PROTON-AIR INELASTIC CROSS SECTION AT $S^{1/2}$ = 30 TeV

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ABSTRACT

We have measured the distribution of the maxima of high energy cosmic ray induced extensive air showers in the atmosphere as a function of atmospheric depth. From the exponential tail of this distribution, we determined the p-air inelastic cross section at 30 TeV center-of-mass energy to be 540 ± 40mb.

1. Introduction. The technique of extracting the p-air cross section from the data obtained by the "Fly's Eye" detector has been described in detail in an earlier paper.(1) We report the results of a recent analysis from data accumulated through the month of April 1985.

2. Discussion. The "Fly's Eye" detector consists of 67 F/1 mirrors, each with 12 or 14 photomultiplier tubes mounted at the focus.(2) These mirrors are arranged so that they cover all but a small portion of the solid angle near the horizon. The detector records the passage of distant extensive air showers by means of the light produced by the shower particles which, depending on the relative geometry between the track and the detector, is usually an admixture of Cerenkov and fluorescent light. The shower direction is reconstructed from the timing information obtained by the photomultiplier tubes. Knowing the reconstructed geometry and the fluorescence efficiency and taking into account the Cerenkov intensity, we calculate the number of particles of each shower as it progresses through the atmosphere. Figure 1 shows the number of particles in a shower as a function of atmospheric depth.

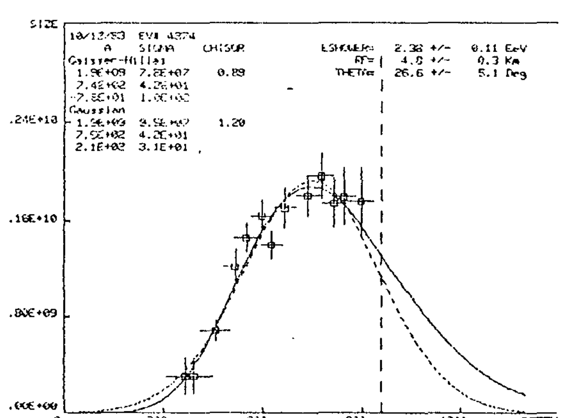

Figure 1. An Extensive Air Shower That Survives All Data Cuts. The solid curve is a GH. shower curve. The dotted curve is a Gaussian distribution.

The shower maximum is obtained by fitting a distribution to the shower profile. We ascertained that the shape of the shower profile can be fitted with either a Gaisser-Hillas (G-H)(3) distribution or a Gaussian distribution. Both distributions yield equally good fits, with the G-H fit consistently giving a slightly lower value (30 g cm^{-2}) to the depth of maxima. Such consistent difference does not affect the over-all shapes of the final data distributions obtained from the two fits.

The error in shower maximum, for showers whose closest distance of approach of exceed one and one half kilometers, arises almost entirely from the uncertainty in the reconstructed polar angle. Showers with zenith angle larger than sixty degrees are excluded in this analysis to avoid bias toward large depths of maxima due to the exponential behavior of the atmospheric density.

Possible track reconstruction bias has been examined by using light beams generated by a roving light pulser, and a fixed position nitrogen pulse laser. Tracks reconstructed from such light pulses show that, regardless of the angle of the light beams, we can measure the polar angle to the order of one degree with a sigma of about 1.7 degrees. Figure 2 shows the result of one of the runs obtained with the roving flasher. Further checks are made with events that are visible from a partially built second detector located about 3.5 kilometers from the "Fly's Eye". In this case, the polar angle is determined from the intersection of the two planes which contain the track. Again, the zenith angles obtained with the coincidence events are in agreement within experimental uncertainties with the angles calculated with the timing information from one eye alone. Figure 3 shows the agreement between the two methods of calculating the zenith angle.

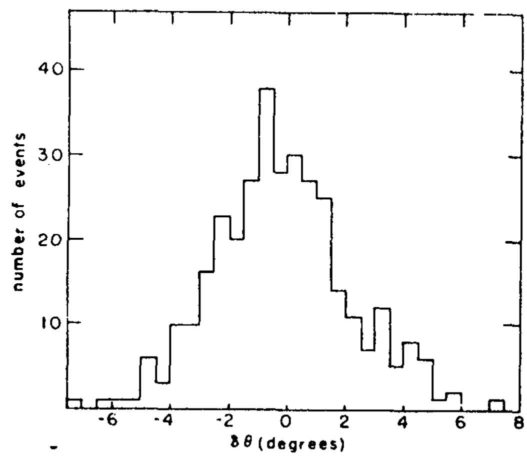

Figure 2. Distribution of differences between known and fitted zenith angles for "upward-going" showers of known geometry generated by a high intensity light flacher. The width of the distribution is $\sigma=1.7°$.

Bias toward large depths of maxima could result from distant showers of very high energy. Such bias is removed by accepting showers of a narrow band of energy between 10^{17} eV and 2×10^{18} eV. Finally, events with shower maximum uncertainty less than 100 g cm^{-2} are accepted for analysis with the average uncertainty of the order of 70 g cm^{-2}.

3. Results and Conclusions. The resulting distribution of the shower maxima as a function of the atmospheric depth is shown in Figure 4. The effect of the finite resolution of $\delta=70$ g cm^{-2} does not effect the shape of the exponent behavior of the tail of the distribution beyond a distance of δ^2/λ where λ is the slope of the tail of the distribution.

A fit of the data based on events beyond a depth of $\sim$ 760 g cm^{-2} is found to be $=70\pm6$ g cm^{-2}.

From a paper by Sokolsky et al(4) submitted to this conference, it seems likely that the primary particles consist of a considerable amount of light particles, i.e., protons. According to the paper by Ellsworth et al(5), those protons dominate the tail of the distribution. In this case, the proton-air inelastic cross-section is found to be 540±50 g cm^{-2}. This result is in agreement with the results published by Hara et al(6).

The extrapolation of proton-proton inelastic cross-section from p-air cross-section is model dependent. With the same assumptions made in our previous paper(1), the p-p inelastic cross-section is found to be 122±11 mb at $s^{1/2}$ of 30 TeV (Figure 5).

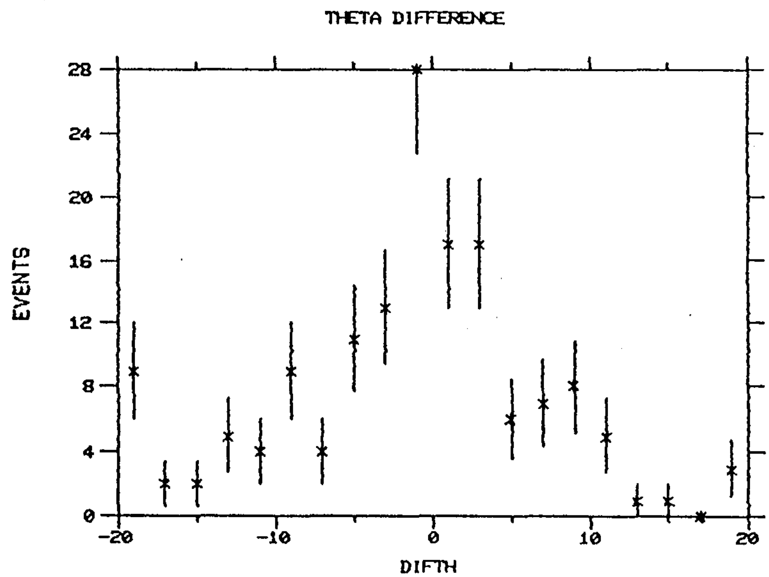

Figure 3. Difference in Zenith Angle for Events Observed by Both Detectors and With One Detector Alone. The average angular length for the track is about 40°.

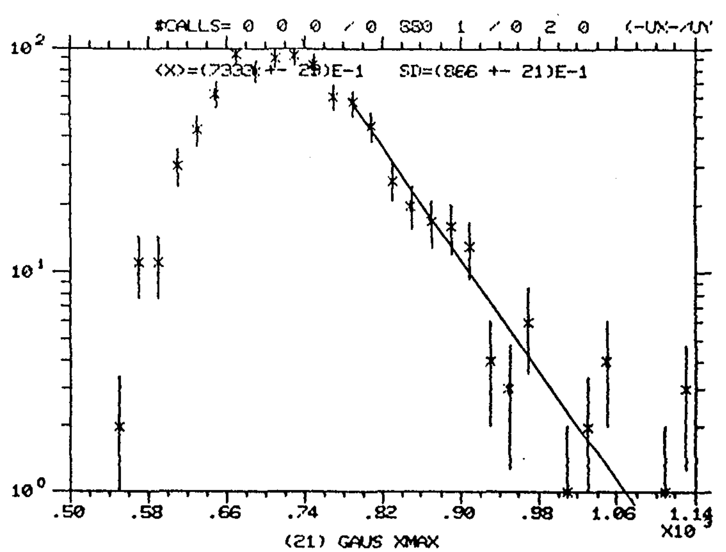

Figure 4. Distribution of Depth of Shower Maxima for Data Whose Fitting Errors Are Less Than δ,100 g cm^{-2}. The slope of the exponential tail is λ = 70 ± 6 g cm^{-2}.

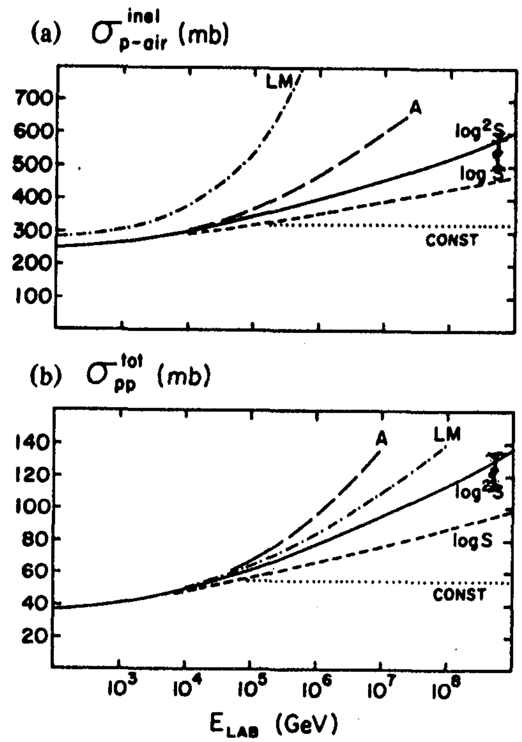

Figure 5.
(a) Pair Inelastic and (b) p-p Total Cross Section With Our Data.

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