Absolute Rigidity Spectrum of Protons and Helium Nuclei Above 10 GV/c

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Abstract

Proton and helium nuclei differential spectra were gathered with a balloon borne magnet spectrometer. The data were fitted to the assumption that the differential flux can be represented by a power law in rigidity. In the rigidity range 10-25 GV/c the spectral indices were found to be $-(2.74 \pm 0.04)$ for protons and $-(2.71 \pm 0.05)$ for helium nuclei.

1. Introduction. The absolute rigiditiy spectra of protons and Helium nuclei have become particularly important due to the recent measurements of secondaries of these particles. The recent publication of the absolute e- spectrum necessitated a very careful analysis of the detection efficiencies and sensitivities of the New Mexico State University magnetic spectrometer. The maximum detectable momentum for the 1976 flight (reported here) was 80 GV/c. During the analysis, it was found that magnet spectrometer measurements in general are subject to systematic errors that affect the spectral index but not the absolute flux at low energies. In this paper we present a brief discussion of the systematic errors, and spectral indices for protons and helium nuclei in the rigidity range 10-25 GV/c. Absolute fluxes will be presented at the conference.

2. Data Analysis. The apparatus is described in detail in references (1) and (2). It was comprised of (top to bottom): a gas Cherenkov counter (G) with a proton Cherenkov threshold of 40 GV/c (rigidity); two plastic scintillators (S1 and S2); 8 multiwire proportional counters (MWPC); and a lead-scintillator shower counter consisting of 7 layers each containing 1 radiation length of lead (P1-P7). The MWPC provide 8 readouts on the x axis (axis of bending) and 4 readouts on the (orthogonal) y axis. All phototubes were pulse-height analyzed. Data readout was initiated for all occurences of an S1*P1*P7 and/or an S1*P1*P7*G 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 lasted 6.4 x 10^4 seconds at an average altitude of 5.8 gm*cm^-2. Data for the spectral analysis were selected from the flight tapes by requiring the following:

(1) The charge of the particle (as determined from S1 and S2) correspond to 0.0-1.8 charge units for protons or 1.8-2.7 charge units for helium.

(2) All MWPC readouts be valid and that the measured trajectory fit to a continuous track with a chi-square of 30 in the x axis, and 8 in the y axis.

Failure of particles to pass the above criteria was dominated by criterion 2. Each MWPC is only about 90% efficient. The measured efficiency for passing criterion 2 was 33% for protons and 24% for helium nuclei.

3. Results. Figures 1a and 1b show the proton and helium data gathered during the flight. The plots show number of events vs magnetic deflection (1/magnetic rigidity), measured in c/GV. The central part (deflection = 0) of each plot represents the highest rigidities. Moving toward the right corresponds to lower rigidities. The decline in number of particles to the right of 0.12 c/GV is due to the combined effects of solar modulation and the geomagnetic cutoff.

The data in Figure 1 have been analyzed by fitting them to the assumption that the differential flux is a power law in rigidity. Other factors which enter the fit are: the resolution function of the instrument, solar modulation, and the exact location of the zero-deflection point. The zero-deflection point in Figure 1 was determined by operating the instrument with the magnet off just prior to the flight. The center of the deflection distribution gathered with the magnet off is taken as the zero-deflection point, and the distribution of deflections is taken as the resolution function for the instrument. Figure 2 shows the resolution function.

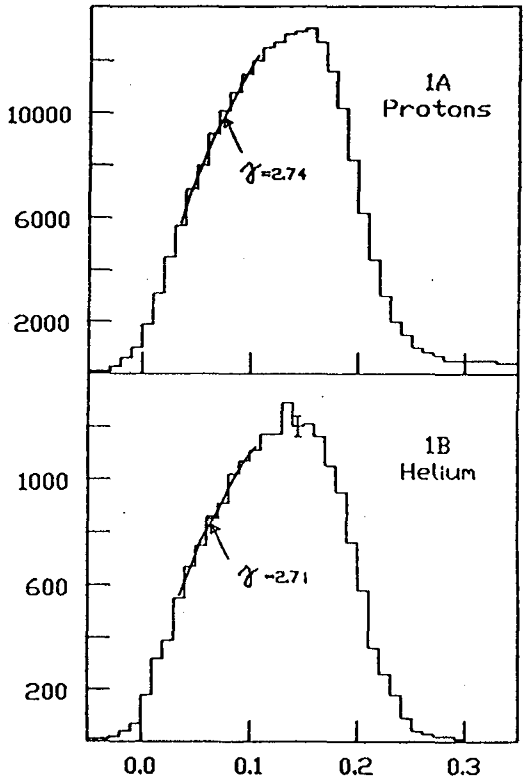

Figure 1. Deflection spectra

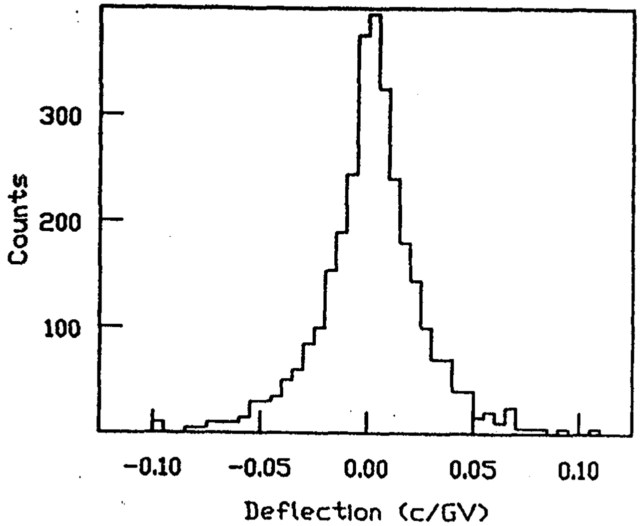

Figure 2
Resolution
Function

One of the most serious sources of possible systematic error for spectral indices is a change in the zero-deflection point between the calibration and the flight. It was hoped to turn the magnet off at the end of the flight for another calibration, but the instrument operation ended abruptly due to battery failure and the calibration was not performed. A cross-check was made however, by using the G-on protons and helium gathered during the flight. These two samples were fit assuming the proton Cherenkov threshold of 40 GV/c (helium threshold of 80 GV/c). Since the Cherenkov thresholds are near the upper limit of the instrument to resolve the deflection, the dominant factor in the fits was the offset of the zero-deflection point. The offset was determined to be $-(0.002\pm0.002)$ c/GV. In order to minimize the effects of the offset error, solar modulation and possible changes in the resolution function, we limit our analyses to the deflection range 0.1-0.04 c/GV (10-25 GV/c rigidity). Further, we have used a solar modulation of 600 MeV, which was determined using the data below 10 GV/c. Under these circumstances we find $\gamma = -(2.74\pm0.04)$ for protons and $-(2.71\pm0.05)$ for helium nuclei. The uncertainty in the proton spectral index is dominated by the offset uncertainty, and statistics dominates the uncertainty for helium nuclei.

References

(1) Golden, R. L. et al. (1978), Nuc. Instr. and Meth. 148, 179.

(2) Golden, R. L. et al. (1984), Ap. J. 287, 622.