MEASUREMENT OF THE IRON SPECTRUM FROM 60 TO 200 GeV PER NUCLEON

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1. Introduction. The high energy gas Cherenkov Spectrometer (HEGCS) was flown by balloon from Palestine, Texas on September 30, 1983. The instrument maintained an altitude of 118,000 ft. (4.7 g/cm^2) for 6 hours. Here we report details of the ongoing data analysis and preliminary results on the Fe spectrum up to 10^{13} eV/nucleus.

2. Charge Measurement. A description of the HEGCS instrument is given in the proceedings of the Paris ICRC (Streitmatter, et al., 1981)[1]. Incident charge is determined by measurement of the scintillation light which escapes from the 6 m^2 hodoscopes of scintillator triangles located in the top and bottom optical chambers. The escaped scintillation light is collected by 12 RCA 4525 PMT's externally located around the circumference of each chamber, giving two independent measurements of the charge.

Four corrections are made to these signals. (1) A cosine correction is made. Position of the incident cosmic ray as it passes through each of the two hodoscopes is determined from the relative size of signal from the three photomultipliers optically coupled to the struck scintillator triangle. The uncertainty in position is about ± 10 cm at present. (2) A correction for variations in scintillator thickness is made. As the cost of machining flat and polishing 12 m^2 of scintillator was prohibitive, the thickness of the hodoscope triangles was mapped. During assembly, an acoustic thickness gage was used to measure (± 0.001 inch) the thickness at 120 points on each of the 48 array triangles. Typically, thickness varies by ± 5 percent over a triangle. (3) The geometrically trapped scintillation light in a triangle has a small probability of escape at each internal surface reflection. The amount of such light escaping over the total triangle surface is a weak function of the position at which the cosmic ray is incident. A systematic correction of up to 12 percent is made for this effect. (4) The top and bottom diffusion chambers are not ideal white boxes. There are position dependent effects upon the relative amount of light collected by each of the twelve external photomultipliers. We are currently working on improvements in the correction of these effects. For charges above 16, the present σ/μ (resolution/mean) of the corrected PMT signals from each chamber is 0.069, corresponding to a charge resolution of 0.8 for Fe. The resolution is dominated by nonphotostatistical systematics.

3. Cherenkov Signal. Cherenkov light from the central gas volume was collected by 24 RCA 4522 photomultipliers located at the upper circumference of the drum. The signal from each PMT was separately digitized. The Freon-12 was kept at a pressure of 2.47 psi, corresponding to a Cherenkov threshold energy of 49 GeV/nucleon. In addition to the above-threshold gas Cherenkov light, incident nuclei at

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all energies above the Palestine cutoff made Cherenkov light in the $BaSO_4$ white paint covering the inner surfaces of the upper and lower pressure bulkheads. The Cherenkov light generated in the two painted surfaces is about 14 percent of the saturated gas signal, displays a cosine effect, and is statistically broadened in a manner indicating that over the painted surfaces there is 20 percent variation in effective emitting thickness of the $BaSO_4$. Figure 1, taken from flight data, is a histogram of the "paint-light" signals to one 4522 PMT from incident iron. The first and second photoelectron peaks are clearly visible. Thus, the Cherenkov signals can be directly expressed in terms of the number of photoelectrons collected. For an iron nucleus passing vertically through the detector, the paint-generated Cherenkov light results in an average of 51 photoelectrons, total, being collected. The saturated ($\beta = 1$) gas signal from a vertical iron is best fit (see below) as 370 total collected photoelectrons.

Because the 4522 PMT's are separately digitized, it is possible to note individual PMT's struck by delta-rays. Typically, one PMT saturates, while the average signal to the other PMT's is increased by less than one photoelectron. The probability of events with a delta-ray tube hit is a strong function of position, being greatest at the periphery of the detector (radius 150 cm) near the PMT's. At the largest radii, multiple delta-ray events can be seen. Although these events can be recovered, we are presently making a conservative geometric cut, restricting accepted events to be within 115 cm of the center of the top hodoscope.

4. High Energy Data. In addition to the geometric cut, we require that the top and bottom charge determination agree within two standard deviations, and that the hodoscope signals be consistent with the passage of a single particle through the detector. These restrictions effectively eliminate fragmentations and nascent air showers. Figure 2 is a cross plot of Cherenkov signal versus charge. For plotting, a cut has been made surpressing events with only "paint-light". The upward fluctuating "paint-light" events appear as a band across the bottom of the plot. For the purpose of analysis, iron is defined as those events with determined charge between 24.7 and 27.7, corresponding to standard deviations in signal of two and three, respectively. The larger acceptance on the high side was made because of the tendency, seen in Figure 2, of high Cherenkov events to deviate toward higher determined charge. We attribute this trend to relativistic rise, but have deferred a quantitative investigation pending improvement in the charge resolution.

The maximum likelihood technique has been used to determine the iron spectral index. The total Cherenkov signal in photoelectrons has been modeled, including the statistical fluctuations from the paint-generated and gas-generated photons. The number of photoelectrons corresponding to the gas $\beta = 1$ point is a free parameter of the model. The assumed spectra used as input to the model have been normalized to the HEAO-3 (Lund, 1984)[2] iron data. That is, the modeled spectra are assumed to attach to the HEAO iron flux at 25 GeV/nucleon and to be a single-index power law above this energy. The index of the power law is the second free parameter of the model. Making a low energy cut of

60 GeV/nucleon and calculating likelihoods from the data in Figure 2, we find that the best fit spectral index is 2.77 ± 0.12. The best fit value for the total number of photoelectrons from gas-generated photons from a vertical, $\beta = 1$ iron is 370. This indicates that the Cherenkov signal retains statistical power in energy discrimination up to about 215 GeV/nucleon.

Future improvement of the charge resolution and inclusion of the full geometric factor should allow improvement of the error in determination of the iron spectral index and sufficient statistics to determine the index of the iron secondaries.

References

1. Streitmatter, R. E., Balasubrahmanyan, V. K., and Ormes, J. F., 1981, 17th ICRC 8, 54.
2. Lund, N., 1984, Adv. Space Res., 4, 5.

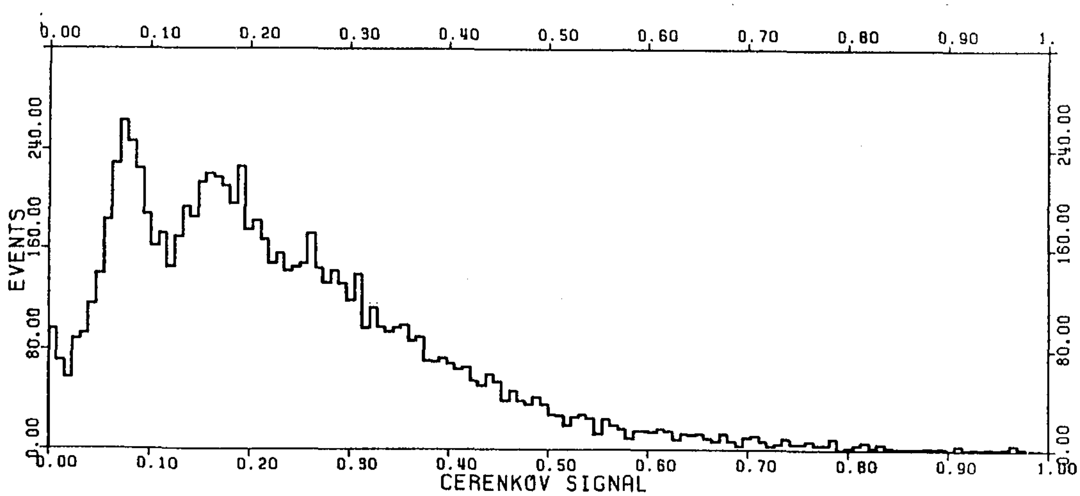

Figure 1

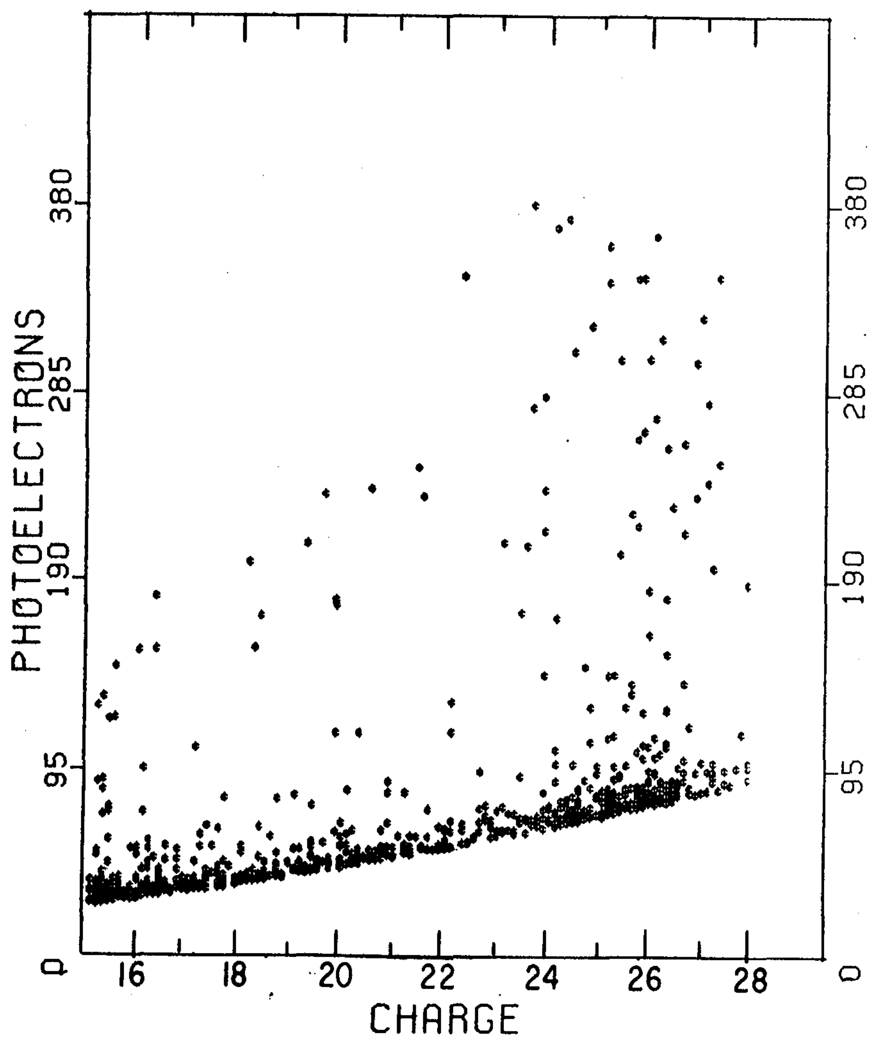

Figure 2