Measurement of the Primary Cosmic Ray Nuclear Rigidity Spectra for Individual Elements of Charge Z≥2

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A superconducting magnetic spectrometer was flown to about 5 gm/cm^2 residual atmosphere on September 18, 1970 and May 7, 1971 by a balloon. 12,500 events with charge 3 and greater were rigidity analyzed on the two balloon flights. The trigger criteria were changed for a short while on each flight so that 12,000 helium nuclei could be momentum analyzed.

The spectrometer, shown in Figure 1, consists of a single superconducting coil and four four-gap optical spark chamber planes. A trigger was provided for the spark chambers by a three-fold coincidence of scintillators S_1, S_2, S_3. A pair of anticoincidence discs were used on either side of the coil to prevent triggering on events which have interacted in the magnet. However, highly-charged, high-momentum cosmic rays might have such numerous delta-rays that the anticoincidence system could be a source of bias in the data-taking. Many of these delta rays from valid events were reflected from the anticoincidence detector by the strongly divergent magnetic field. As a check on this, however, the anticoincidence detectors were eliminated from the trigger criteria during a portion of the flights.

Later examination of these data showed that the relative abundances were the same in the two sets of data. The majority of the data on the second flight was in fact taken without the antidetectors in the trigger criteria, but with a light lit when a pulse was detected in either of them.

The specific charge of each event was determined by three detectors shown in Figure 1. Upon a valid trigger signal, the anode and one dynode of the photomultipliers were pulse height analyzed and the digital pulse heights displayed on a light panel. The light panel and sparks of the chambers were photographed by either of two 35 mm cameras.

After the equipment was flown and recovered, the film was developed and measured on an automatic encoding machine. Computer programs filtered the measurements to eliminate background events, extract the pulse-height information, and determine the rigidity and goodness of fit for each event. Table I indicates the major corrections applied in the data analysis:

Table I

Types of Corrections or Calibrations

Applied in the Data Analysis

Charge ($\Delta Z = \pm .15$ unit charge at Carbon)

Source of Fluctuation	Correction
a) Electronic "pedestal" variation. (zero level fluctuation)	Use known constant gain of anode/dynode to calculate proper zero level for each event.
b) Landau broadening, and electronic fluctuations.	Reduce its effect by averaging the pulse heights of three detectors.

Charge - cont'd.

Source of Fluctuation	Correction
c) Angular and spatial non-uniformities of detectors.	Use spark chamber information to correct pulse heights; counters were mapped using the carbon events as a standard.

Rigidity (maximum detectable rigidity of 85 GV on first flight and 97 GV on second flight)

Source of Fluctuation	Correction
a) Spark jitter and Random Measurement Error.	Reduce it by averaging measurements of four spark gaps. (∿.1 mm/spark)
b) Mirror distortions in optics.	Use a set of $\frac{1}{2}$-inch spaced grid lights to compute corrections which are then applied to data. (residue = ±.14 mm/spark chamber)
c) Drift and distortion in measuring machine.	Apply correction results from daily calibration precedure. (residue = ±.2 mm/spark chamber)
d) Possible shift of fiducial reference lights since original survey.	Re-position the lights by analyzing the magnet-off data taken for each flight at altitude and constraining the tracks to an average straightness. (negligible residue)
e) Multiple scattering.	Minimize the amount of material in the beam on second flight.

Absolute Flux

Source of Error	Correction
a) Dead time of electronics and camera.	A "zero dead time" counter scales true trigger rate. The dead time is known (218 ms) and constant, and can be used to calculate live time.

Absolute Flux - cont'd.

Source of Error	Correction
b) Geometry factor (660 cm^2 sr).	This was determined with a monticarlo program of isotropic events. Interpretation of data below about 7 GV is complicated by the influence of Geomagnetic cut-off, even though nominal vertical cut-off was 4.5 GV .

A set of internal publications describe the above corrections in detail. If the reader is interested in obtaining them he can write the authors.

Relative Abundances

The relative abundances were determined for the individual elements of helium to Si and above Si as a group. The table included here is from the first flight's data only. It is hoped that all the data will be analyzed by the time of the conference. The abundances relative to carbon are corrected for gondola material attenuation and atmospheric spallation. The errors given are based on statistical fluctuations plus an estimate of some possible instrumental errors.

Table II

	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si
Abundance relative to C (above atmosphere)	5919	23	13	33	100	31	67	3	15	4	9	<4	6
Error on abundance	±931	±2	±1	±2		±3	±8	±1	±4	±2	±4		±2

Rigidity Spectra

At the time of submission of this paper spectra of only Helium, Carbon, Oxygen and Nitrogen have been made from the first flight. Spectra with greater statistics will be shown at the conference. The relative abundance as a function of rigidity will eventually be obtained with the greater statistics obtained by combining data of both flights. The Helium integral flux on the first flight was measured at 72 $\frac{\text{particles}}{m^2,\text{sr},\text{sec}}$ at the Palestine, Texas geomagnetic cut-off of 4.5 GV . The statistical errors are negligible but the systematic errors arising from the geometry factor, and live time could be about 10%. The integral flux of carbon at this same cut-off is 1.2 $\frac{\text{particles}}{m^2,\text{sr},\text{sec}}$. Since the geomagnetic cut-off is not sharp, this is an effective integral flux above about 5.5 BV .

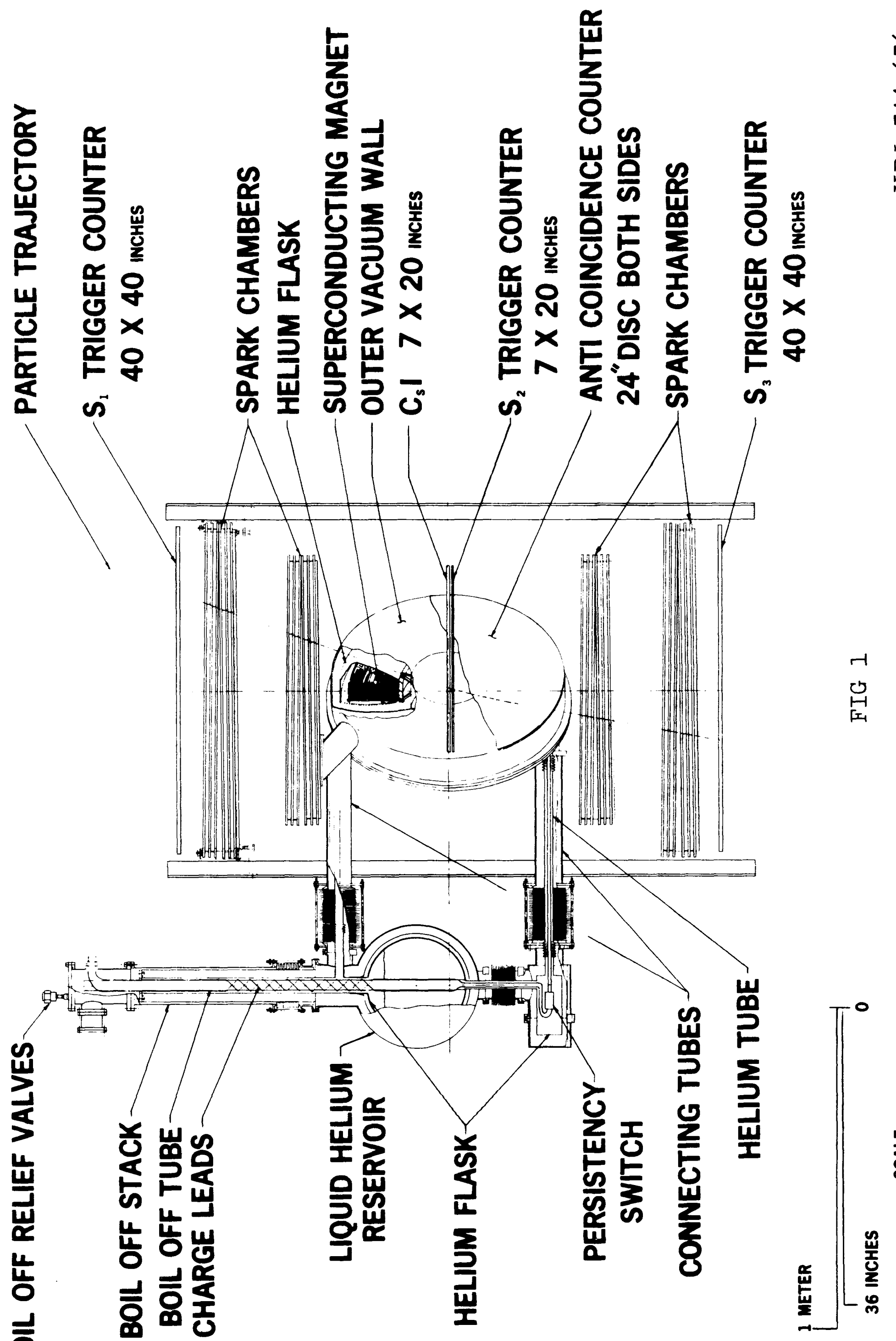
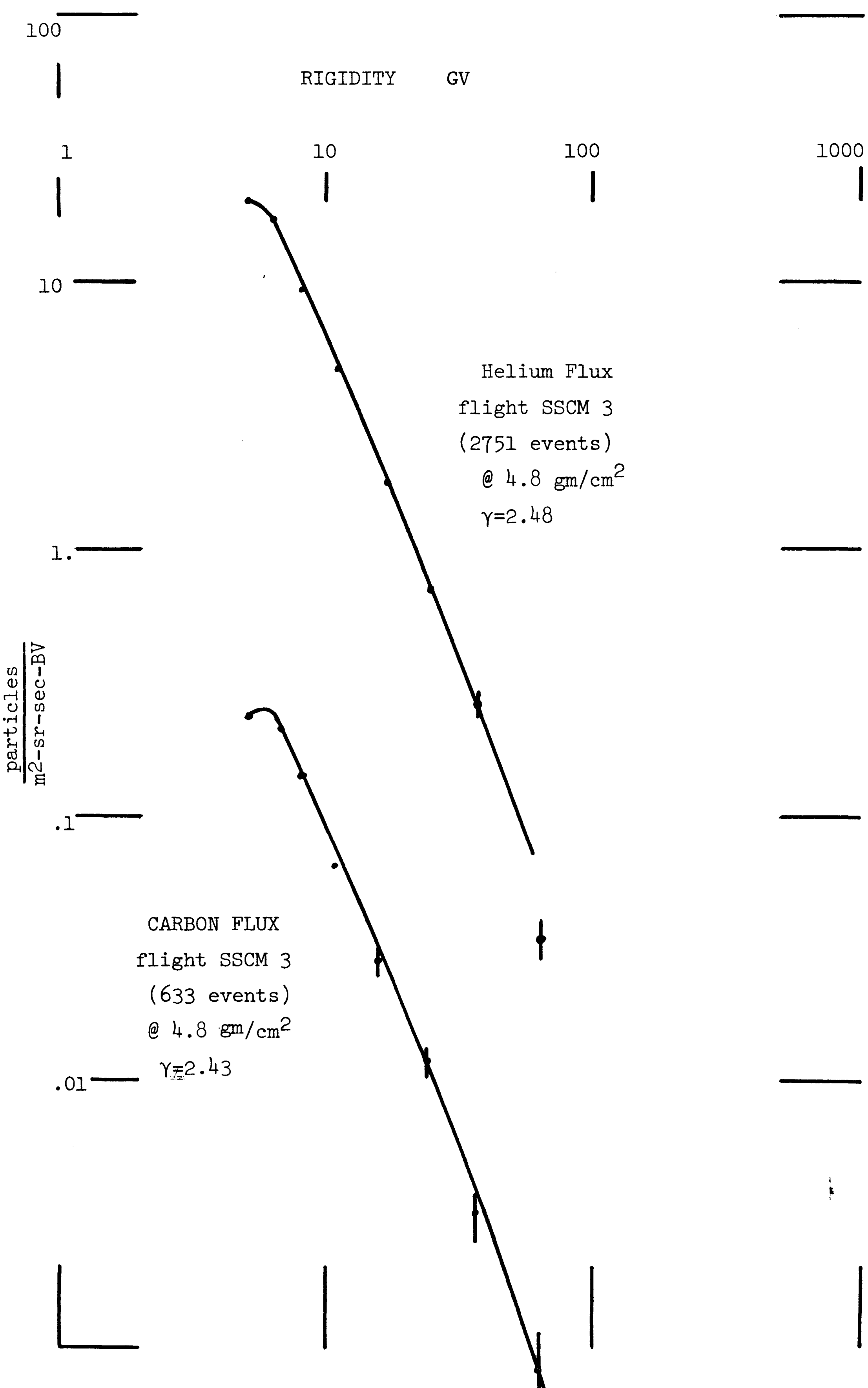
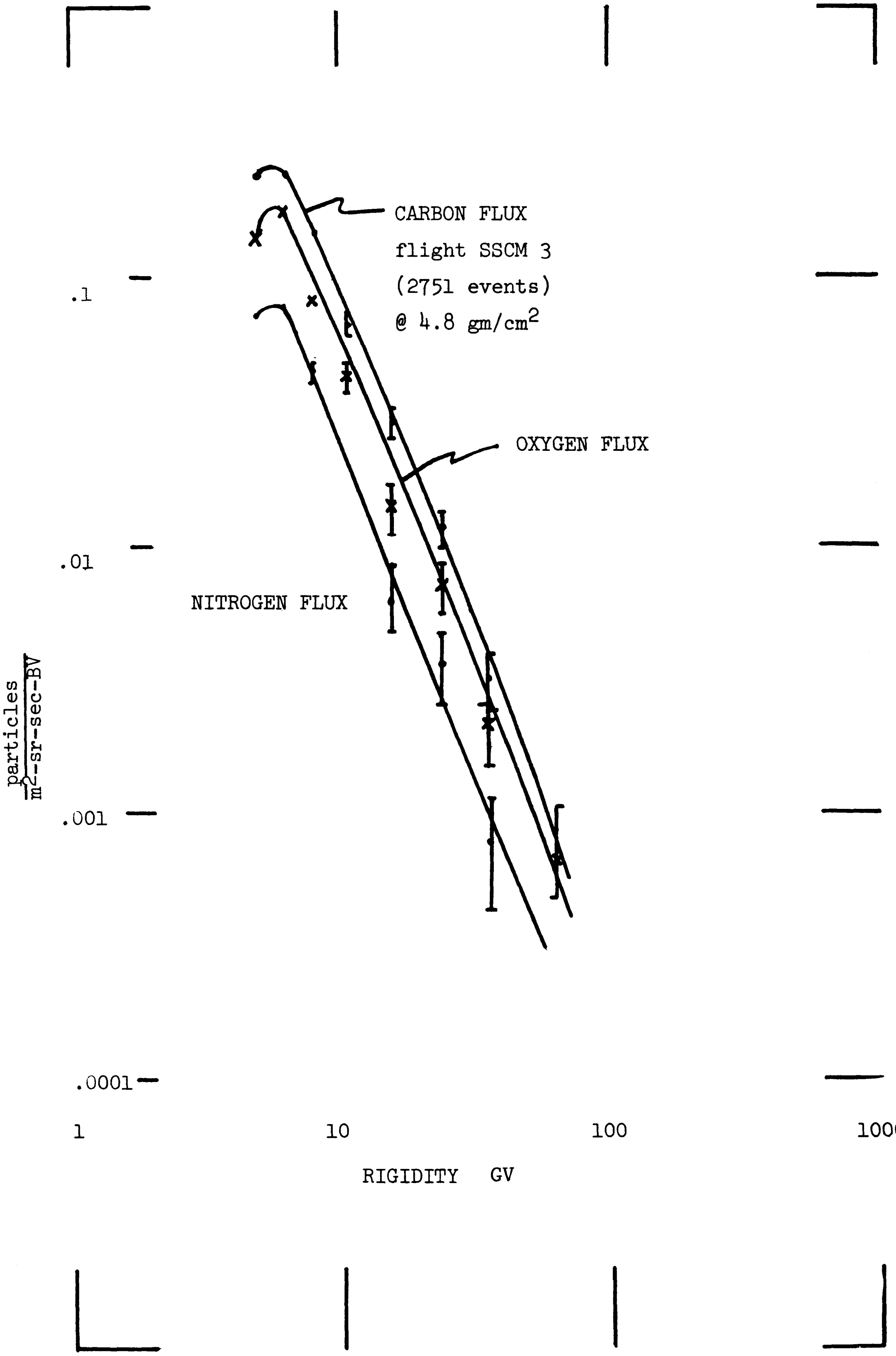


FIG 1

XBL 714-676


100
RIGIDITY GV
1
10
100
1000
10
Helium Flux
flight SSCM 3
(2751 events)
@ 4.8 gm/cm2
γ=2.48
1.
particles
m2-sr-sec-BV
.1
CARBON FLUX
flight SSCM 3
(633 events)
@ 4.8 gm/cm2
γ=2.43
.01


CARBON FLUX
flight SSCM 3
(2751 events)
@ 4.8 gm/cm2
OXYGEN FLUX
NITROGEN FLUX
.1
.01
.001
.0001
particles / m2-sr-sec-BV
1
10
100
1000
RIGIDITY GV