Flavor Identification of Neutrinos in In-Ice Experiments

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Introduction

The Standard Model of particle physics predicts there are three generations of quarks and leptons with their associated Gauge Bosons.

Neutrinos are leptons that carry no electric charge. Their charged partners, electrons, muons and taus each have 1 unit of elementary charge 1.6 e-19 Coulomb. Having no charge, neutrinos can only interact through the weak force.

There are four fundamental forces in the universe. These are the electromagnetic, weak, strong, and gravitational forces. The electromagnetic force acts on any particle with electric charge and interacts through the exchange of photons. In interactions involving the weak force, Z and W bosons are exchanged. The weak force is responsible for nuclear decay which allows the sun to burn. The strong force holds the quarks inside protons and neutrons together and is carried by the gluon. Gravity is the weakest force but is dominant at the scale for shaping the structure of galaxies and stars.

What Are Neutrinos?

Neutrinos are fundamental particles that have very little mass and only interact through the weak force. They can travel through matter with low probability of interaction. This makes them ideal messenger particles. There are three types of neutrinos each associated with the lepton it is named after: Electron neutrino, muon neutrino, tau neutrino.

There are many sources of neutrinos. They are produced in the sun during nuclear fusion, and about 100 billion of these stellar neutrinos pass through your thumbnail every second. There are also neutrinos from the Big Bang that can provide scientists the earliest insights of the universe. However, once a neutrino is produced, it will oscillate over time between the three flavors. This discovery was not predicted by the Standard Model.

How does Radio Neutrino Observatory (RNO) work?

Neutrinos are difficult to detect because they interact very weakly with other matter such as proton, neutrons, and electrons. RNO searches for neutrinos by detecting Askaryan radiation produced when high energy neutrinos (> 10 PeV) pass through ice faster than the phase velocity of light in that medium. This creates a shower of charged particles which emits a cone of radiation at radio wavelengths.

RNO is designed to detect these radio waves using detector arrays both on the surface and 60 meters deep within the Antarctic ice.

Experiment

In-ice radio arrays like the Radio Neutrino Observatory in Greenland (RNO-G), IceCube Gen2-Radio, and the Radar Echo Telescope will have improved sensitivity to the highest energy neutrinos (few PeV to >10 EeV). The Radio Neutrino Observatory in Greenland is currently under construction and the first stations will be deployed this summer. The Radar Echo Telescope is a novel approach that plans to use radar transmitted in the ice to search for PeV scale neutrinos.

All of these experiments are sensitivity to all flavors of neutrinos, but few studies have been that show they can distinguish among the different flavors of neutrinos. We intend to run detector simulations to determine optimized radio station configuration that minimizes backgrounds and is optimized for improved neutrino flavor (electron, muon, or tau) identification.

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