

Limits on the Diffuse Neutrino Flux from HiRes Data

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The High Resolution Fly's Eye detector (HiRes) has the largest data set for cosmic rays observed with the fluorescence technique. We will present a flux limit for the diffuse neutrino flux derived from the HiRes data.

1. Introduction

Neutrinos are able messengers of cosmic acceleration: Expected to be stable, they traverse large distances undeflected. Given the observation of ultra high energy cosmic rays interacting with hadronic cross sections in the earth's atmosphere, neutrinos are expected to bear witness to the acceleration as well as the propagation of these cosmic rays. Two other observations by the HiRes experiment are relevant here: The measurement of a largely protonic composition of cosmic rays at the highest energies [1], and the evidence for the expected GZK feature at the end of the observed spectrum [2].

In this paper we will concentrate on shock acceleration as the engine driving the observed cosmic rays. Hadronic acceleration is bound to be associated with pion production, and therefore accompanied by neutrinos from pion decay [3][4]. As cosmic ray spectra measured in the HiRes experiment strongly suggest the existence of the expected GZK feature, pions are also created in the GZK process when highest energy protons are excited to a Δ -resonance by photons from the cosmic microwave background radiation [5], [6].

Pion decay produces electron- and muon type neutrinos in a one to two ratio. Super-Kamiokande has shown that muon neutrinos oscillate into tau neutrinos with an oscillation length much shorter than astrophysical distances [7]. The flavor ratio of neutrinos from the sources discussed above should therefore be equal over all three flavors: one third ν_e , one third ν_μ , and one third ν_τ .

Neutrino interactions proceed through neutral (NC) or charged current (CC) interactions. In the more common CC interactions a hadronic shower initiated by transfer of energy to the hadronic target that the neutrino interacts on is accompanied by a lepton that carries the flavor of the neutrino. If this lepton is an electron, its energy is immediately absorbed in an electromagnetic shower that is superimposed with the hadronic one. The total energy of the neutrino will be visible in the particle shower. If the lepton is a muon, it will add a single particle track to the hadronic shower, which thus will be the only energy visible to cosmic ray experiments. The case of the tau lepton is similar to the muon, except that the tau lifetime very short and its decay modes are mostly hadronic. So the tau itself will likely initiate its own hadronic shower after leaving the region where its neutrino originally interacted. At high enough energies this behavior particular to the tau neutrino gives rise to hadronic showers emerging from the ground or surrounding mountains in which the original neutrino interacted. The hadronic shower initiated by the original neutrinos interaction directly is likely to be absorbed in the dense mountain or earth crust material that it interacted in. The slightly upward going events generated by tau decays in the atmosphere surrounding HiRes constitute the most likely neutrino signal to be detected in the HiRes detector.

2. Discussion

HiRes [8][9] is an air fluorescence experiment. As it monitors the surrounding atmosphere for the Nitrogen fluorescence light emitted from particle showers in the air, upward going or deeply penetrating horizontal events will not escape detection. To determine the sensitivity of the HiRes detector we use a modified ANIS [10] Monte Carlo code. For the cross-sections we follow the smooth power-law extrapolation of the pQCD CTEQ5 parameterization as provided in ANIS. A standard atmosphere was introduced into ANIS' description of the earth, which already includes a reasonable density profile throughout the earth. Topographic data for a square of 600 km side length around HiRes are used to further augment ANIS. This level of detail is relevant for tau neutrino events: Tau lepton decay topologies in the atmosphere above HiRes are significantly modified by the local mountain ranges. The approximation of continuous energy loss for the tau lepton is used as provided in ANIS.

For electron and muon neutrinos interacting in the atmosphere we use a simple spherical earth. Muon neutrino events will only be noticed by the energy they transfer to the nucleus they interact on. Fluorescence detectors cannot detect the trace of a single charged particle like the muon. The LPM effect for electron induced showers is taken into account in Corsika [11].

An upper limit on the diffuse neutrino flux at HiRes will be presented at the conference.

3. Acknowledgements

This work is supported by US NSF grants PHY-9321949, PHY-9322298, PHY-9904048, PHY-9974537, PHY-0098826, PHY-0140688, PHY-0245428, PHY-0305516, PHY-0307098, and by the DOE grant FG03-92ER40732. We gratefully acknowledge the contributions from the technical staffs of our home institutions. The cooperation of Colonels E. Fischer and G. Harter, the US Army, and the Dugway Proving Ground staff is greatly appreciated.

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