College of Arts and Sciences / Department of Physics

Searching for the most energetic neutrinos with the Askaryan Radio Array (ARA) experiment

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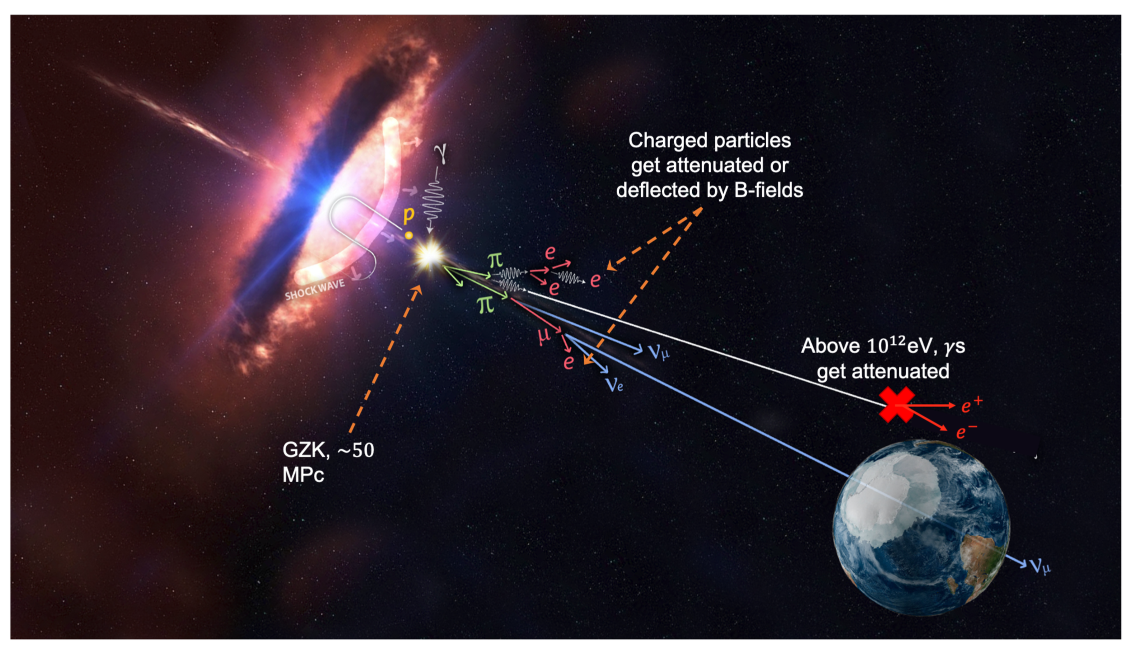
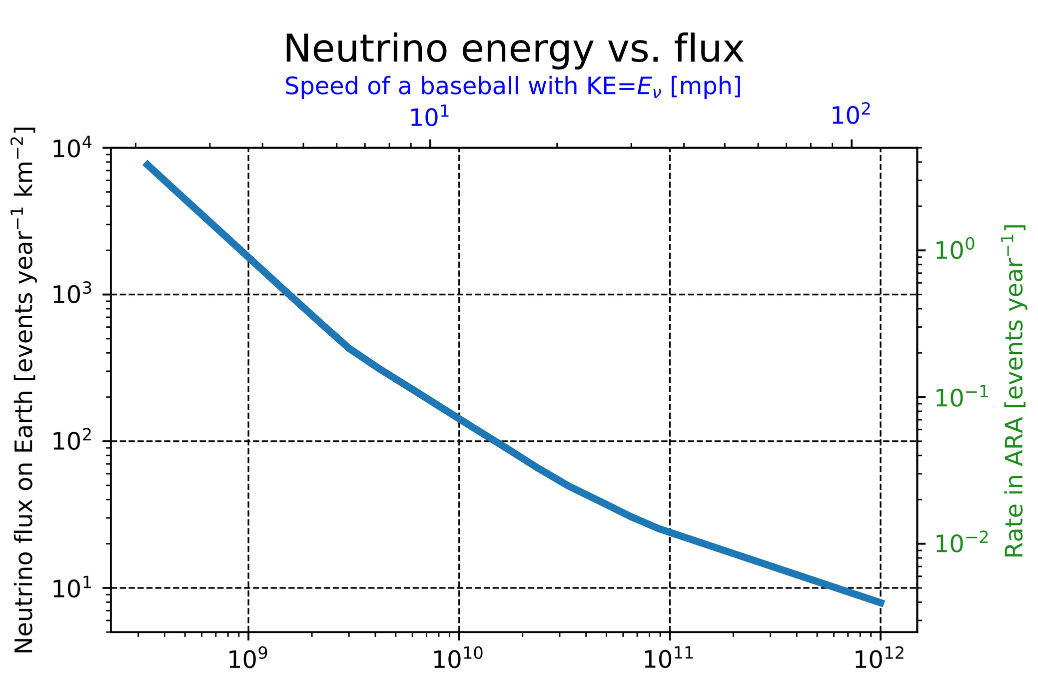
INTRODUCTION AND MOTIVATION

Neutrinos are elusive particles. They have **no charge**, they are **point particles**, and they **interact weakly** with matter. This provides a window to study the universe, as they travel through it undisturbed, pointing back to their source.



Neutrinos are the only particles that can travel very large distances in the Universe undisturbed. Photons can get attenuated, and charged particles get bent by magnetic fields. Figure (modified version) by the IceCube collaboration.

Although they are abundant at low energies, at ultra-high energies (UHE, >10^8 GeV) they are **extremely rare**. Combined with the fact that they barely interact with matter, observing one of these particles becomes very challenging, needing extremely big detectors (order of **km³**), or waiting a long time (**years**).



Detecting UHE neutrinos will help us to:

- Understand how and where they originate.
- Study UHE cosmic rays, since neutrinos can be their daughter particles.
- Study fundamental physics at ultra-high energies.

METHODS

The ARA experiment

- Located in Antarctica, a **radio quiet** continent with immense detection medium (ice).
- Consists of five stations under the ice, each having sixteen antennas.
- These antennas can detect **radiation** produced by neutrinos interacting with ice.

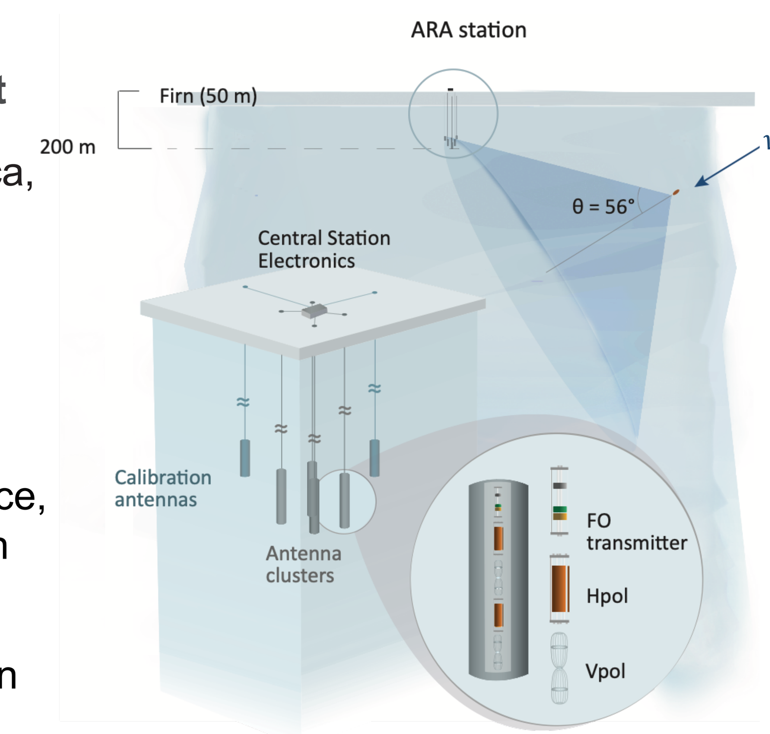
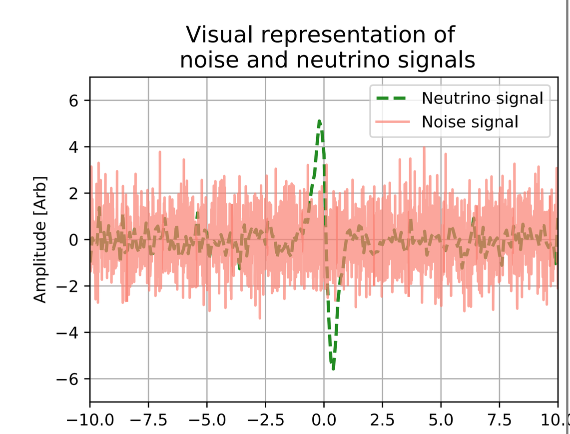
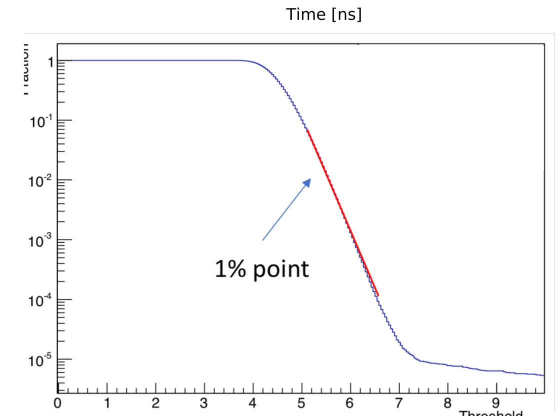


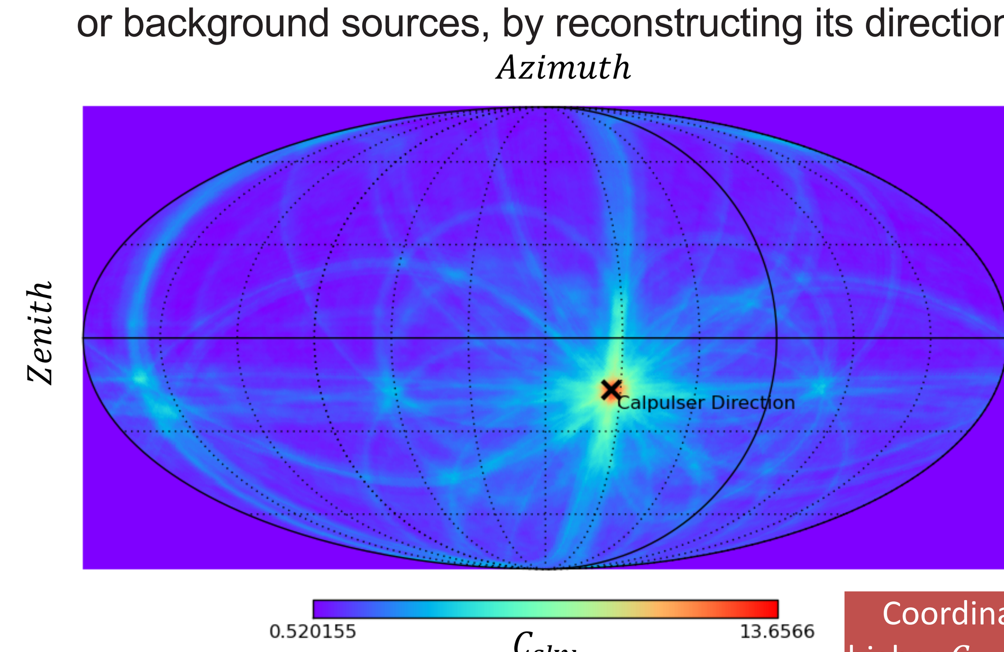
Figure by the ARA collaboration

Data analysis

- We analyzed four years of data for two stations
- **>99.99%** of the data are **noise** produced by ice or by human sources in Antarctica.
- Calibration runs and glitches are excluded, then a filter is applied to exclude low signal-to-noise ratio (SNR) events.
- We know what neutrino signals are expected to look like, so that allows us to impose **cuts** on noise signals.
- We can **distinguish** a signal coming from a human source, or background sources, by reconstructing its direction.





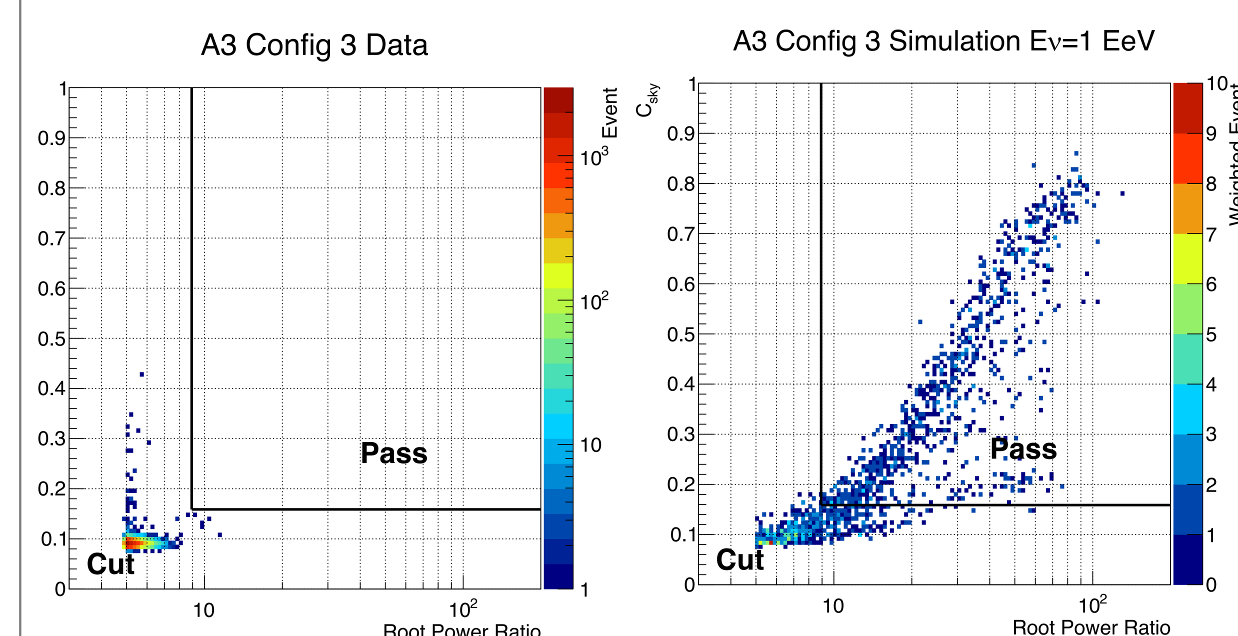


Coordinates with higher C_{sky} represent a potential source.

Figure by Ming-Yuan Lu

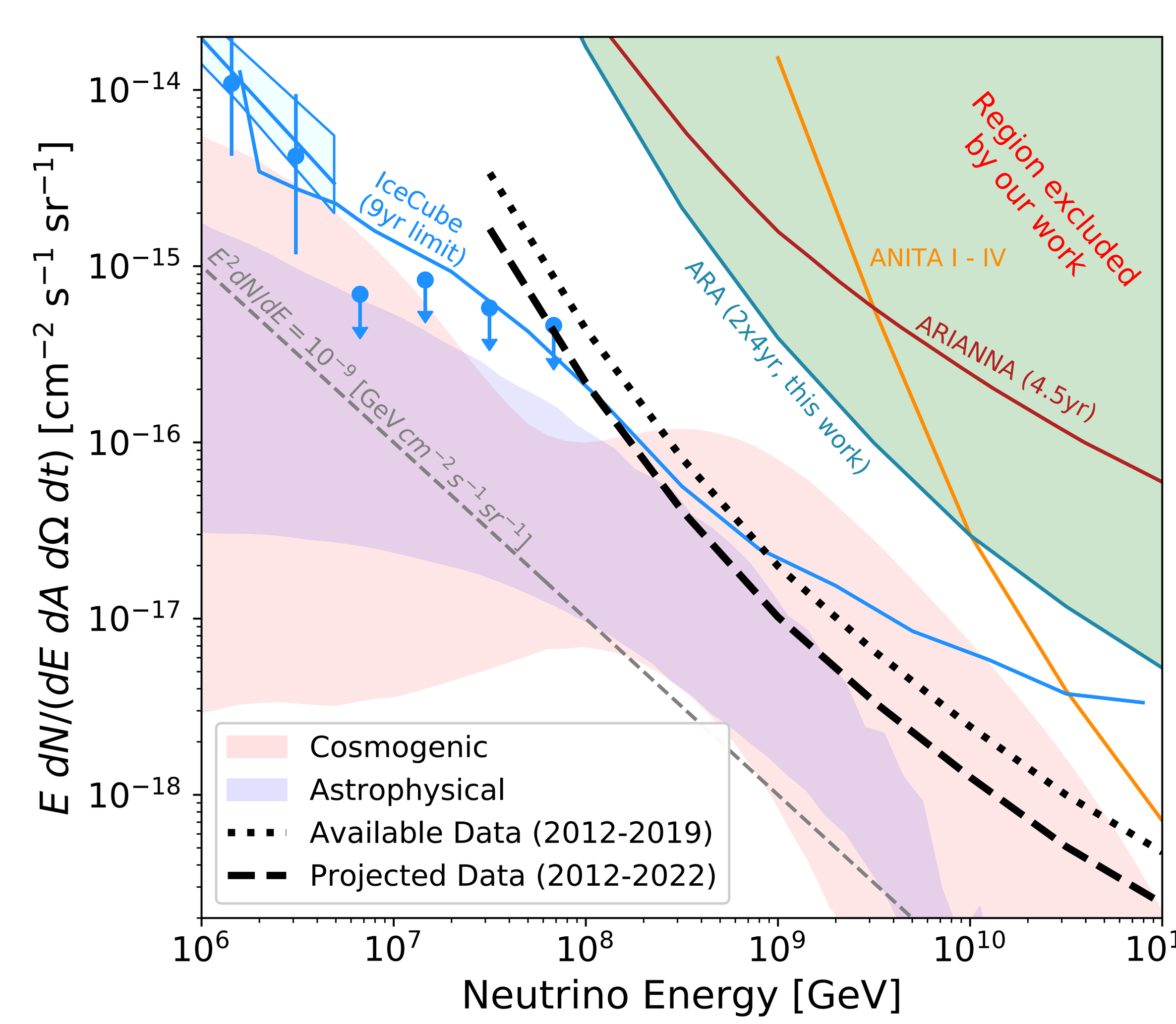
Data analysis (cont.)

- We expect neutrino signals to be strong in amplitude (high SNR) and to reconstruct well with interferometric methods (C_{sky}).
- Simulations allow us to predict what we would observe for a neutrino event.



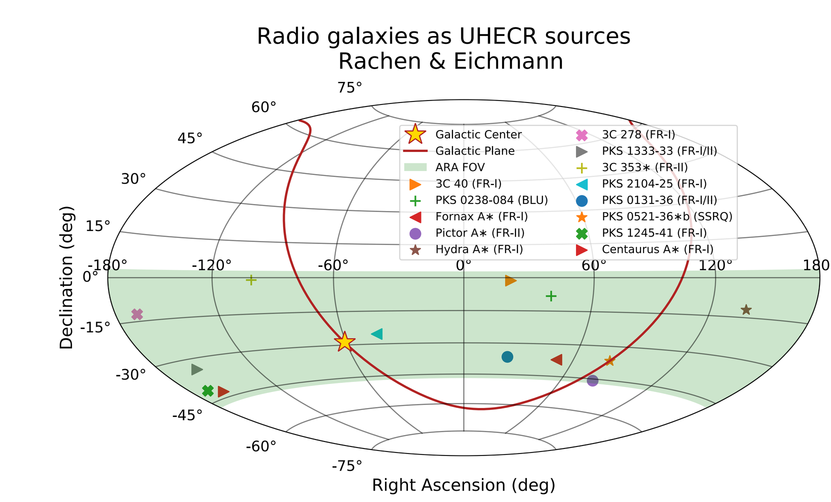
RESULTS AND OUTLOOK

We performed a search using four years of data for two stations of the ARA experiment. We found **zero** neutrino events, but we were able to constraint the neutrino flux, achieving the best limit for an in-ice neutrino experiment between $10^8 - 10^{11}$ GeV.



Outlook

- Analysis on accumulated data for the 5 stations will soon be in progress.
- Improvement of reconstruction algorithms, as well as the development of sub-threshold searches and point-source searches are currently **in progress**.



CONCLUSIONS

- The Askaryan Radio Array (ARA) experiment looks for ultra-high energy neutrinos, as they provide a unique window to the distant, very energetic universe.
- In this work we analyzed four years of data in two stations of the ARA experiment.
- The resultant limit is the **best** set by ARA to date, and the best limit produced by an in-ice radio neutrino detector above 100 PeV.
- The projected sensitivity for the five-station array shows ARA achieving **world-leading** sensitivity to neutrinos above 10^8 GeV by 2022.

BIBLIOGRAPHY

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