LIMITS ON ASTROPHYSICAL õ$_e$ FLUX at E„ > 1019

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ABSTRACT

We report on a search for upward EAS using the University of Utah Fly's Eye detector. No events have been found in $3.9X10^{6}$ sec of running time. The resultant õ flux limit varies from $3.9X10^{-6}$ õ/cm^2-sec-ster to $2.0X10^{-14}$ õ/cm^2-sec-ster for ó$_õ$ between 10^{-33}cm^2 and 10^{-32}cm^2. We also present flux limits for larger ó$_õ$ using near horizontal events originating in the atmosphere.

1. Introduction

We report on a search for neutrino induced EAS of astrophysical origin in the energy range 10^{19} - 10^{20}eV. Such events are searched for in conjunction with the normal operation of the University of Utah Fly's Eye detector. The signature distinguishing such events from hadronically induced EAS's is their deeply penetrating nature in the following, we search for such EAS, using the Earth and the atmosphere both as a hadron filter and a neutrino target.1

We have been stimulated in this search by the theoretically clean prediction of an astrophysically produced neutrino flux with energies ~10^{19} - 10^{20}eV. Such neutrinos are produced in the interaction of ~10^{20}eV primary cosmic rays with the 2.7°k black body radiation. In the rest frame of the proton, this energy corresponds to the onset of N*(1238) photo-production. Several authors have calculated the ring õ flux from π and ì decays,[2] most recently Schramm and Hill. The main inputs to these calculations are:

a) the universality and black-body spectral shape of the 2.7°k radiation
b) the universality and high-energy shape of the primary cosmic ray spectrum,
c) the 300 MeV/c photo-production cross-section
d) π and ì decay kinematics.

Since items c and d are well known, observation or non-observation of such a flux tests issues a and b. The most recent calculations lead to õ fluxes of order ~10^{-17} õ/cm^2-sec-ster. Under certain circumstances described below, the Fly's Eye can set limits on such a

2. Detector

The Fly's Eye detector has been described in detail elsewhere.[3] Briefly, the detector collects light from nitrogen fluorescence, produced by EAS in their passage through the atmosphere, in 880 phototubes spanning the hemisphere of the sky. Analysis of timing and pulse height information allows the determination of direction of arrival, total energy, shower development and position of shower maximum for EAS with energies greater than 10^{17}eV. For the energy domain under consideration, the effective volume of atmosphere over which EAS's can be detected is roughly a cylinder ~15km high by 20 km in radius. To fully reconstruct an EAS with good accuracy, a shower must have a track length, projected on the celestial sphere, of > 50° and an impact parameter > 1.5km. This requirement implies a reconstruction efficiency of ~60% over this volume for near-horizontal upward and ward events described below.

3. Search Philosophy

The Weinberg-Salam model of weak interactions predicts óõ at 10^{19}eV to be ~10^{-33}m^2. Corrections for Q.C.D. effects may make this cross-section somewhat larger.[4] In the following analysis, we quote flux limits for 10-33< a <10-32cm2. In this interval, the spherical shape of the Earth allows a significant v flux to pass through. As óõ 10^{-32}cm^2 only the nearly horizontal v flux has appreciable probability of reaching the surface. We search for õe events exclusively because our sensitivity is then increased many-fold because of the turn-on of the Landau-Pomeranchak-Migdal effect.[5] The source of the EAS for these events is the high energy > 1019eV electron produced in the interaction. The LPM boosted radiation length in earth is ~300m.[6] Events with interactions < 2 r.l. of earth find zenith angles >95° will be detected by the Fly's Eye with good efficiency. If óõ >10^{-32}cm^2 near horizontal downward (80°<ez<90°)events can be used to search for õ candidates. Such events, originating in the detection volume described above, must traverse >5000 gm/cm^2 of atmosphere. We again consider õe events only because the resulting electron shower

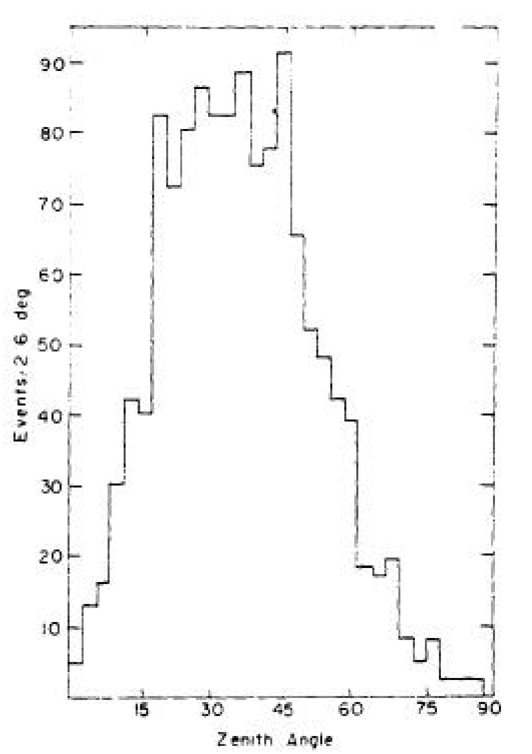

Figure 1. Zenith Angle Distribution.

takes most of the incident õe energy and gives the same detection area as for upward showers.

4. Results

Fig. 1., gives the distribution in zenith angles of. all EAS events with >50° track length and impact parameter > 1.5km for 3.9 X 10^6 sec of run time. Although we expect no hadronically induced events with zenith angles >80° finite angular resolution folded on a falling spectrum inevitably generates such events. We observe no events with θ_z >90°, however. Table 1 gives the resulting flux limits using upward events as a function of $ó_{õ}$ based on no events observed with θ_z>95°. Note that in this cross-section interval, the limit, before acceptance correction, is almost independent of cross-section. This is because, for a near horizontal v flux, decreases in the flux due to increasing interaction length in the Earth are compensated for by an increasing probability of the õ interacting in the 2 r.l below the Earth's surface. The decrease in sensitivity as $ó_{õ}$ 10 ^{32} is due to the fact that most events will then have θ <95°. We note that since both the LPM enhanced radiation length and the detection efficiency increases with increasing energies, these numbers are also upper limits for E v > 10^{20}eV.

Table 1

Limits based on upward events.

$\sigma_\nu$cm^2	$\langle\theta_z\rangle$	flux limit ν/cm^2-sec-ster
10^{-33}	106°	3.9×10^{-16}
3×10^{-33}	95°	7.5×10^{-16}
5×10^{-33}	93°	2.2×10^{-15}
1×10^{-32}	92°	2.0×10^{-14}

Table 2 gives limits using the atmosphere as a target. The six events with θ_z>80° are used to set this limit.

Table 2

Limits based on downward events.

$\sigma_\nu$cm^2	flux limit ν/cm^2-sec-steo
1×10^{-33}	3.5×10^{-13}
1×10^{-32}	3.5×10^{-14}
1×10^{-31}	3.5×10^{-15}
1×10^{-30}	3.5×10^{-16}
1×10^{-29}	3.5×10^{-17}

5. Conclusions

limits presented in this paper are ~ an order of magnitude greater than the most optimistic calculations. A detailed Monte Carlo of the LPM effect and the detector response to 10^{19}eV electron showers is under way, and should allow us to push the limits on and events by a factor of ~ 5. That and several more years of running will allow us to place much more stringent limits on the astrophysical calculations.

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7. Reference

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