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THE ULTRA HIGH ENERGY COSMIC RAY SPECTRUM

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Abstract

We will update the differential cosmic ray spectrum above 0.3 EeV obtained from the Fly's Eye detector data. Preliminary results support previously published data of no events with primary energy above 100 EeV.

Introduction Data from the Fly's Eye (Baltrusaitis, R.M. et al., 1985a) have been published on the Spectrum previously (Baltrusaitis, R.M., et al., 1985b ; Baltrusaitis et al., 1987). The previous analyses have found that the differential spectrum obeys well a power law in the region 0.1-10.0 EeV with spectral index of -2.94 ± 0.02. Above 10.0 EeV, the spectrum flattens yielding an index of -2.42 ± 0.27. Only one air shower was detected with an energy exceeding 50.0 EeV--the threshold energy for the Greisen-Zatsepin-Kuz'min mechanism (Hill, C.T., and Schramm, D.N., 1984).

Detector Operation The Fly's Eye Detector has been operating with full 2π steradian coverage since November, 1981. Since that date, there have been a series of changes to the detector in an attempt to increase the detector aperture. These changes include (1) the installation of UV-pass filters in November, 1985, (2) construction of a second detector 3.4 km from the first Fly's Eye with a partial sky coverage in September, 1986, (3) refurbishing of both detectors with anodized mirrors in July, 1987, (4) a set of changes to the triggering electronics of Fly's Eye I in December, 1987 and August, 1988. Except for the last change, the net result has been an increase of detector aperture in the Fly's Eye acceptance with most of the gain occuring at the lower energy end (0.1 - 1.0 EeV region). The changes to the detector triggering have increased the sensitivity to events with larger impact parameters and reduced the acceptance at smaller impact parameters (Rp < 1km).

Since the first report (Baltrusaitis, R.M., et al., 1985b), the total running time has increased by a factor of 4 with total running time now exceeding 5200 hours.

Energy Calibration The Fly's Eye energy calibration has been checked using a nitrogen laser. It has been fired at many impact parameters ranging from 1 to 19 km. Analysis of scattered light detected by the Fly's Eye has led us to conclude that the standard atmospheric model used in the analysis is adequate, and that the calibration is known within 15 %.

A systematic check of the Fly's Eye air shower energy determination (Baltrusaitis, et al., 1985c) to the ground array method of energy determination by the S(600) parameterization can be done. The Yakutsk group has determined calorimetrically the relationship between the number of muons in an EAS and the primary energy of the incident cosmic ray (Dyakonov, M.N. et al., 1987). We have checked the systematics using coincident data from the Fly's Eye and the Michigan Muon Array (Cassiday et al., 1989) by comparing the predicted muon number from the Yakutsk parametization with the number we observe. Our analysis shows that the two values are in good agreement. Furthermore, the surface electron size distributions determined from our data are also in good agreement with the Yakutsk size vs. energy parameterizations.

Cutoff and Spectrum No events have been observed with total energy exceeding 100 EeV. We therefore set a 95% confidence limit to the integral spectrum:

$$I(>100\ \mathrm{EeV}) < 1.8\times10^{-16}\ \mathrm{m}^{-2}\mathrm{sec}^{-1}\mathrm{sr}^{-1}$$

based on our running time and a very conservative detector aperture of 900 km^2sr. This value is the aperture at 80 EeV determined by monte carlo methods for the data obtained prior to November, 1985. (The actual value from the later running conditions exceeds 1000 km^2sr.) We choose 900 km^2sr, since it is a lower limit to the detector aperture at 100 EeV.

Our limit is consistent with observations made by the Yakutsk (Khristiansen, 1985) and Akeno (Teshima, et al., 1987) groups, but it is inconsistent with observations made by the Haverah Park (Brooke, et al., 1985), and Sydney (Winn, et al., 1986) groups. To determine the significance of this discrepency we calculate the number of particles we should have seen based on the Haverah Park integral flux value above 100 EeV:

$$I(>100\ \mathrm{EeV}) = 3\times10^{-16}\ \mathrm{m}^{-2}\mathrm{sec}^{-1}\mathrm{sr}^{-1}.$$

From their intensity, 5 events are expected in an aperture of 900 km^2sr for our live time of 5200 hours. From Poisson statistics, the chance probability of seeing no events when 5 are expected is $P=6.7\times10^{-3}$.

At the conference, we will present a spectrum comprised of data from November, 1981 to the present.

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