THE PRIMARY COSMIC RAY ELECTRON SPECTRUM IN THE ENERGY RANGE FROM 300 MeV TO 4 BeV FROM 1964 TO 1966*

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ABSTRACT

Measurements of the primary electron spectrum were made during the summers of 1964, 1965 and 1966 using a balloon-borne counter telescope which was flown from Fort Churchill, Manitoba. Several balloon flights were carried out in each year in order to eliminate short term intensity variations. This paper addresses itself to two questions: (1) The determination of the energy spectrum of primary electrons in the energy interval from 300 MeV to 4 BeV; and (2) the long term intensity variations of the primary electron flux from 1964 through 1966. The energy spectrum was determined with improved accuracy in 1966 and agrees with our previous results. Comparison of the electron spectra obtained in 1964, 65 and 66 shows that, within the errors of our measurements, there existed no long term intensity variation. The upper limit for the change of flux with respect to 1965 amounts to 20% in all energy intervals studied.

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I. Introduction

An understanding of the origin and the energy loss processes in the galaxy and of the modulation in the solar system of the primary cosmic ray electron component requires accurate measurements of the electron energy spectrum and a study of the changes of this spectrum as a function of time. This has motivated our attempts to measure the primary electron spectrum with improved accuracy and to extend such measurements over many years. In this paper we wish to report our results which were obtained from 1964 through 1966 on the spectrum of primary electrons in the energy interval from 300 MeV to 4 BeV and on the intensity variation with time over this period.

II. The Experiment

Our measurements of the primary electron spectrum have been made with an energy-loss vs. total energy detector. We shall not describe the instrument here, since details of the experimental method have been published elsewhere (L'Heureux and Meyer, 1965; L'Heureux, 1967). Several balloon flights were made with the same instrument in each year in order to eliminate the possibility of influencing the results by the occurrence of short term intensity variations. The dates of each flight and the atmospheric depth at which each measurement was made are summarized in Table I. Also given in Table I are the Mount Washington and Deep River neutron monitor daily averages for the flight dates. An important aspect of all 1966 flights is the smaller depth of residual atmosphere. This led to more reliable results, particularly in the low energy portion of the spectrum. While in 1964 and 1965 the correction for secondaries amounted to as much as 50% of the total electron flux measured in the low energy intervals, it never exceeded 30% in 1966. Fig. 1 shows the differential energy spectrum of all electrons measured in 1966 under 2.5 g/cm^2 of atmosphere, together with the spectrum of atmospheric secondary electrons. The secondary spectrum was obtained from the electron intensity vs. altitude curves (see L'Heureux, 1967) and agrees reasonably well with theoretical estimates (Verma, 1967).

III. Results and Discussion

a) The primary electron energy spectrum.

Primary electron spectra are obtained by subtracting the atmospheric secondary electrons from the spectra measured at balloon altitude and correcting for energy loss by ionization and bremsstrahlung in the overlying atmosphere. In Fig. 2 we show the resulting primary spectra that were obtained from our measurements in 1964, 65 and 66. The 1966 spectrum is the most reliable in the low energy range since secondary corrections were reduced by almost a factor of two as compared to our earlier measurements (L'Heureux, 1967). No difference appears between the spectra obtained in the three years within the experimental errors. The power laws which give the best fit to a combination of these three spectra have the following forms:

$$\frac{dJ}{dE} = 31\ E^{-1.3}\ \text{electrons}\ m^{-2}\sec^{-1}\text{ster}^{-1}\ \text{BeV}^{-1}$$
$$250\ \text{MeV} < E < 1.5\ \text{BeV}$$

$$\frac{dJ}{dE} = 54\ E^{-2.4}\ \text{electrons}\ m^{-2}\sec^{-1}\text{ster}^{-1}\ \text{BeV}^{-1}$$
$$1.5\ \text{BeV} < E < 4\ \text{BeV}$$

b) Limits on the intensity variation of the primary electron flux from 1964 to 1966.

In order to investigate the time variation of the electron intensity it is of no advantage to compare the primary spectra of Fig. 2 since these contain uncertainties due to corrections for secondary electrons as well as due to extrapolations to the top of the atmosphere. Particularly, since the floating altitudes of the 1964 and 1965 flights were signficantly lower than in 1966, one has to be careful not to introduce (or remove) a possible time variation when one corrects for secondaries. We have found it advantageous to compare the intensities for the different years by grouping the data in three energy intervals and to compare the fluxes measured at floating altitudes in each year with a typical growth curve. In Fig. 3 we have superposed the 1964 and 1965 fluxes measured at floating altitudes onto a growth curve constructed using all the data from the 1966 flights. The solid line represents the contributions of secondaries in each energy interval. This flux of secondaries has two components which are respectively proportional to the depth and to the square of the atmospheric depth. To all the data measured from 1964 to 1966 at floating altitude we have fitted an intensity vs. depth curve which has the form

$$\text{flux} = (Ax + Bx^2) + P\exp(x/L)$$

where the constants A and B are obtained from the calculation of Verma (1967). L is the effective absorption length of primaries and depends on the shape of the primary spectrum. In the energy intervals considered here, L is of the order of 37 g/cm^2. Adjusting the parameter P, the best fits of this expression to the total electron fluxes are shown by dashed lines in Fig. 3.

Examination of these altitude curves shows that a time variation, if it exists, is smaller than the statistical fluctuations. We can put an upper limit of 20% on this variation in all energy intervals. These data alone do not yet provide a basis on which to critically evaluate modulation models.

We are greatly indebted to H. Boersma for his invaluable help in carrying out this experiment and to R. Ekstrom and P. McIntyre for their assistance in the data analysis.

REFERENCES

L'Heureux, J. 1967, Ap. J. 148, 399.

L'Heureux, J. and P. Meyer 1965, Phys. Rev. Letters 15, 93.

Verma, S. D. 1967, Proc. Ind. Acad. Sci. (in press).

TABLE I

Electron Experiment Flights from 1964 to 1966

Flight Date	Atmospheric Depth at the Floating Altitude (g/cm^2)	Time at Altitude (hrs.)	Mt. Washington Neutron Monitor (1)	Deep River Neutron Monitor (2)
July 22, 1964	3.9	7	2390	6917
July 28-29, 1964	4.1	13	2411	6981
June 25, 1965	3.6 to 4.0	13	2467	7077
July 16, 1965	4.5 to 5.6	13	2438	7023
June 10, 1966	2.4	14	2383	6932
June 15, 1966	2.4	14.5	2407	6994
June 20, 1966	2.4 to 3.8	17	2375	6907

(1) Courtesy of Prof. J. A. Lockwood, University of New Hampshire, Durham, N. H.

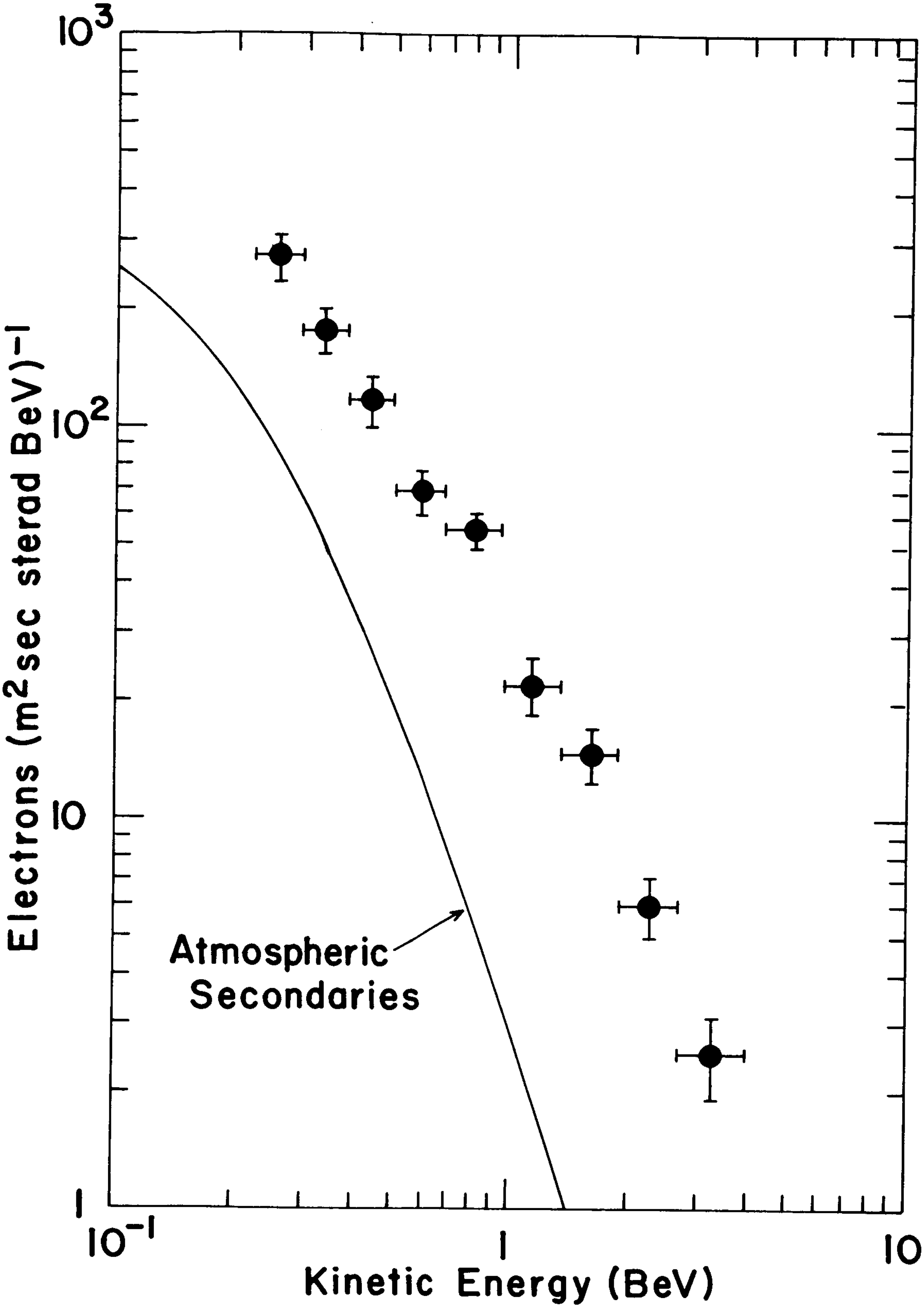
(2) Courtesy of Dr. H. Carmichael, Atomic Energy of Canada, Ltd. Chalk River, Ont.

FIGURE CAPTIONS

Fig. 1 The total differential electron energy spectrum (primary plus secondary) as measured at an average atmospheric depth of 2.4 g/cm^2 in the summer of 1966. The contribution of atmospheric secondaries is also shown.

Fig. 2 The differential energy spectra of primary electrons measured in 1964, 1965, and 1966.

Fig. 3 The vertical electron flux in three energy intervals, measured in 1964 and 1965 at floating altitudes superposed on the 1966 growth curves. The solid line represents the calculated flux of atmospheric secondary electrons versus atmospheric depth. The dashed curve represents the sum of primaries and secondaries. It is normalized to the fluxes measured at floating altitudes.



10^3
10^2
10
1
10^{-1}
1
10
Electrons $(m^2 sec\ sterad\ BeV)^{-1}$
Kinetic Energy (BeV)
Atmospheric
Secondaries

Figure 1

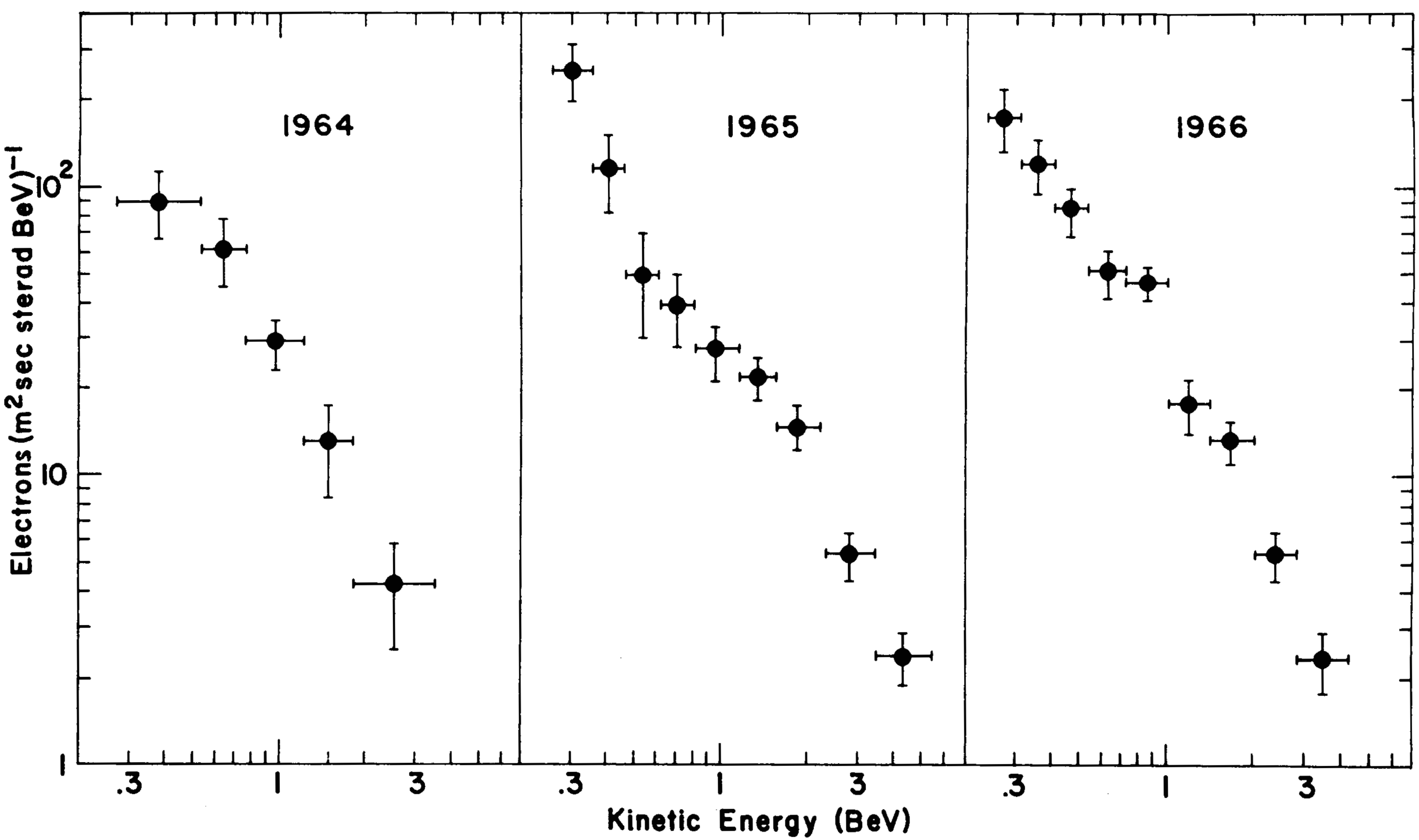

1964
1965
1966
Electrons (m^{2}sec sterad BeV)$^{-1}$
10^2
10
1
.3
1
3
.3
1
3
.3
1
3
Kinetic Energy (BeV)

Figure 2

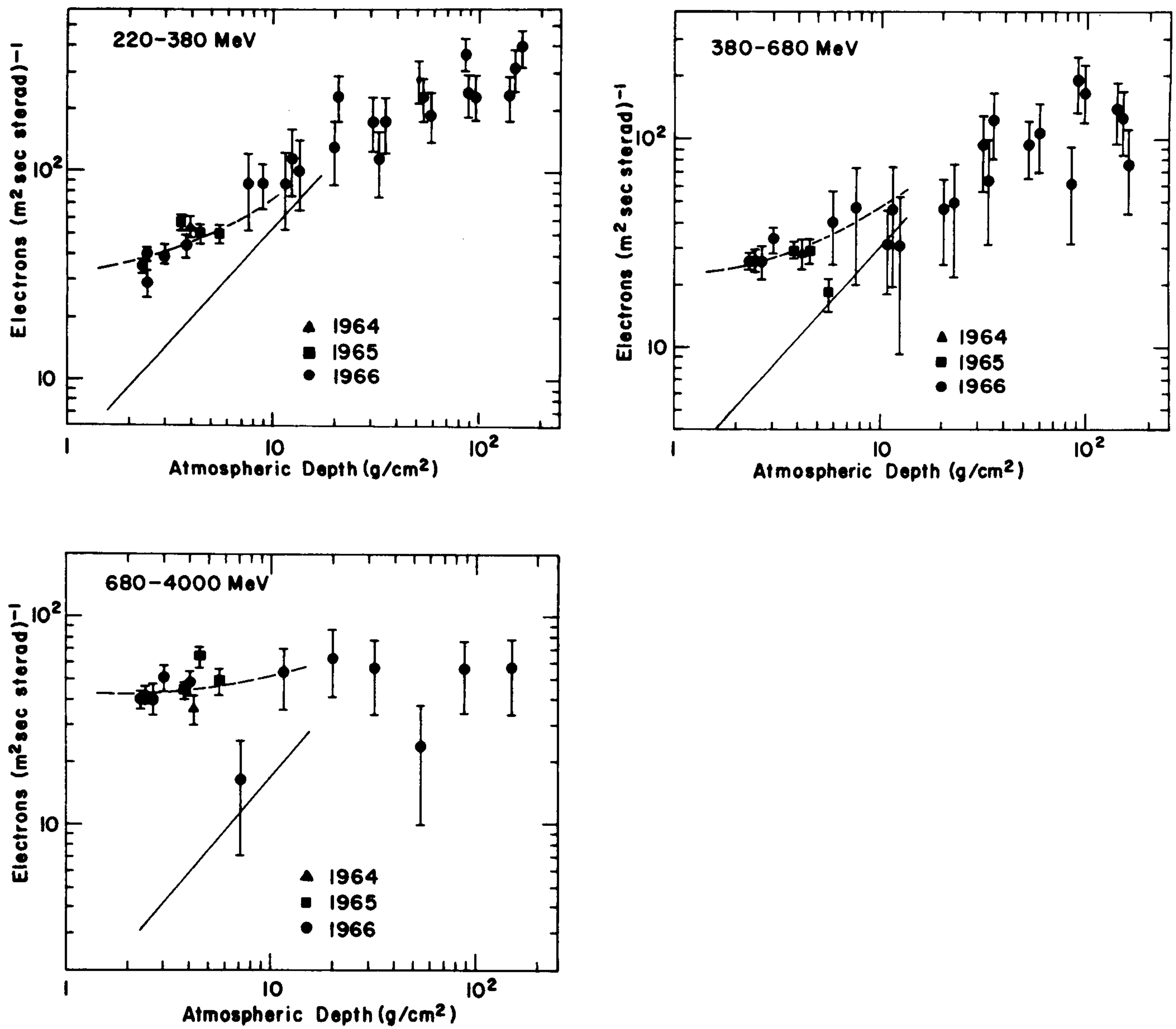

220-380 MeV
380-680 MeV
680-4000 MeV
Electrons (m² sec sterad)⁻¹
Atmospheric Depth (g/cm²)
1964
1965
1966

Figure 3