Observation of Cosmic Ray Positrons From 5 to 25 GeV

R. L. Golden, B.G.Mauger, and S. Horan
Department of Electrical and Computer Engineering
New Mexico State University
Las Cruces, NM 88003
USA

G. D. Badhwar, J. L. Lacy, J. E. Zipse
NASA, Johnson Space Center
Houston, TX 77058
USA

R. R. Daniel, S. A. Stephens
Tata Institute For Fundamental Research
Homi Bhabha Road
Bombay, India

1. Introduction. We report here the positron data gathered in conjunction with electron data published elsewhere (1). The basic recognition scheme was to look for low-mass positive particles that cause a cascade in a 7 radiation length shower counter. The mass criteria is imposed by selecting particles that were accompanied by Cherenkov light but whose rigidity was below the proton Cherenkov threshold. Thus the proton Cherenkov threshold represents an upper limit to the range of the experiment.

2. The Apparatus. The principal detector elements are (from top to bottom): a gas Cherenkov detector (G); plastic scintillators S1 and S2; 8 multiwire proportional counters (M1-M8); and a lead-scintillator shower counter comprised of 7 layers. Each layer of the shower counter consisted of 1 scintillator and 1 radiation length of lead (P1-P7). The multiwire proportional counters (MWPC) were arranged in three pairs located at the top, middle and bottom of the spectrometer with the remaining two chambers located at the 1/4 and 3/4 points in the spectrometer stack. All phototubes were pulse-height analyzed, 8 measurements were made of the particle position on the x axis (axis of deflection), and 5 measurements were made on the y axis. Data readout was initiated for every occurence of an S1*P1*P7 coincidence. The geometric factor of the instrument was 324±5 cm^2-str and the live time fraction was 0.80. The data were gathered on a balloon flight from Palestine Texas on May 20,1976. The data gathering period was 6.4 x 10^4 seconds at an average altitude corresponding to 5.8 gm*cm^-2.

3. Data Analysis. Selection of the positrons started with using the same criteria used for the e-:

1) MWPC data. There must be at least 5 valid MWPC readouts for the X coordinate, and 3 valid readouts for the Y axis. The

reconstructed trajectory must fit to a valid, continuous track with a chi-squared of less than 50 in the x axis and 30 in the Y axis. And finally, one MWPC from each of the pairs have valid readouts.

2) Charge. The average of the pulse-heights for scintillators S1 and S2 correspond to less than 1.8 I_0 where I_0 is the pulse-height for a Z=1, β=1 vertically incident particle.

3) Cherenkov Detector. The Cherenkov detector be above a discriminator level corresponding to 0.25 photo-electrons.

4) Shower Counter. The sum of the shower-counter pulse-heights correspond to at least 50 I_0

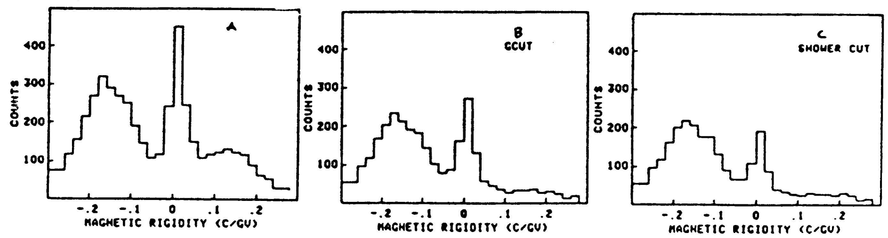
Criteria 1 differs slightly from that used in (1). The old MWPC criteria required that the bottom MWPC pair both have valid readouts. This was replaced with the criterion that each pair must have a valid readout. It was found that the revised criterion has a 13% higher efficiency without any degredation of resolution.

The criteria 1-4 yield a sample which is roughly 80% protons and 20% positrons. The main source of background is the high noise level in the Cherenkov detector. In order to reduce the background we require a minimum Cherenkov pulse-height corresponding to about 1 photoelectron. The Cherenkov mirror was divided into 4-quadrants, each viewed by a separate phototube. Phototubes from opposite quadrants were summed before digitization. Trajectory analysis was used to determine which quadrant pair should have registered the light. It was demanded that the correct pair have at least the minimum pulse-height, and the other pair have less than the minimum pulse height. This selection is called criterion 5. Application of these criteria to the e- sample revealed that 93% passed the test, and an estimated 75% of the remaining protons were rejected.

The next criterion was to examine the shower counter output. Each set of P1-P7 outputs was fitted to the hypothesis that there was an electromagnetic cascade. The starting point and energy of the shower were used as unconstrained variables in the fit. Criterion 6 was that the shower fit have a chi-square of less than 10. Once again it was observed that 93% of the e- pass this test, and in this case about 30% of the remaining protons were rejected.

Figure 1a shows the deflection (1/rigidity) spectrum of the events selected by criteria 1-4. We have include both positive and negative deflections (corresponding to positive and negative charged particles). The peak near zero deflection is due to protons above Cherenkov threshold. The gradual rise with increasing positive deflection is due to the combination of positrons and protons accompanied by an accidental G pulse. The decline above 0.2 c/GV is due to the geomagnetic cutoff. The events to the left of zero deflection are the e-. Note that the corresponding geomagnetic cutoff is smeared due to bremsstrahlung losses. Figures 1b and 1c show the progressive effects of criteria 5 and 6. The peak due to protons above Cherenkov threshold is broadened by the finite resolution of the rigidity resolution. We have chosen the upper limit for the experiment to be 0.04 c/GV which is 1.5 standard deviations below the proton Cherenkov threshold. With this restriction it is possible to generate a sample of protons by applying the e+ selection criteria except demanding that no G pulse occur. Given this sample of protons, and the e- it is possible to perform quantitative evaluations of the remaining background in the e+ sample.

Figure 1
Effects of Positron Selection Criteria



The starting point distributions for protons, e- and our candidate sample of e+ will be shown at the conference. The e- distributions are peaked sharply at about +1 radiation length. This is as expected for electrons (and positrons) except that the peak is slightly offset due to an arbitrary factor in the shower fitting program. The proton distributions reflect a basically flat interaction probability biased by the criteria that there be at least a 50 I_0 shower sum. The e+ candidates show that the sample is comprised of mostly electron-like events with a small admixture of protons except at high energies, where the proton component dominates.

A background subtraction was made on the assumption that all e+ would have starting points between $+3.5X_0$ and $-2.5X_0$. If one counts events outside this region in the proton distributions, one can form a background multiplication factor M = (total protons)/(protons outside the electron starting point limits). Each rigidity interval is then analyzed and the number of e+ is determined by the formula #e+ = (#candidates inside limits)-M*(#candidates outside limits). Table 1 gives some of the details of the background subtraction process for e+. Table 1 also gives the number of e- determined by applying criteria 1-6 and performing a similar background subtraction.

Table 1. Background subtractions

deflection c/GV	e+ crit 1-6	Proton bkgrnd	Atmos bkgrnd	e+ w/o bkgrnd	e- w/o bkgrnd
0.04-0.08	74 ± 15	69.6 ± 19.5	2.8	1.6 ± 16.5	132 ± 15
0.08-0.12	51 10	41.5 13.8	4.7	4.8 12.0	304 18
0.12-0.16	60 6	22.3 9.4	7.1	30.6 10.2	377 18
0.16-0.20	55 5	19.2 8.8	8.1	27.7 9.9	412 21
0.20-0.24	54 1	3.8 3.8	10.8	39.4 8.5	268 17
0.24-0.28	28 0	0.0 4.3	13.3	14.7 7.3	137 13

4. Results. Reference 1 contains the details of the exposure factors (solid angle x area x time x efficiency) for e- during the flight. The exposure factors for the e+

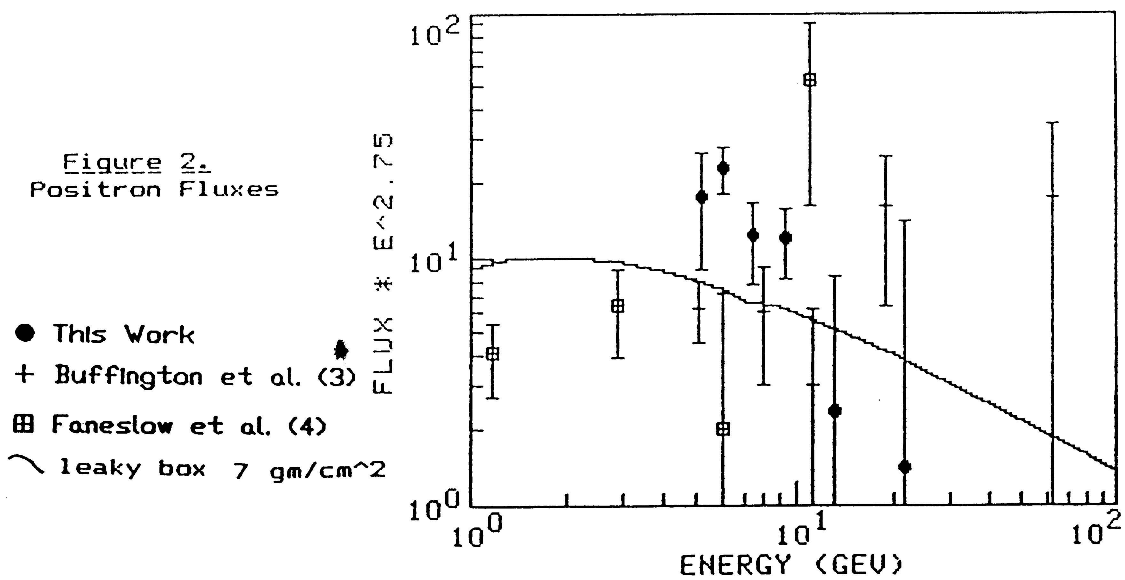
observation are obtained by using the e- data in the rightmost column in Table 1. The ratio of e- in Table 1 to the number in (1) gives a correction to the exposure factor reported in (1). Table 2 gives the computed exposure factors and fluxes. Reference 1 gives a detailed discussion of the corrections for geomagnetic cutoff, solar modulation and bremsstrahlung energy losses. In (1) a mean ISM energy ($\bar{E}$), an equivalent bin width (Δ E) and a propagation efficiency (p) are computed for each deflection interval in Table 1. These factors are also given in table 2.

Table 2 Positron Flux Calculations

$\bar{E}$ (GeV)	e+ counts	$e+/(e^+ + e^-)$	exposure cm^2 -str-sec	p	ΔE (GeV)	flux e+/(m^2-str-sec-GeV)
21.7	1.6 ± 16.5	0.01 ± 0.12	408 ± 23	1.05	14.5	(0.3±2.7)E-3
13.1	4.8 ± 12.0	0.02 ± 0.04	463 ± 12	1.02	5.13	(0.2±0.5)E-2
9.39	30.6 ± 10.2	0.08 ± 0.02	480 ± 13	0.99	2.61	0.025 ± 0.008
7.37	27.7 ± 9.9	0.06 ± 0.02	501 ± 13	0.71	1.57	0.050 ± 0.018
6.08	39.4 ± 8.5	0.13 ± 0.03	557 ± 13	0.43	1.02	0.161 ± 0.035
5.19	14.7 ± 7.3	0.10 ± 0.05	588 ± 13	0.18	0.75	0.190 ± 0.094

Figure 2 shows the fluxes as determined in Table 2, along with the results of other observers, and the fluxes predicted for a simple leaky box (with energy dependendt leakage) and 7 gm/cm^2 of matter traversed. A least squares fit to the fluxes in table 2 gives a spectral index of -4.2±0.6 and an integral flux (above 5.2 Gev) of (0.51±0.09) e+/m^2-str-sec-GeV. The chi-square for the fit was 2.1.

Figure 2.
Positron Fluxes



References

(1) Golden, R. L. et al. (1984), Ap. J. 287, 622.
(2) Stephens, S. A. (1981), Proc 17th ICRC (Paris) 4, 282.
(3) Buffington, A. et al. (1975), Ap. J. 199, 669.
(4) Faneslow, J. L. (1969), Ap. J. 158, 771.