In-Ice Phased Antenna Arrays for Radio-Detection of Energetic Neutrinos

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Ultra-High Energy Neutrinos

Cosmic rays have been detected up to enormous energies (>100 EeV), yet the sources of the ultra-high energy cosmic rays (UHECRs) remain unknown. Interactions of the UHECRs with the cosmic microwave background not only attenuate the cosmic ray flux, but are also expected to produce neutrinos through photomuclear processes, for example the GZK process for protons:

\[ p + \gamma \rightarrow \nu \gamma \rightarrow \nu \nu \rightarrow \nu \nu \]

These ExEeV-scale cosmogenic neutrinos can reach Earth unimpeded, providing an excellent probe of the high-energy universe. Successful measurement would also probe the Standard Model at a new scale. Due to the low expected flux, enormous detectors must be deployed.

IceCube has also detected a separate population of PeV-scale astrophysical neutrinos, which may extend to higher energies. A large detector with a low-enough energy threshold could probe the cutoff.

Active galactic nuclei are a potential source of the UHECRs. (NASA)

The Askaryan Radio Array (ARA)

The Askaryan Radio Array (ARA) experiment searches for Askaryan radio emissions from ultra-high energy neutrinos interacting in the Antarctic ice cap. ARA is located near Amundsen-Scott Station at the geographic South Pole. ARA is made up of independent stations, located approximately 2 km apart. Power and network are provided by IceCube lab. In the 2017-2018 Austral summer, two stations were deployed, bringing the total to five. A total of 47 stations are planned.

Near the surface, the ice gradually transitions from loose snow to deep glacial ice. This changing density (and therefore index of refraction) adversely affects acceptance and reconstruction, so ARA buries antennas 200 m below the surface.

The trigger efficiency, measured in situ with a calibration pulser, as a function of single-antenna signal-to-noise ratio at various rates with the phased array and for the ARA station's self-trigger without the phased array. (E. Oberla)

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