IceCube Search for Earth-traversing ultra-high energy Neutrinos

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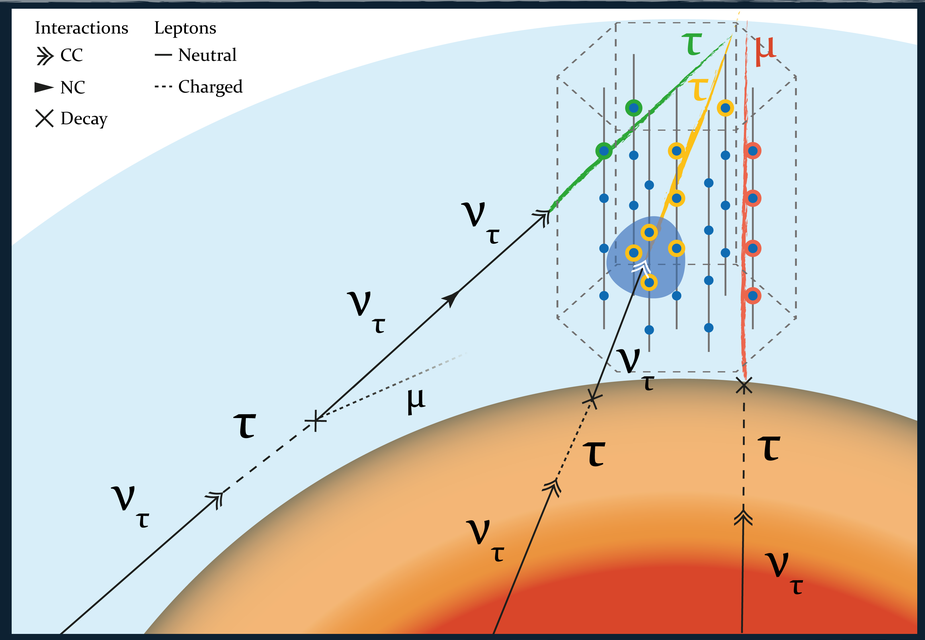
Motivation

- Tau lifetime is ~10^7 times smaller than the muon, tau decays rapidly [1].
- EeV tau neutrinos traversing the Earth reach IceCube at O(100) TeV - O(10) PeV energies [2].
- Taus make muons in 18% of decays. IceCube's through-going muon samples may contain EeV tau neutrinos.
- We present an analysis to search for tau neutrinos in Northern Sky track event selections.



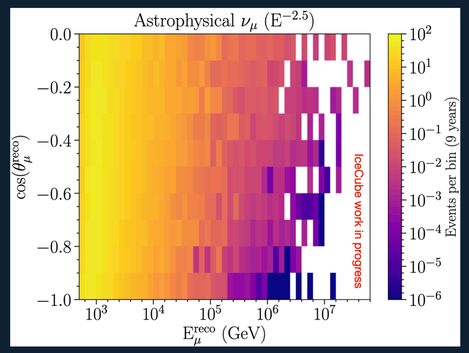
Event Signatures from Earth-traversing ~EeV ν_τ

Green: CC-interaction just outside the detector manifests as an upward-going τ track, possible at energies at or above 10 PeV.

Yellow: CC-interaction where the vertex is contained in the detector. A cascade is seen followed by an outgoing τ track.

Red: Muons created as a byproduct of tau decay 18% of the time. In that case, a muon track can be seen if the interaction happens a few km from the detector.

Analysis



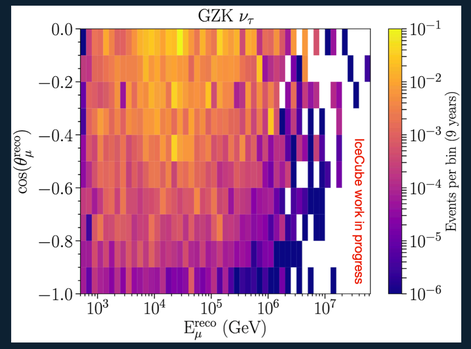


Fig. 1: Expected number of events shown in reconstructed quantities for both energy and zenith angle. Left: Muon neutrino events Assuming an equal-flavor astrophysical flux with a spectral index of 2.5 and a normalization of $10^{-18} GeV^{-1} cm^{-2} s^{-1} sr^{-1}$. Right: Muon events in the Northern Sky from GZK tau neutrinos assuming the best-fit flux given in [6].

- We use a northern track muon sample with more than 99.9% neutrino purity [3]
- Binned likelihood analysis with a modified Poisson likelihood [4]
- Muons from tau decay can be accounted for by reweighing muon simulations. The weight is given by,

$$w_\tau\left(E_{sh}, E_\mu\right) = \int dE_\tau \frac{d^2\sigma}{dE_{sh}dE_\tau}\left(E_{sh}, E_\tau; E_\nu = E_{sh} + E_\tau\right) \frac{dN_\mu}{dE_\mu}\left(E_\mu; E_\tau\right) \beta_{\tau\mu}$$

Differential neutrino cross section as a function of the hadronic shower energy E_{sh} and the lepton energy E_τ

Muon energy spectrum from tau decay

Tau to muon branching fraction

Northern Sky muons from UHE tau- neutrinos

At or above PeV energies, the UHE ν_τ contribution to northern sky muon samples becomes comparable to the astrophysical ν_μ flux (Fig. 2), but with a distinct energy and zenith distribution (Fig.1)

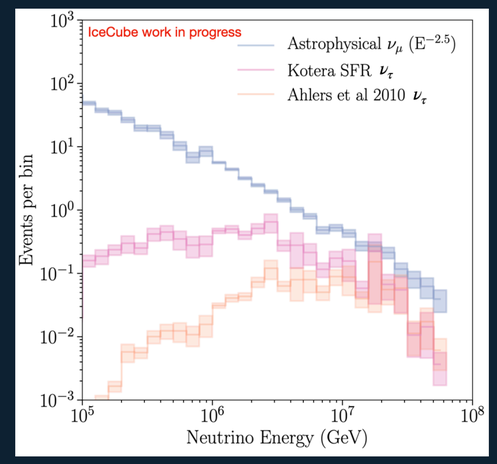


Fig. 2: Expected number of muon events in the northern sky. This assumes nine years of data and an unbroken power-law with a spectral index of 2.5 for the astrophysical muon-neutrino flux. The GZK contributions according to two models, Kotera SFR [5] and the best-fit Ahlers et al [6] have comparable rates above a few PeV in true neutrino energy. Error bars encompass statistical monte carlo uncertainties.

References

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