ASKARYAN RADIO ARRAY

Recent Results from the Askaryan Radio Array

Amy Connolly*, for the ARA Collaboration
*Ohio State University and CCAPP

Proceedings arXiv:1907.11125

The ARA Collaboration

Figure credit: C. Pfendner

USA

Cal Poly	University of Kansas
The Ohio State University	University of Maryland
Otterbein University	University of Nebraska
University of Chicago	University of Wisconsin-Madison
University of Delaware	Whittier College

International Collaborators

Chiba University

National Taiwan University

University College London

Vrije Universiteit Brussel

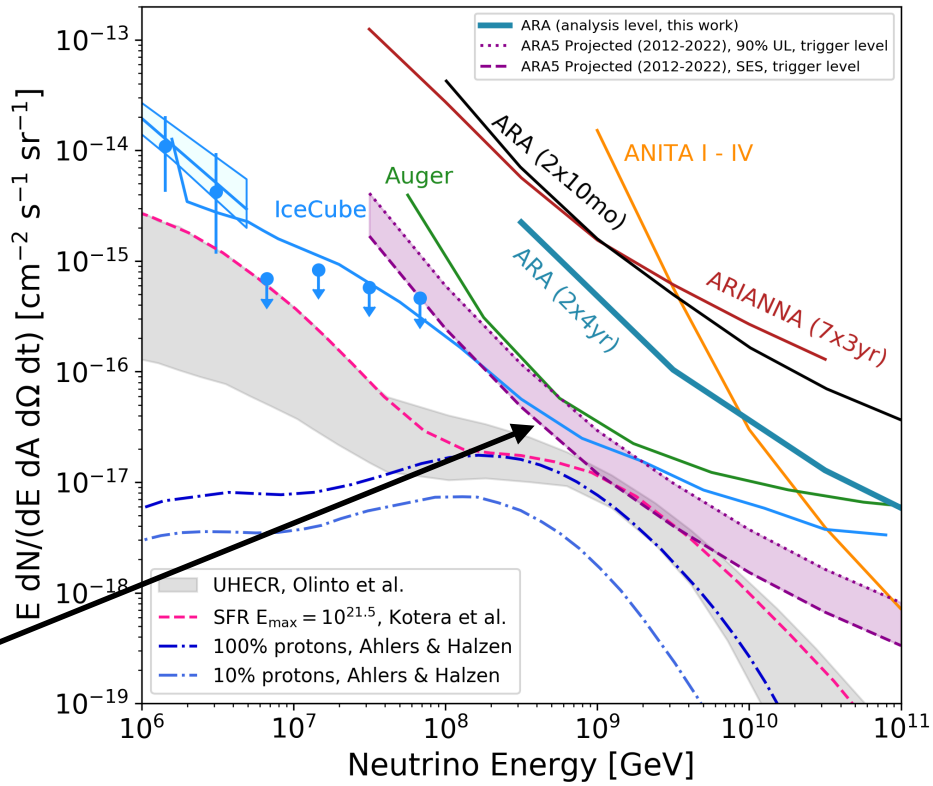
Weizmann Institue of Science

Why ARA?

- First neutrino > 100 PeV will:
  - Bring UHE neutrinos into multi-messenger program
  - Be most distant > 100 PeV particle ever seen
    → test fundamental physics
  - Establish scale of detectors needed for:
    - Neutrino astronomy > 100 PeV
    - ν-N cross-sections at record-breaking $\sqrt{s}$

ARA is at discovery potential NOW

- Five stations currently taking data in the ice: competitive sensitivity >10^{18} eV by 2022

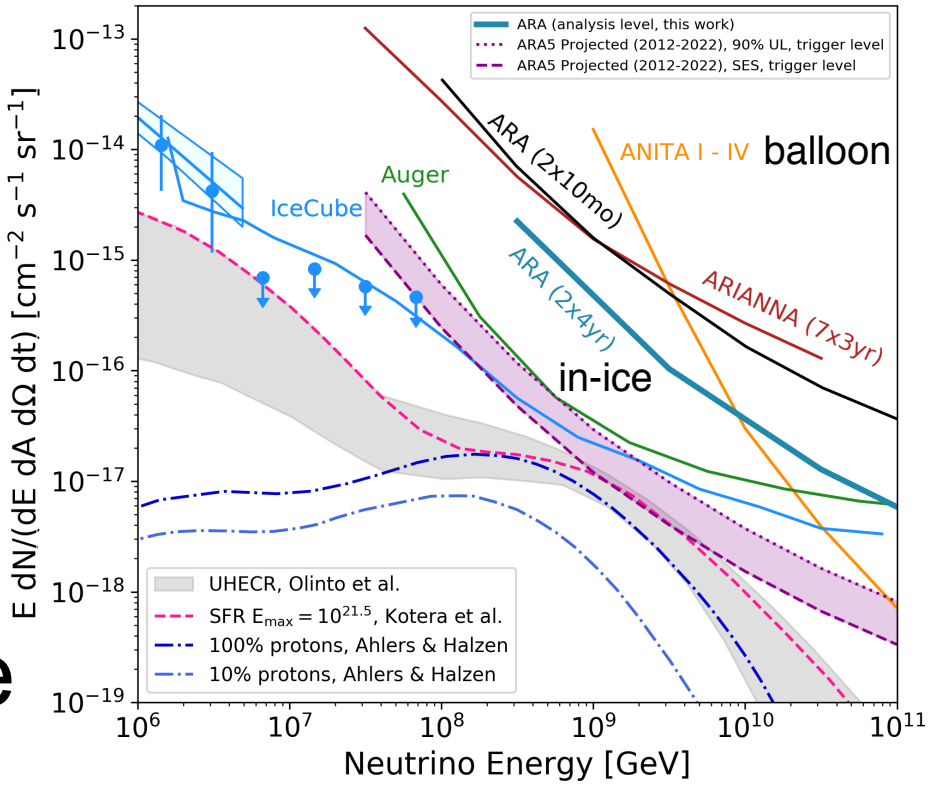


Radio is essential

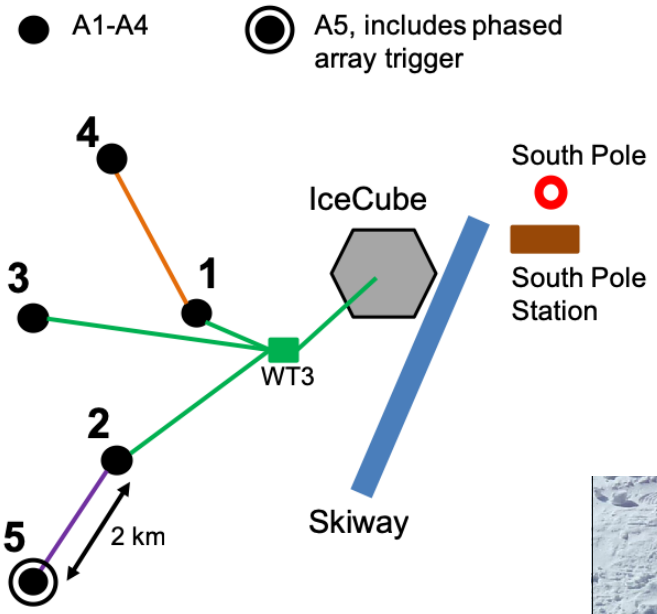
- 10^{-2} neutrinos/km^3/year $\gtrsim 10^{18}$ eV

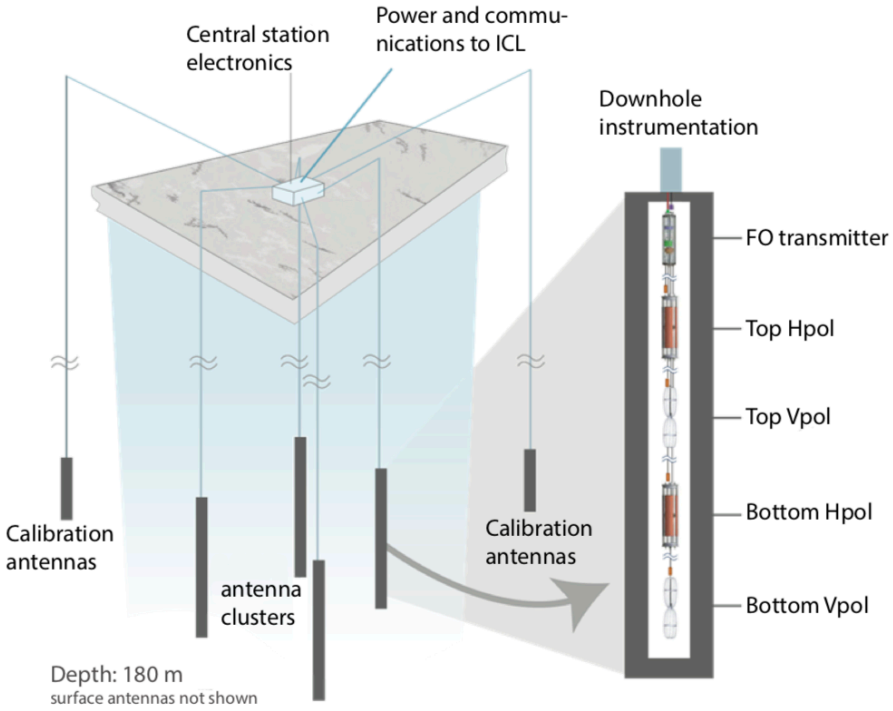
  Need detection volumes > 100's km^3

  - Enabled by ~1 km attenuation lengths in ice
  - In-ice: ARA, ARIANNA



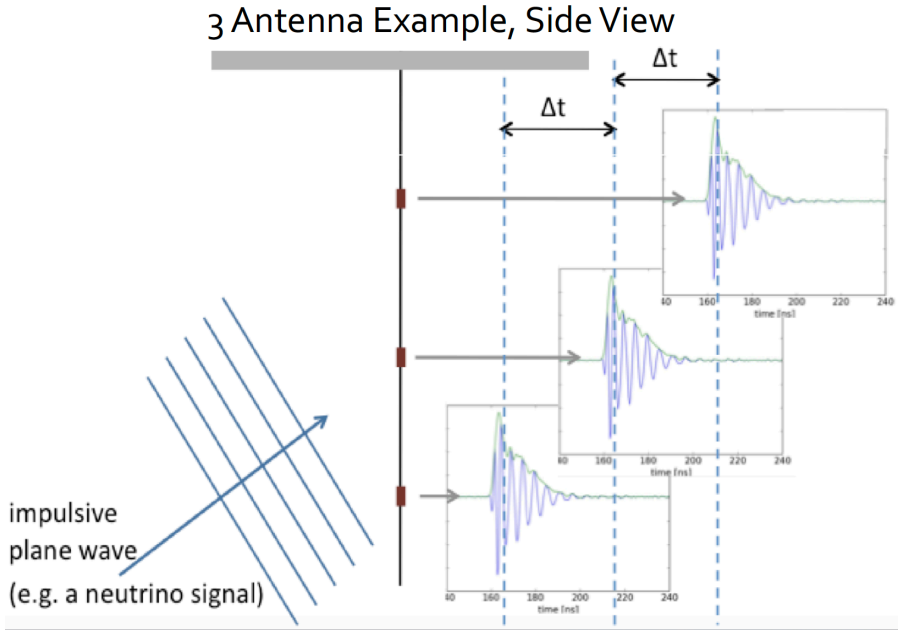
Askaryan Radio Array (ARA)





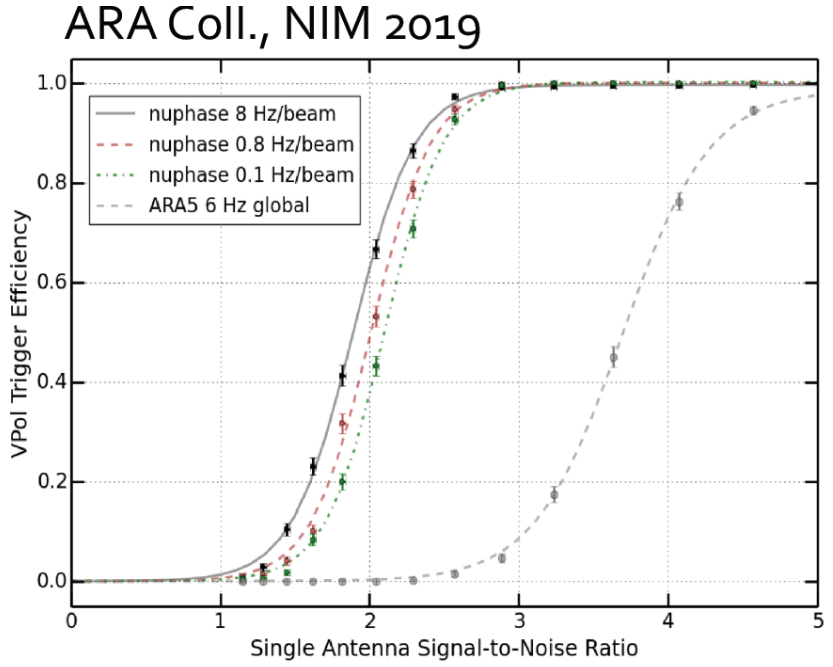
Phased Array Trigger

- Trigger on coherent sum



A. G. Vieregg, et al., JCAP 1602 (2016) no.02, 005.

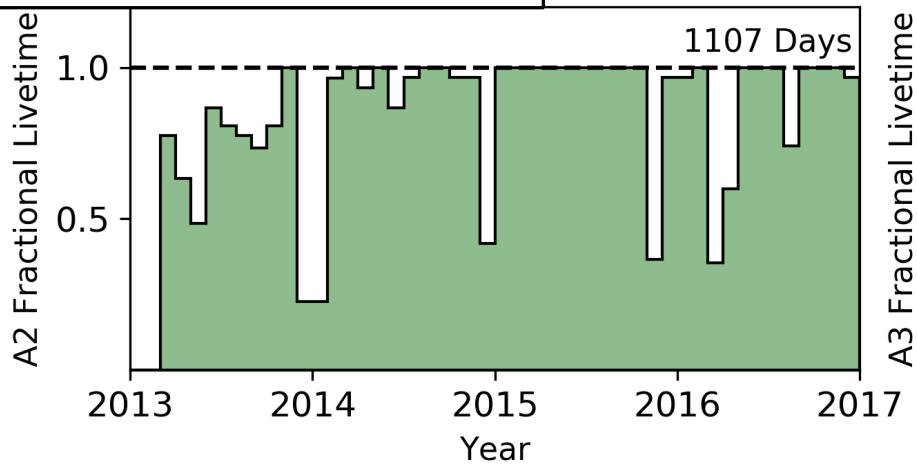
Figure credit: Univ. of Chicago

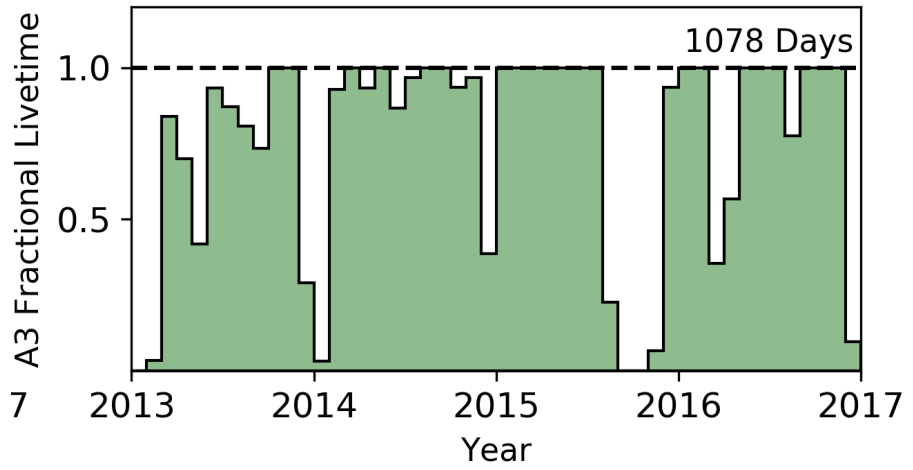


Diffuse searches:
Brian Clark (OSU→MSU), Ming-Yuan Lu (UW)
Jorge Torres-Espinosa (OSU)

Livetimes

- Data for this analysis from 2013-2016
- Keep 98% of livetime for analysis, through targeted rejection of anthropogenic noise (previously 62%)

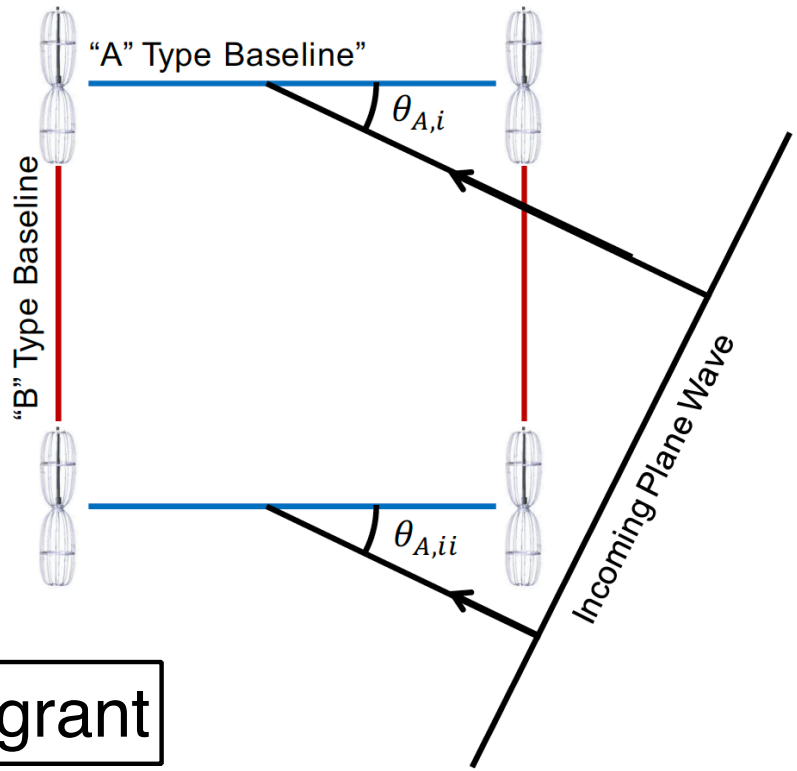




Event filter

- Requires arrival times consistent with plane wave
- Allows deeper analysis of events of interest
- Keeps 90% of events, reduces dataset by factor of 10

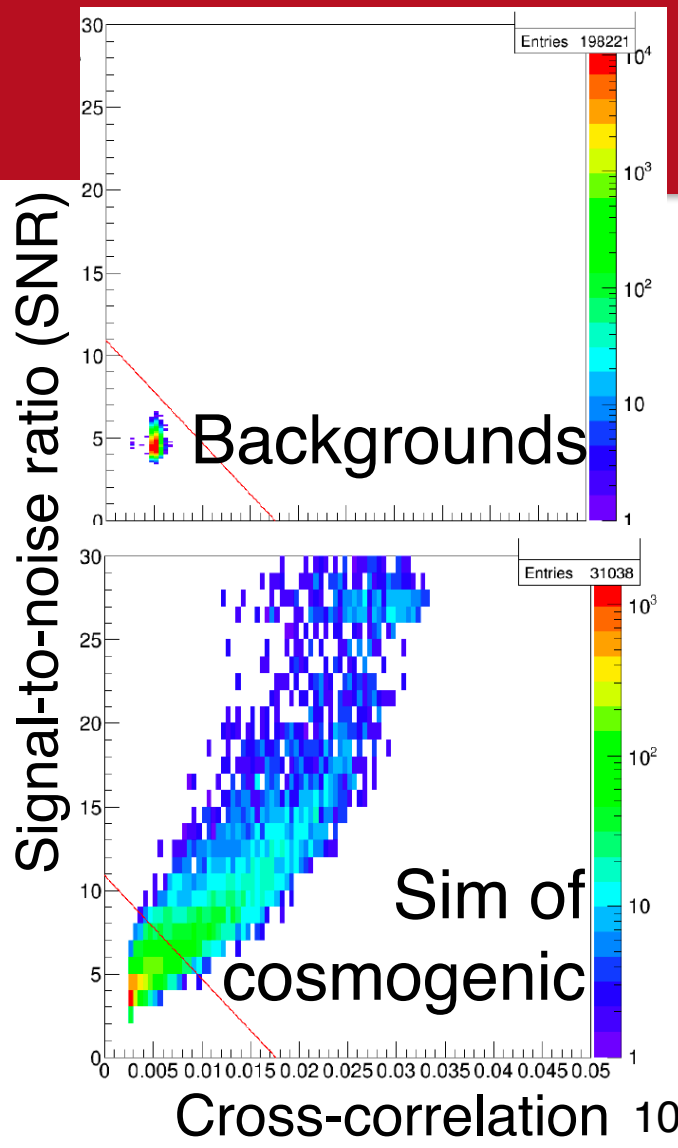
Prof. Carl Pfendner (Denison)



NSF BIGDATA grant

Selection Criteria

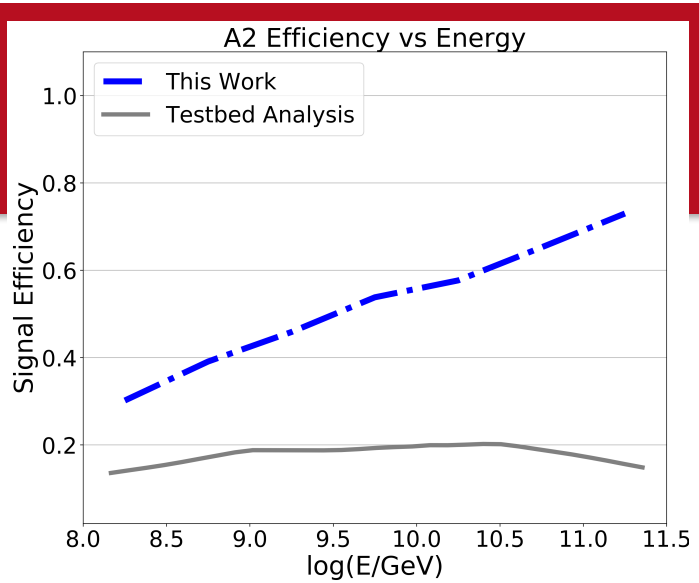
- Cut in 2d space in signal-to-noise, cross-correlation
- Optimize: best expected limit
- Expected backgrounds: 0.01-0.02 events/polarization/station

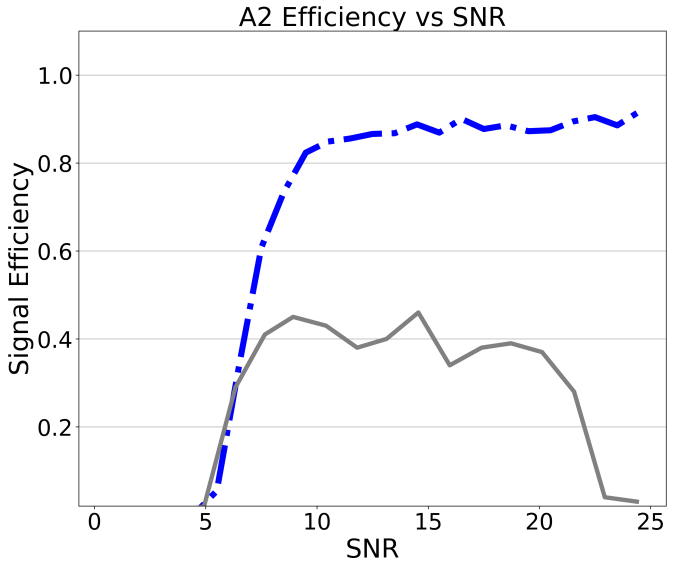


Efficiencies

- Improved over the first ARA searches
- Reduced backgrounds while reducing number of cuts
- Box opening imminent

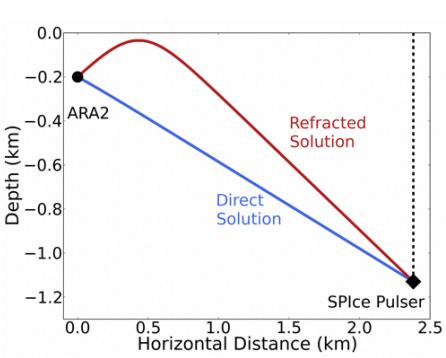
Quality cuts
Event filter
SNR-CC cut

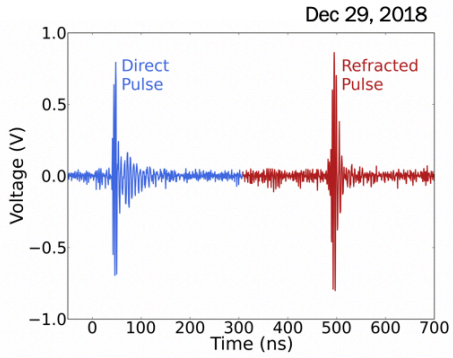


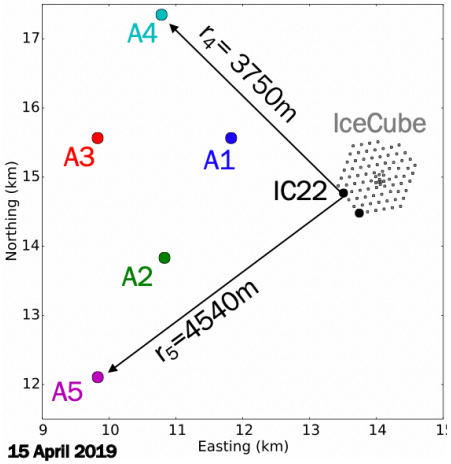


Ice Properties

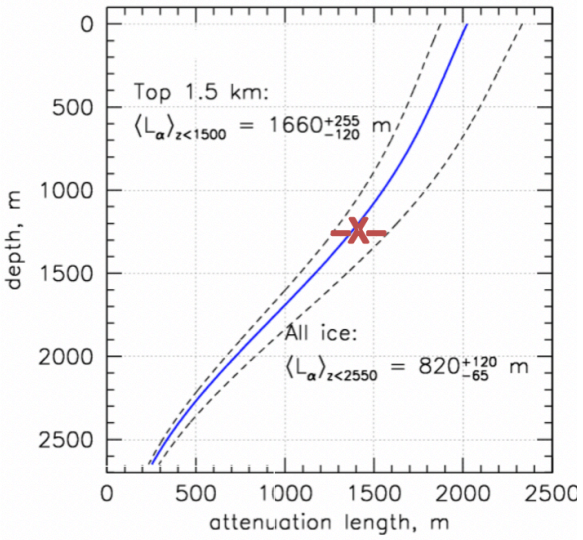
- Pulsers from
  - IceCube strings 1&22
  - South Pole IceCore (SPIce) hole







Adapted from [P. Allison *et. al.* j.astropartphys.2011.11.010]



- Attenuation lengths

New measurement:
$L_{\alpha,1500m} = 1.43 \pm 0.25$ km

- Direct, refracted from same pulse

Uzair Latif (KU)

ASKARYAN RADIO

Cosmic Rays

- Ongoing search template-based

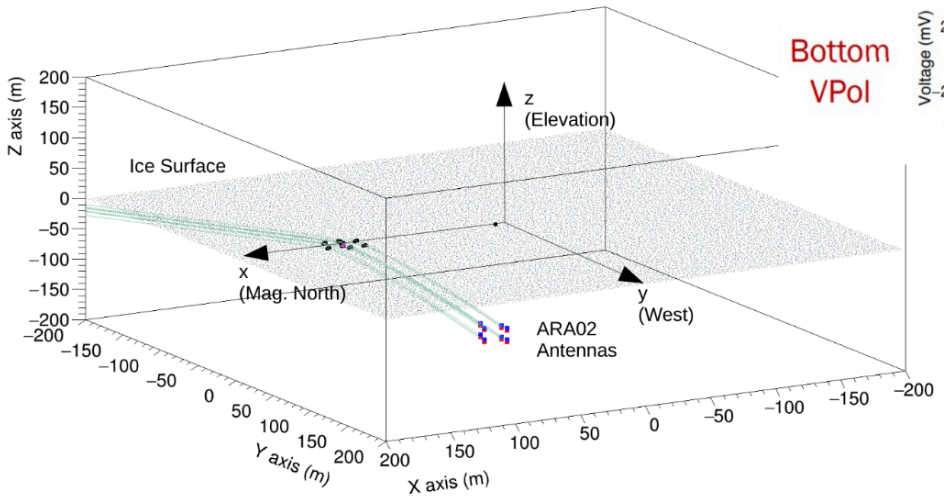
Simulating EAS for ARA using CoREAS

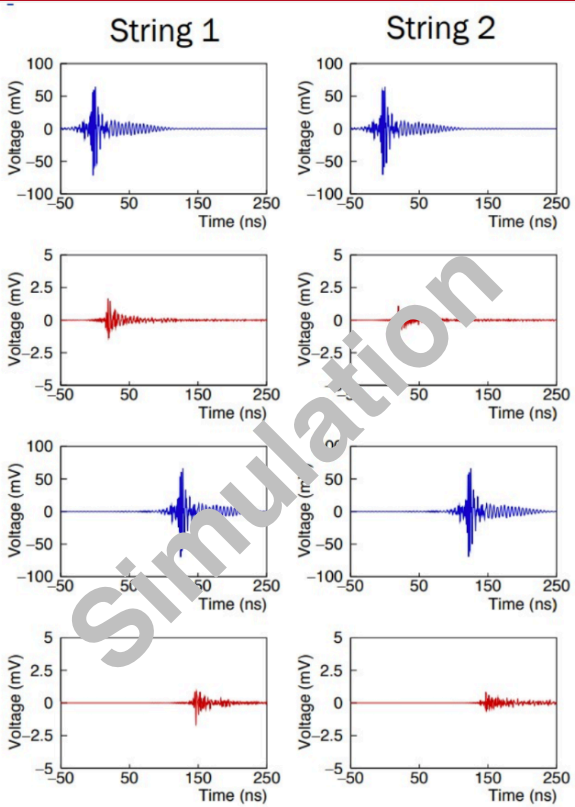
- Shower simulated with theta=60 deg, phi=360 deg and 10^18 eV

.

- CoREAS provides emission at the ice surface, which is propagated to the antennas, and folded with the detector response
  - The hadronic models use are QGSJETII.04 and UrQMD 1.3.
  - Thinning was ON, with a thinning fraction of 10^-6.

- Hpol waveforms have stronger signal which is expected as most of the geomagnetic emission happens in Hpol at SP.

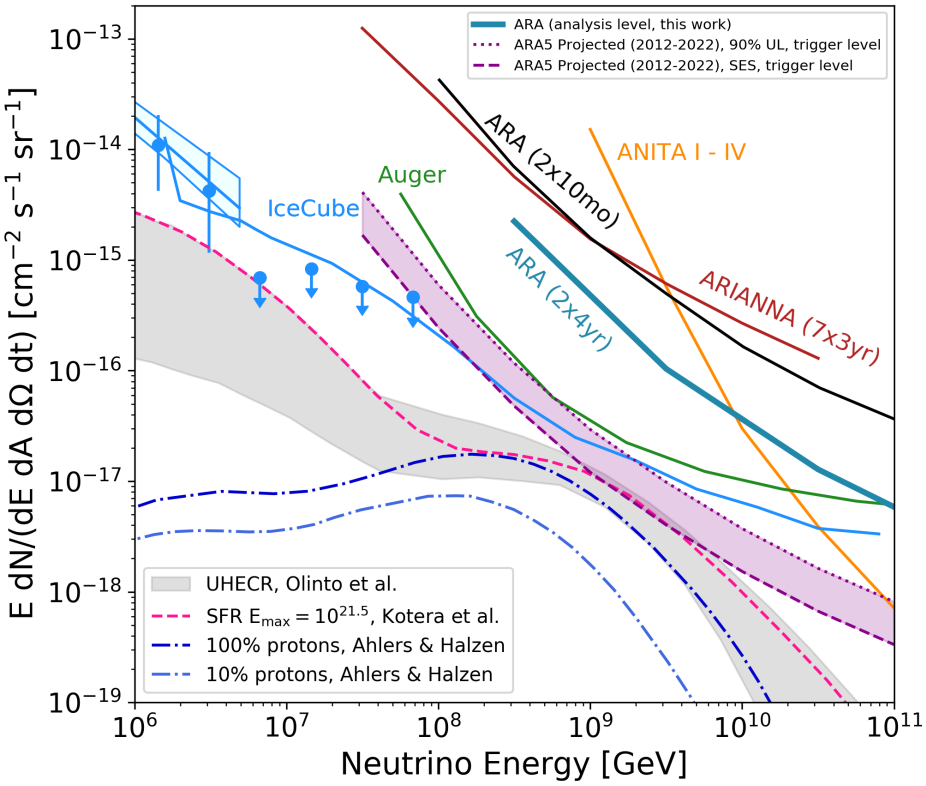




Pink dot is the shower core.
Black dots are where it enters the ice.
Red and blue are the ARA antennas.
Origin is at SE corner of ARA02 DAQ box.

Future of ARA

- ARA is taking data with five stations
- This is potentially a discovery instrument
- First ν will mark the beginning of neutrino astronomy >100 PeV



Looking ahead

- We look forward to a larger array (e.g. proposed RNO) Submission to Decadal Survey on Astronomy and Astrophysics (ASTRO2020)
  - Neutrino astronomy, fundamental physics with ~tens of neutrinos >100 PeV
  - First deployment seasons would also be pathfinding for radio component of IceCube Gen2