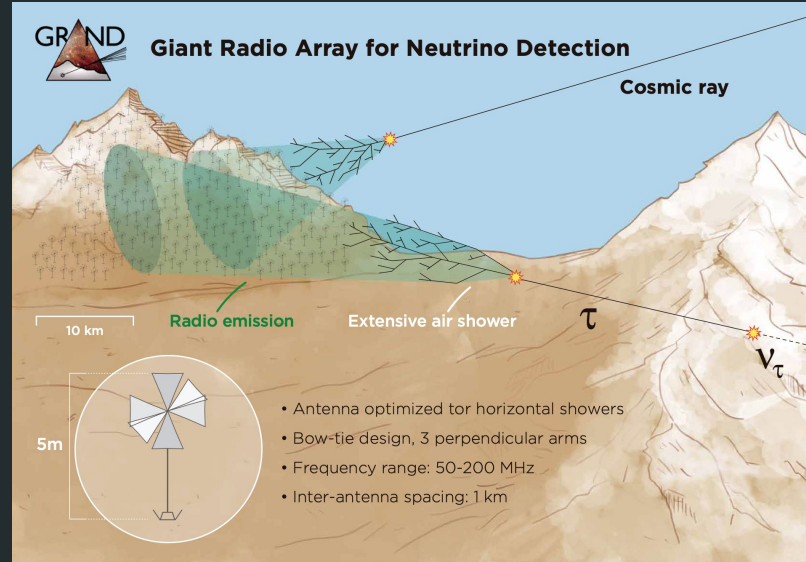
Neutrino Interactions with Earth



The tau lepton leaves the Earth emitting radio radiation.



<https://arxiv.org/abs/2004.12718>



<https://arxiv.org/abs/1810.09994>



TAROGÉ

ARIANNA



Observing UHE Neutrinos with the 3 Elements

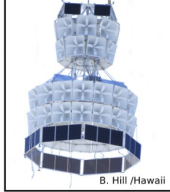
	Earth	Ice	The Moon
Experiments	BEACON, TAROGE, GRAND, ARIANNA		
Methods	Looking for Earth-skimming UHE Tau Neutrinos in mountains or Earth's crust		

<https://arxiv.org/abs/2203.08096>

Balloon Detectors

<https://www.hep.ucl.ac.uk/uhen/anita/>

interferometric payload

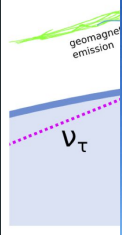


B. Hill /Hawaii



balloon

Not to scale,
angles don't
reflect reality



<https://www.science.org/content/article/oddball-particles-tunneling-through-earth-could-point-new-physics>

ics NASA

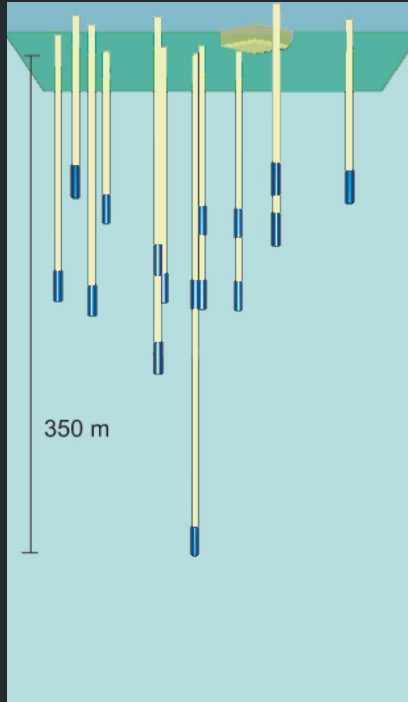
ANITA



<https://news.uchicago.edu/story/find-energetic-particles-space-new-detector-will-soar-over-antarctic-ice>
Christian Miki, University of Hawaii

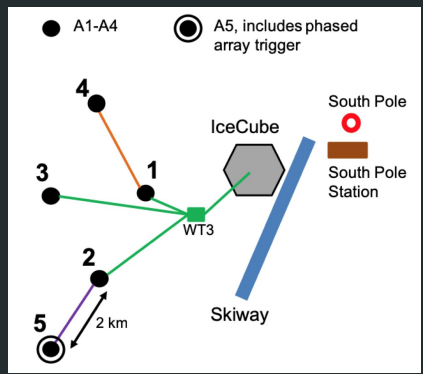
PUEO

RICE

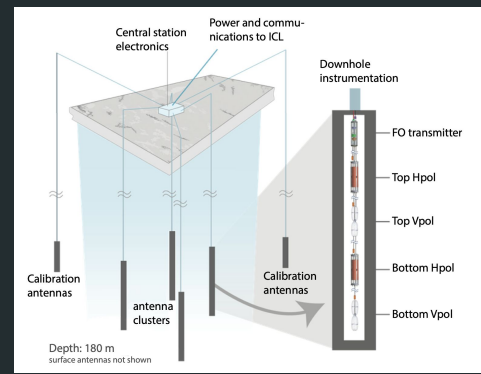


<https://arxiv.org/abs/1106.1164>

ASKARYAN RADIO ARRAY

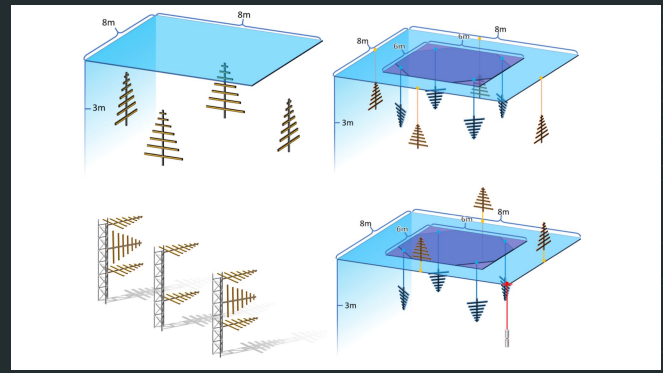


<https://arxiv.org/abs/1907.11125>



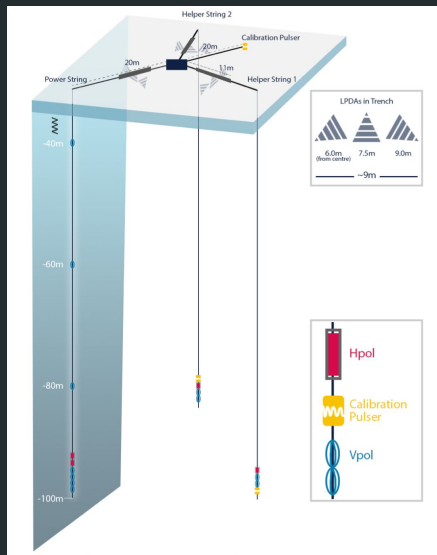
<https://arxiv.org/abs/1507.08991>

ARIANNA

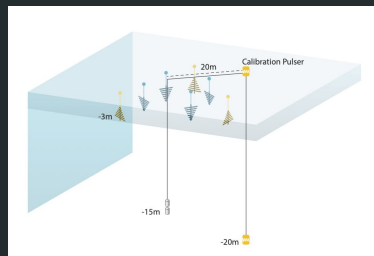
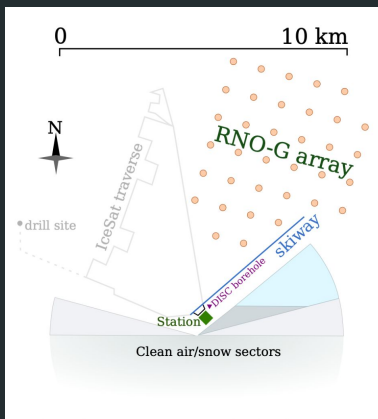


<https://arxiv.org/abs/1903.01609>

RNO-G

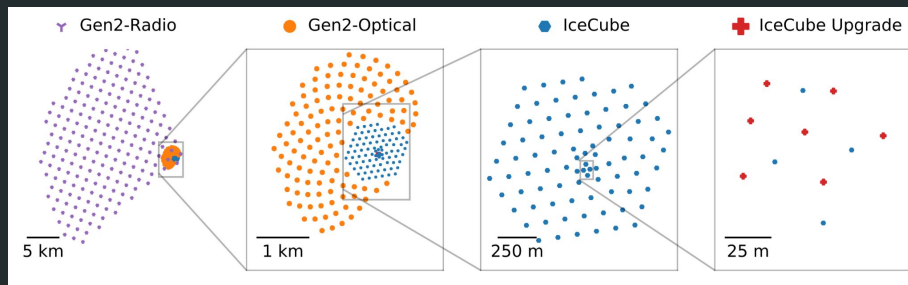
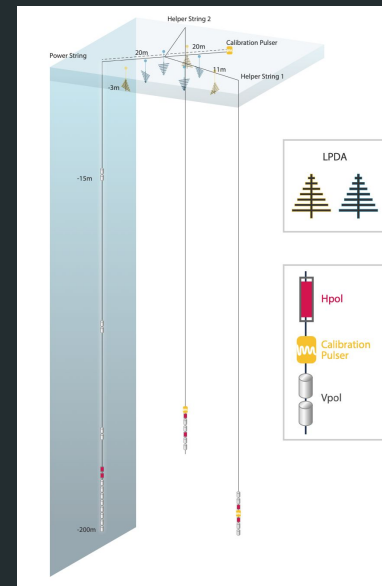


<https://arxiv.org/abs/2010.12279>



<https://arxiv.org/abs/2017.08910>

<https://arxiv.org/abs/2107.08910>

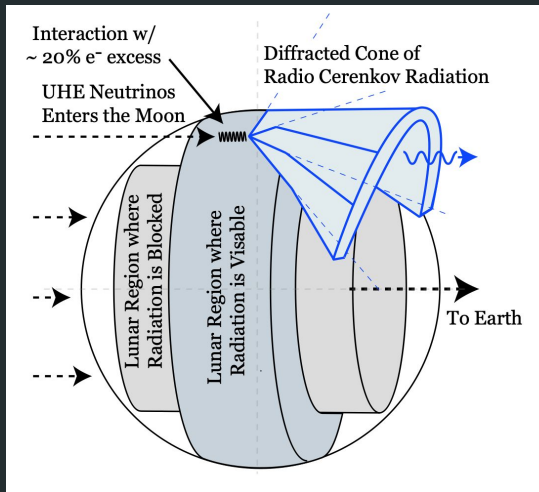


<https://arxiv.org/abs/2008.04323>

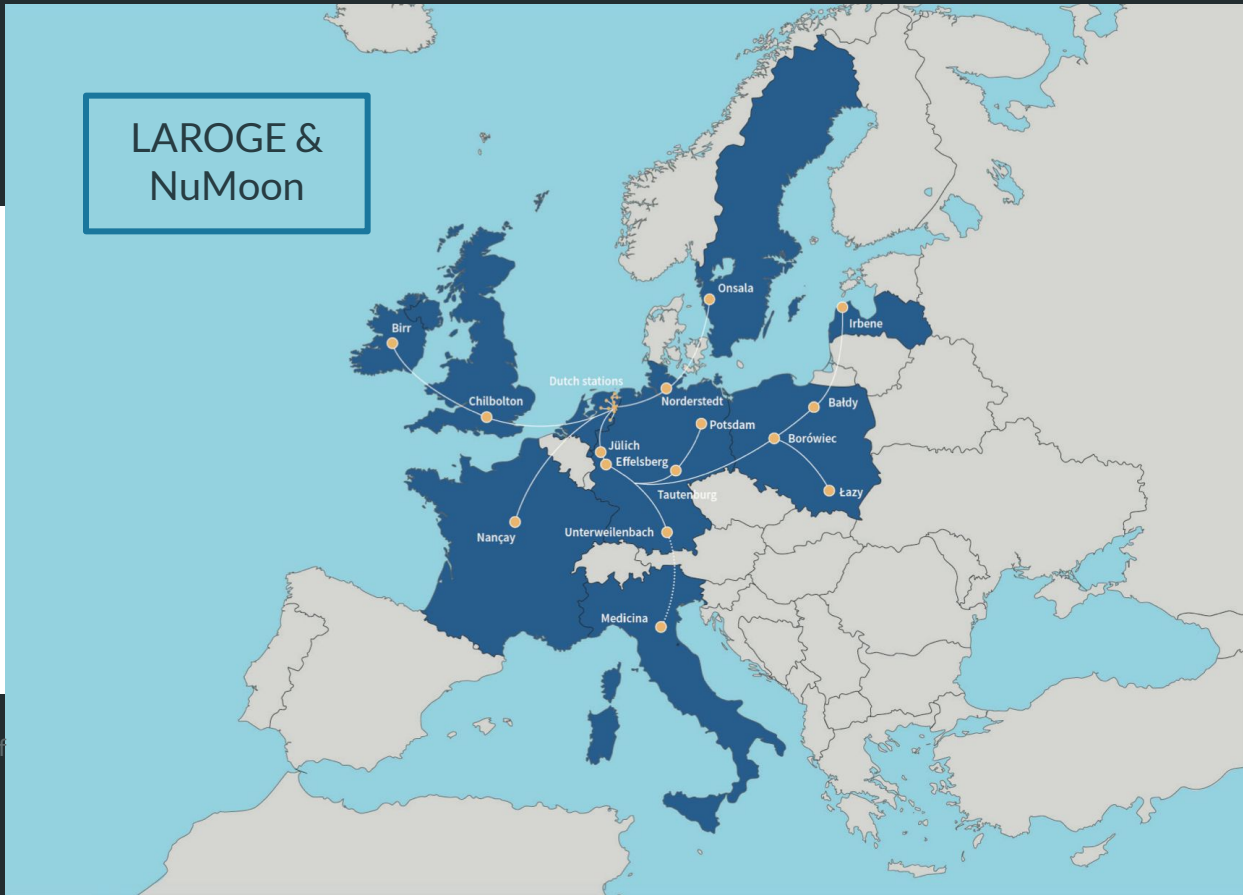
Observing UHE Neutrinos with the 3 Elements

	Earth	Ice	The Moon
Experiments	BEACON, TAROGE, GRAND, ARIANNA	ANITA, PUEO, RICE, ARIANNA, ARA, RNOG, IceCube-Gen2-Radio	
Methods	Looking for Earth-skimming UHE Tau Neutrinos in mountains or Earth's crust	Look for UHE neutrino interactions in Ice	

<https://arxiv.org/abs/2203.08096>



<https://arxiv.org/pdf/0910.5949.pdf>
<https://pos.sissa.it/395/1148/pdf>



<https://www.astron.nl/telescopes/lofar/>

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A lot of this information came from the HE/UHE Snowmass Paper
Check it out here: <https://arxiv.org/abs/2203.08096>

Questions?