PRIMARY COSMIC RAY SPECTRA IN THE RANGE 20-60 GeV/n

The JACEE Collaboration+

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ABSTRACT

Energy spectra for primary cosmic rays C-Fe above 20 GeV/n were measured on a balloon flight from Greenville S.C. in June 1982 with a hybrid electronic counter-emulsion chamber experiment. Fluxes above the atmosphere appear in general agreement with previously published values. The heavy events included in this data will be used along with the JACEE passive chamber data to provide a heavy composition direct measurement from 10^{12} to 10^{15} eV total energy.

INTRODUCTION

The JACEE collaboration has been using emulsion chambers since 1979 in a series of balloon flights to measure the composition, energy spectra, and interactions of energetic (>1 TeV/n) cosmic rays. The apparatus used in JACEE's 0,1,2,4,5 have been largely passive, events being detected by the development of dense electromagnetic showers which produced visible dark spots in x-ray films. In 1982 a different kind of experiment was flown by the collaboration. This incorporated electronic detectors mounted above an emulsion chamber. The counters were used to define the charge and energy of incident primaries and provide trajectory information so the primaries could be traced through the emulsion chamber from the top down. For heavy ions this has proven to be an efficient process, and the results of measurements on ~130 heavy interactions ($Z \geq 22$) at primary energies >20GeV/n are described at this conference.

The primary objective of this experiment was to obtain a statistically significant sample of heavy ion interactions in the energy range 20-60 GeV/n, below the energy range of detection for totally passive chambers. Other objectives were to allow direct calibration of some techniques used in JACEE, albeit in a lower energy range than the other experiments. The electronic counters also allowed the direct measurement of heavy primary cosmic ray fluxes in the range 20-100 GeV/n (1-5 TeV total energy for Fe) for comparison with the other JACEE direct composition measurements above 10^{13} eV total energy, (see paper OG4.1-13 this conference). In this paper we describe the measurement of the abundances and spectra of elements from C to Fe above 20 GeV/n.

Experimental

The apparatus was previously described (Ref.1) and is only briefly reviewed here. It consisted of two solid Cerenkov counters (Teflon and lead-glass) which were in saturation at the energies reported here and provided primary charge definition; a gas Cerenkov counter (1 atmosphere Freon-12, 81 cm most probable depth) which provided differential energy measurement in the range Eo = 20 - 65 GeV/n; and an eight-plane multiwire proportional counter hodoscope which enabled particle trajectory intersection points in the top layers of the emulsion chamber to be found with rms position error 3.5 mm. A scintillation counter was placed below the emulsion chamber to provide a measure of shower-size from individual energetic interactions within the chamber. (paper HEI.4-1 this conference)

A cross-plot of the outputs of the Teflon (CT) and lead-glass (ClG) Cerenkov counters allowed separation of individual charge identification. The ratio CT/CLG at Eo>20GeV/n gives a narrow distribution for all particles passing through both counters without interacting. This effect was used, together with the hodoscope track information to reject most events interacting in the electronic instrument. All detector signals were corrected for path-length in the detector, PM tube temperature, detector non uniformities, and ADC offsets. Charge resolution was limited by back-scatter from the emulsion chamber, an effect which was assessed by correlation of CT and CLG signals with the burst scintillator. Charge resolution was = 0.25 charge units FWHM at oxygen and 0.5 at Fe. Figure 1 shows a charge histogram of a portion of the data. For the gas Cerenkov detector, in which the PM tube outputs were analyzed in four sets of tubes, assessment and correction for δ-ray effects in tube windows was possible. Energy assignment for individual events was made using a Monte Carlo method which incorporated the instrument response function and an assumed cosmic ray spectrum. The response function was based on normal statistics of photoelectrons from Cerenkov light plus a scintillation and $BaSO_4$ paint Cerenkov contribution. The flight oxygen gas-Cerekov data is shown in Figure 3. It should be noted that energy assignments based on this method are insensitive to changes in γ of 0.3 or so.

The balloon and instrument were launched on June 2nd from Greenville, S.C. and cut down near Roswell, N.M., after 39 hours at a mean float depth of 4.9 g cm^{-2}. Effective live time was 35.6 hrs. yielding an exposure of 5.7 m^2 sr hrs of the best quality data. The geometric aperture 0.16 m^2 sr in this case included all the electronic detectors except the burst-counter.

RESULTS

The derived differential energy spectra for the principal elements and groups are shown in Figures 3 to 6, using data at the instrument. Note that the amplitudes given in these figures are per 5 GeV bin and for the whole flight. Calculation of the differential and integral intensities at the top of the atmosphere using average values of atmosphere and instrument fragmentation show essential agreement with the HEAO C-2 data. Maximum likelihood fits have been made to the raw spectra above 25 GeV/n and derived values of γ are given in the table ($dN/dE = AE^{-\gamma}$). Although primary/secondary element ratios await the full interaction correction, an estimate of the Fe/C+O ratio above 25 GeV/n is 5.4×10^{-2}, if the ratio of the interaction corrections for Fe and (C+O) is taken as 1.12. This primary ratio has been reported as 6×10^{-2}(Refs. 2,3).

References:

1. Austin, R.W., et.al., Papers of 18th ICRC T2-15, (1983)
2. French-Danish HEAO-3 Collaboration, Papers of 18th ICRC Vol 2, p 17 et. seq. (1983)
3. Simon, M. et.al., ApJ, 239, 712-724 (1980)

TABLE 1

MAXIMUM LIKELIHOOD FITS TO ELEMENTAL SPECTRA ABOVE 25 GeV/n
ASSUMING SIMPLE POWER LAW, $dN/dE = AE^{-\gamma}$

	A	γ
	Particles $(m^2 sr\ s\ GeV/n)^{-1}$	
Oxygen	21.7	2.77 + 0.07 (-0.04)
Neon	4.2	2.72 + 0.13 (-0.12)
Magnesium	1.5	2.44 + 0.12 (-0.10)
Silicon	5.8	2.85 + 0.15 (-0.10)
16 z 25	1.4	2.89 + 0.18 (-0.10)
Iron	0.51	2.79 + 0.25 (-0.19)
Sum of Z=8,10,12,14	5.8	2.72 + 0.05 (-0.06)

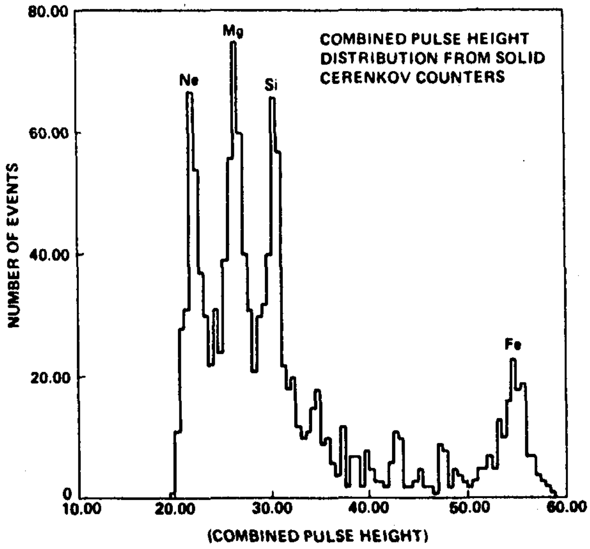


Fig. 1. Charge Histogram of Flight Data; $E_0 \geq 20$ GeV/n

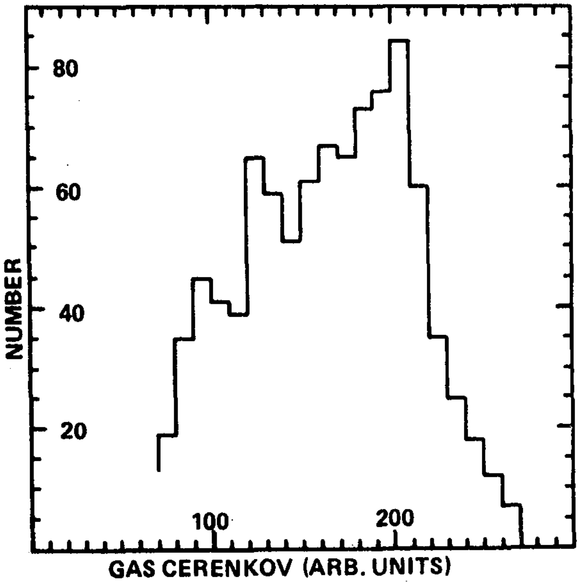
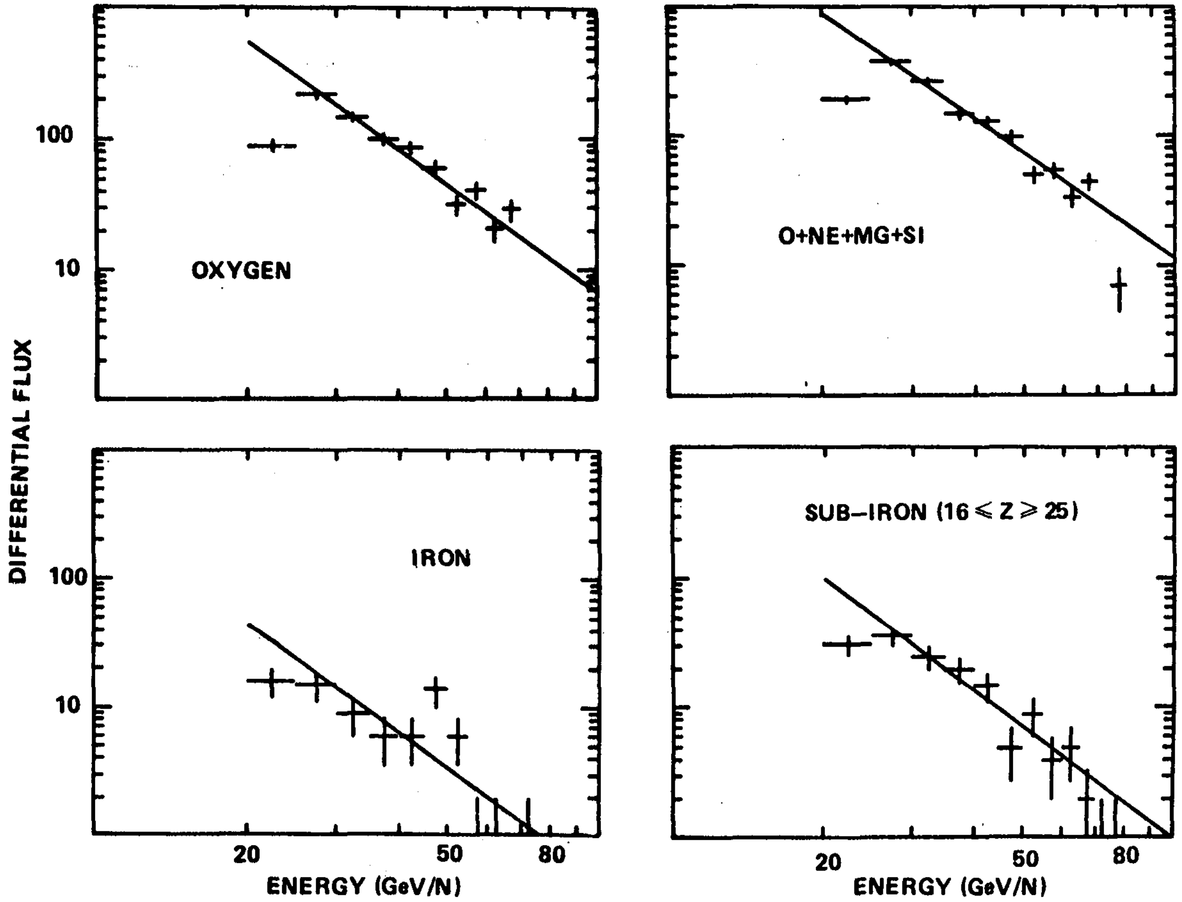


Fig. 2. Histogram of Oxygen Data in the Gas Cerenkov



Figures 3-6. Differential Spectra of Individual Elements and Groups of Elements Measured at the Instrument. Note that Amplitudes are per 5 GeV bin and per Entire Flight, and Interaction Corrections have not yet been applied. Straight Lines are M-L fits to the Data.