A Template-based UHE Neutrino Search Strategy for the Askaryan Radio Array (ARA)

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Introduction

Ultra-High Energy (UHE) neutrinos are essential particles for understanding powerful accelerators in the universe. The detection of UHE neutrinos requires the ability to detect ~1 event per gigaton per year due to the low cross-section for their interaction. Thus, the radio transparent ice in Antarctica, with an attenuation length of ~1 km for radio waves, provides an optimal environment for constructing a large detector.

The Askaryan radio array (ARA) is a largest neutrino telescope constructed in the glacier ice near the South Pole. It is designed to detect UHE neutrinos above 10^{16}eV by utilizing the Askaryan effect.

The Matched Filter method for ARA

The amplitude of the neutrino-induced waveform can be similar to the thermal noise background and anthropogenic noise from the South pole station, which can be also detected by the ARA detector. The matched filter method using a neutrino template, inspired by LIGO, is designed to distinguish low signal-to-noise ratio (SNR) signals from the noise waveforms. Lowering the amplitude of neutrino signals that we can detect would increase our sensitivity.

Analysis

The matched filter method is applied to individual waveforms generated from the simulation. Two sets of simulations were produced. The noise-only simulation is for estimating the background level and the power spectral density of noise used as weights. . The template is correlated with data in the frequency domain and normalized. In this proceeding, only the maximum weighted correlation value was chosen for scoring the individual waveform.

The analysis cut is set by the estimated three-station livetime for separating noise from signal events. The neutrino simulation is weighted by the Kotera neutrino flux model and applied to the matched filter method. Based on the cut, the preliminary event rate of the detector was established on different energies.

Summary

The matched filter method gives a strategy to search for low-SNR signals in a radio detector. The actual data will be tested against the simulated neutrino template. In the future, the number of templates including double-pulse signals and vertex reconstruction will be implemented for improving the cut and sensitivity.