Measurement of the Diffuse Muon Neutrino Spectrum using IceCube Starting Track Events

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Introduction

Measured flux from Fermi, IceCube, and Auger suggest common source of high energy photons, neutrinos, and cosmic rays. IceCube measurements targeting different energies have shown tension in measurements between TeV and PeV neutrinos. This might be an indication that there is structure in the astrophysical diffuse neutrino spectrum. We use starting tracks to provide a unique measurement using a dataset that is inclusive of both lower energy and higher energy astrophysical neutrinos.

Starting Track Events

Starting Track events are muon neutrinos undergoing a charged-current interaction within the volume of the detector (figure 2). The exiting muon track is used to point backwards and form the “dark region”, this region is where neutrinos travelled and no Cherenkov light should be detected.

We then compute the probability of being a real starting track event (equation 1)

\[ p(\lambda, k = 0) = \prod_{i=1}^{N_{\text{IceCube}}} p(\lambda, k = 0) \]

Equation 1: Probability of observing no light in IceCube assuming a muon track initiated Cherenkov light is 0. Total probability for all IceCube modules in dark region.

Methodology

A binned likelihood approach is used assuming Poisson statistics for each bin (eq 2)

\[ L = \prod_{i=1}^{N_{\text{IceCube}}} \frac{e^{-\lambda} \lambda^{k_{i}}}{k_{i}!} \]

Equation 2: Likelihood function for the Poisson distribution for the observed number of counts. \( \lambda \) is the parameter of interest.

Results

IceCube diffuse flux measurements in figure 8 as solid lines

"Inelasticity" paper [10] is most like this work, it focused on starting track events

We compute for expected measurements displayed in figure 8 as dashed lines assuming various models

This event selection is competitive to and will improve our current understanding of the diffuse neutrino flux

Discussion and Outlook

Detector and ice systematics will soon be implemented into our likelihood in addition to atmospheric flux uncertainties. The role of prompt neutrino fluxes is expected to be non-negligible and will also be included

We expect to observe \( \sim 1000 \) starting track events per year and negligible atmospheric muons events

As-is, this event selection will be able to contribute substantially to our understanding of the diffuse neutrino flux

Expected Rates

HKKMS cosmic-ray flux model [5] used for atmospheric neutrinos

Self-veto effect [5] is applied as correction to HKKMS

Self-veto effect enables us to select for astrophysical muon neutrinos at TeV energies

References