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EXPLORER 12 OBSERVATIONS OF CHARGED PARTICLES IN THE INNER RADIATION ZONE*

by

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Abstract

Measurements of energetic charged particles in the inner radiation zone with two shielded, omnidirectional Geiger-Mueller tubes flown on Explorer 12 have been used to construct B-L contours of the omnidirectional intensities of protons $E_p > 21$ Mev and $E_p > 70$ Mev for the period 16 August to 19 September, 1961, prior to the Starfish high-altitude nuclear burst on 9 July 1962. The values of proton ($E_p > 21$ Mev) omnidirectional intensities are in substantial agreement with the post-Starfish values from Telstar 2 and with other observations. Upper limits for the omnidirectional intensities of electrons $E_e > 1.6$ Mev at the geomagnetic equator before the Starfish test are $J_o \leq 10^4$ $(cm^2\text{-sec})^{-1}$ at L = 1.2, $\leq 4 \times 10^4$ $(cm^2\text{-sec})^{-1}$ at L = 1.25, $\leq 2.5 \times 10^5$ $(cm^2\text{-sec})^{-1}$ at L = 1.5, $\leq 8 \times 10^4$ $(cm^2\text{-sec})^{-1}$ at L = 1.8 and $\leq 1.5 \times 10^4$ $(cm^2\text{-sec})^{-1}$ at L = 2.4.

I. Introduction

Explorer 12 observations of charged particle intensities in the inner radiation zone during August-September 1961 provide significant contributions to the existing body of knowledge concerning the inner radiation zone in two major areas of interest. First, the B-L contours of the omnidirectional intensities of protons $E_p > 21$ Mev and > 70 Mev over the ranges $1.2 \lesssim L \lesssim 2.2$ and $B_o \lesssim B \lesssim 0.20$ as derived from the counting rates of two shielded, omnidirectional Geiger-Mueller tubes and presented herein furnish further information concerning the stability of inner zone proton intensities during the epoch approximately three years after the solar activity maximum. These observations supplement and are compared in part with previously reported observations extending over the period late-1958 to 1964 [cf. McIlwain, 1961; Freden and White, 1959; Naugle and Kniffen, 1963; McIlwain, 1963; Gabbe and Brown, 1965]. The second purpose of the present report is to provide upper limits for the electron ($E_e > 1.6$ Mev) omnidirectional intensities at the geomagnetic equator from $L \simeq 1.2$ to $\simeq 2.4$ during the period approximately ten months previous to the injection of energetic electrons by the Starfish high-altitude nuclear burst on 9 July 1962.

II. Description of the Apparatus

Explorer 12 was launched at 1321 U.T., 16 August 1961, into a highly eccentric orbit with initial apogee 83,600 km and perigee 6700 km geocentric radial distances, inclination 33° and period 26.5 hours. The satellite was spin-oriented with its spin axis directed initially toward right ascension 47.0° and declination - 27.5°. The spin rate slowly increased during the period of observations reported here, 27.8 r.p.m. at launch to 28.9 r.p.m. in mid-September.

The satellite transited the inner radiation zone approximately twice each day (one inbound and one outbound pass). The duration of these transits, perigee to $L \simeq 2.5$, was ~ 30 minutes. Approximately 30% of the telemetered data from these passes over the above L range were received by tracking stations and were provided by the Goddard Space Flight Center for further processing at the University of Iowa.

Of present interest are the responses of two shielded Geiger-Mueller tubes designated as the 302, an Anton type 302 G.M. tube shielded with ~ 1 $gm(cm)^{-2}$ (Al and stainless steel), and the SPB, an Anton type 213 G.M. tube shielded with ~ 5 $gm(cm)^{-2}$

(Pb and other materials) [Laughlin, 1960]. A description of the entire complement of University of Iowa detectors on Explorer 12 has been given previously by Freeman [1964]. Table I provides a summary of the omnidirectional geometric factors and shielding materials for the two G.M. tubes. The energy threshold for penetrating protons is 70 ($\pm$ 4 Mev) over a solid angle of 10 steradians for SPB; the remaining solid angle is shielded by an additional shielding ~ 3 gm(cm)$^{-2}$. The electron bremsstrahlung efficiency of SPB is $\sim 2 \times 10^{-4}$ counts-cm^2(electron)$^{-1}$ for E_e = 8 Mev and $\sim 8 \times 10^{-6}$ counts-cm^2(electron)$^{-1}$ for E_e = 2 Mev and decreases rapidly with decreasing electron energies $E_e \lesssim 1$ Mev [Van Allen, Frank and O'Brien, 1963]; the energy threshold for penetrating electrons is ~ 20 Mev. Energy thresholds for penetrating protons and electrons for the shielded 302 G.M. tube are E_p = 21 Mev and $E_e \simeq 1.6$ Mev, respectively (for a detailed analysis of a nominally identical detector see Frank, Van Allen and Hills [1964]). The omnidirectional geometric factor of SPB was determined by comparing its response to galactic cosmic rays at apogee, 0.36 counts(sec)$^{-1}$, with the simultaneous response of the 302, 1.5 counts(sec)$^{-1}$. Since the omnidirectional geometric factor ϵG_o of the 302 is known by laboratory measurements within an uncertainty of 20%,

TABLE I

Omnidirectional Geometric Factors and
Shieldings for the 302 and SPB G.M. Tubes on Explorer 12

Detector	302	SPB
eG_o for Penetrating Particles	$0.55(\pm 0.1)$ cm^2	$0.13(\pm 0.02)$ cm^2
Shielding	265 mg/cm^2 Al 400 mg/cm^2 stainless steel	3.5 gm/cm^2 Pb 0.9 gm/cm^2 stainless steel 0.2 gm/cm^2 potting materials 1.0 gm/cm^2 Mg
Penetrating Particles	protons $E_p > 21$ Mev electrons $E_e \gtrsim 1.6$ Mev	protons $E_p > 70(\pm 4)$ Mev electrons $E_e \gtrsim 20$ Mev

0.55 ($\pm$ 0.1) cm^2, the SPB omnidirectional geometric factor, ϵG_o, is (0.36/1.5) (0.55) = 0.13 ($\pm$ 0.03) cm^2.

The response of each detector was accumulated for 10.24 seconds, or ~ 5 spin periods of the spacecraft, and the contents of the accumulators were redundantly telemetered once each 79 seconds. All of the University of Iowa detectors operated satisfactorily from launch until transmission of data by the spacecraft terminated on 6 December 1961 with the exception of the SPB which failed on 20 September. No failure of the SPB prior to 20 September has been detected after a careful inspection of plots of the entire body of data [Frank, Bohlin and DeCoster, 1966], and subsequently the SPB responses for the period extending from launch on 16 August through 19 September 1961 have been used in the present analysis.

III. Observations

The responses of the SPB and the 302 G.M. tubes for the period 16 August through 19 September 1961 for $L < 2.4$ have been organized in plots of counting rate versus B for selected values of L and are shown in Figures 1 and 2 (302 responses) and 3 and 4 (SPB responses). A prelaunch laboratory calibration curve has been used to convert the telemetered apparent counting rates of the G.M. tubes to the true counting rates shown in the above graphs; this correction is negligible for apparent counting rates $\lesssim 1000$ counts $(\text{sec})^{-1}$. Observations on L-shells within $\Delta L = \pm\, 0.05$ of the specified L-shell have been used in constructing these counting rate versus B plots. The largest uncertainty in the assignment of B to a given observation occurs at the lowest L-values and has been designated in Figures 1 and 3 by appropriate horizontal error bars. Vertical error bars indicate the calculated standard deviations for selected counting rates of the detectors.

Omnidirectional geometric factors for penetrating protons $E_p > 21$ Mev and $E_p > 70$ Mev for the 302 and the SPB, respectively, have been included in the legends of the graphs. It is important to note that the complement of University of

Iowa detectors on Explorer 12 is inadequate to eliminate penetrating electrons $E_e > 1.6$ Mev and $E_e \gtrsim 20$ Mev as substantial contributors to the responses of the 302 and SPB, respectively. The identification of the responses of these shielded G.M. tubes in the inner radiation zone $L < 2.4$ resides primarily in the observed temporal stability of inner zone proton intensities and the close agreement of the present measurements with other observations of energetic proton intensities (see Discussion). Early measurements of inner zone proton intensities and spectra which identified the principal contributors to the inner zone responses of shielded (~ 1 gm(cm)$^{-2}$) G.M. tubes as penetrating protons were reported by Freden and White [1959], Armstrong, Harrison, Heckman and Rosen [1961], and Naugle and Kniffen [1961]. Bremsstrahlung from nonpenetrating electrons can be eliminated as a significant contributor to the responses of the 302 and the SPB by simultaneous measurements of the total energy fluxes of electrons $E_e \gtrsim 100$ eV with unshielded CdS crystals (for a discussion of the Explorer 12 CdS detectors, see Freeman [1964]). This upper limit for the electron ($E_e > 100$ eV) energy fluxes is ~ 50 ergs(cm^2-sec)$^{-1}$ throughout the region of observations reported here. The maximum efficiency for counting nonpenetrating electrons for the 302 is $\sim 10^{-5}$ count-cm^2(electron)$^{-1}$ $E_e \sim 0.5$ Mev [Frank, 1962]. Hence a 302 response $\sim 10^4$ counts(sec)$^{-1}$ due to bremsstrahlung from nonpenetrating electrons requires a minimum electron energy flux ~ 1000 ergs(cm^2-sec)$^{-1}$. A comparison of this upper limit with the CdS observed upper limit on the electron $E_e > 100$ eV energy fluxes, ~ 50 ergs(cm^2-sec)$^{-1}$ shows that bremsstrahlung from nonpenetrating electrons is negligible for 302 responses $\gtrsim 10^3$ counts(sec)$^{-1}$. The maximum efficiency of the SPB for counting nonpenetrating electrons 1.6 Mev $\lesssim E_e \lesssim 20$ Mev is $\sim 10^{-4}$ counts-cm^2(electron)$^{-1}$ [Van Allen, Frank and O'Brien, 1963; Petschek, 1963]. A solid upper limit for the electron intensities in the above energy range can be obtained by attributing the entire 302 response to penetrating electrons $E_e > 1.6$ Mev. For example, at $B = 0.14$ gauss $L = 1.7$ the 302 response is $\sim 3 \times 10^3$ counts(sec)$^{-1}$ and the corresponding upper limit for electron 1.6 Mev $\lesssim E_e \lesssim 20$ Mev intensities is $\sim 3 \times 10^4$ (cm^2-sec)$^{-1}$, an intensity corresponding to a SPB bremsstrahlung response of $\sim (10^{-4})\ (3 \times 10^4) =$ 3 counts(sec)$^{-1}$. Comparison of this upper limit with the observed SPB response $\sim 3 \times 10^2$ counts(sec)$^{-1}$ eliminates nonpenetrating electrons 1.6 Mev $\lesssim E_e \lesssim 20$ Mev as a substantial contributor to the SPB response. For electrons $E_e = 1.6$ Mev, the efficiency of SPB is $\sim 4 \times 10^{-6}$ count-cm^2(electron)$^{-1}$ and rapidly decreases with decreasing electron energy. Utilizing an argument similar to that applied above to the 302 response, an electron ($E_e \sim 1.6$ Mev) energy flux ~ 50 ergs(cm^2-sec)$^{-1}$ corresponds to a SPB response ~ 80 counts(sec)$^{-1}$, a severe upper limit for the SPB response due to nonpenetrating electrons $E_e \lesssim 20$ Mev for the inner radiation zone observations reported here. Hence it is unlikely that substantial contributions to the 302 and SPB responses in the inner radiation zone can be attributed to bremsstrahlung from nonpenetrating electrons.

The observations shown in Figures 1 through 4 have been summarized in B-L coordinates as contours of constant counting rate in Figures 5 (the 302 responses) and 6 (the SPB responses). Each point in these graphs represents a single observation. The densities of observations are reasonably adequate for the determination of the iso-count contours shown. The contours in the two regions, $0.14 \lesssim B \lesssim 0.18$, $1.3 \lesssim L \lesssim 1.6$ and $1.0 \lesssim B/B_o \lesssim 1.3$, $1.6 \lesssim L \lesssim 2.0$, with sparse or no observations have been determined by interpolation of the counting rate versus B plots of Figures 1-4. Responses of the 302 and the SPB at the geomagnetic equator for $1.2 \lesssim L \lesssim 2.4$ are shown in Figures 7 and 8, respectively.

For $L \gtrsim 1.6$ the observations as summarized in Figures 1-4 have been extrapolated to the magnetic equator, $B/B_o = 1.0$ ($\lambda_m = 0°$) from typically $B/B_o \lesssim 1.3$ ($\lambda_m \lesssim 15°$). These extrapolated values are judged to be accurate to within 50% of the responses of the detectors at the magnetic equator.

IV. Discussion And Comparison With Previously Reported Observations

Comparisons of these Explorer 12 observations with several previously reported measurements of inner zone proton intensities have been undertaken and are summarized as follows.

Telstar 2. The omnidirectional proton 21 Mev $< E_p < 145$ Mev intensities versus B for selected L = 1.3, 1.5, 1.9 and 2.3 observed with Telstar 2 during summer 1963 [Gabbe and Brown, 1965] are shown in Figure 9 with the corresponding Explorer 12 measurements with the shielded 302 G.M. tube. Omnidirectional intensities of protons $E_p > 21$ Mev corresponding to the 302 responses have been calculated by assuming its entire response is due to penetrating protons. The vertical error bars in Figure 9 and the following Figure 10 are the estimated errors in our calculations of intensities from published data obtained with other satellites and the calculated standard deviations for the counting rates of the Explorer 12 G.M. tubes. Within the ranges of B and L shown in Figure 9 these two sets of observations are in substantial agreement and strongly indicate that (1) the 302 responses are predominantly due to penetrating protons and (2) no large temporal variation (i.e., by a factor $\gtrsim 2$ in proton intensities at a given position) in the structure of inner zone proton $E_p > 21$ Mev intensities occurred over the two-year period extending from September 1961 to September 1963. It is possible, of course, that transitory intensity variations did occur during unmonitored intervals between the periods of these observations.

1964-45A. Figure 10 displays the results of a comparison of measurements of proton ($E_p > 70$ Mev) omnidirectional intensities with satellite 1964-45A in August 1964 reported by Freden, Blake and Paulikas [1965] with Explorer 12 observations at L = 1.8 and 2.0 in August-September 1961. The proton $E_p > 70$ Mev omnidirectional intensities observed with Explorer 12 have been calculated by assuming that the SPB response is wholly due to penetrating protons. These observations are in agreement within experimental errors as indicated in Figure 10. Although the intensity versus B curves observed with Explorer 12 are apparently characterized by a steeper slope when compared with the measurements of Freden et al, the experimental uncertainties in comparing observations with dissimilar apparatus and at different periods prohibit the conclusive identification of this feature as a temporal variation of proton $E_p > 70$ Mev intensities.

Explorer 4. McIlwain (1961) has summarized the responses of an 'unshielded' 302 G.M. tube flown on Explorer 4 for the period August-September 1958; several of these curves of constant counting rate have been reproduced in Figure 11. The Explorer 4 302 G.M. tube has nominally the same omnidirectional geometric factor but has excess shielding materials by ~ 0.5 gm(cm)$^{-2}$ [Van Allen, McIlwain and Ludwig, 1958] when compared to those of the Explorer 12 G.M. tube. The Explorer 12 observations during August-September 1961, three years after the period of Explorer 4 measurements, are also included in Figure 11. The two sets of contours of constant counting rate are in general agreement. The depression of the Explorer 12 1,000 counts(sec)$^{-1}$ contour toward lower B values at $L \simeq 1.2$ to 1.4 may be a manifestation of a combination of atmospheric heating and a temporal variation in neutron albedo source strength [Blanchard and Hess, 1964] or an artifact of the differing penetrating proton energy thresholds of the Explorer 4 and 12 G.M. tubes, 31 and 21 Mev, respectively. These two groups of observations are in agreement to within the accuracy possible in comparing intensity observations at a given B-L position; the single possibility of disagreement originates from the differing characters of the contours, 1,000 counts(sec)$^{-1}$, over the ranges $1.2 \lesssim L \lesssim 1.6$ and $0.18 \lesssim B \lesssim 0.20$ (Figure 11).

<u>Injun I.</u> An omnidirectionally shielded 213 G.M. tube utilized as a background detector (also designated as SPB) for an electron magnetic spectrometer flown on Injun I (launch, 29 June 1961) was nominally identical to the Explorer 12 SPB G.M. tube with respect to omnidirectional geometric factor and shielding materials. Van Allen [1965] has summarized the inner radiation zone responses of the Injun I SPB for the period July 1961 through June 1962. Injun I measurements overlap some of the Explorer 12 observations displayed in Figure 6 and comparisons at selected B and L coordinates show that the SPB responses are in agreement to within an experimental uncertainty of ~ 50% (see Table II for an abbreviated table of selected observations). Hence the Explorer 12 SPB responses reported here provide a useful extension in B-L coordinates of pre-Starfish SPB responses for the study of the decay of the artificially injected radiation [cf Van Allen, 1965; Walt, 1964].

Table II

Comparison of Injun 1 and Explorer 12 SPB Responses

at Selected B and L Coordinates.

L	B	Injun 1 SPB Response (counts$(sec)^{-1}$)	Explorer 12 SPB Response (counts$(sec)^{-1}$)
1.25	0.165	800	700
1.30	0.172	800	500
1.40	0.180	500	600
1.50	0.194	200	200
1.50	0.218	50	30
1.60	0.215	50	40

The temporal stability of inner zone proton intensities for L $\lesssim$ 2 indicated here by the above comparisons of Explorer 12 measurements with observations by other satellites during various epochs in the solar cycle has been previously reported [cf. Freden and White, 1962; Rowland, Bakke, Imhof and Smith, 1963; Gabbe and Brown, 1965; Freden, Blake and Paulikas, 1965; Filz and Holeman, 1965; Fillius, 1966]. Explorer 7 observations [Pizzella, McIlwain and Van Allen, 1962] during the period October 1959 through December 1960 revealed temporal variations in inner zone proton intensities by factors $\sim$ 3 at L $\gtrsim$ 1.3. Since the Explorer 7 measurements were obtained with a 302 G.M. tube similar in shielding and geometric factor with respect to the 302 G.M. tubes flown on Explorers 4 and 12 and are enclosed in time by the Explorers 4 and 12 observations during August-September 1958 and August-September 1961, respectively, (Figure 11) it appears that, although increases in proton intensities occurred during the period of Explorer 7 observations, the proton intensities returned to intensity values observed in 1958 by late 1961. The epochs (time spans from the beginning of solar activity cycle 19 [Central Radio Propagation Laboratory Bulletin-F, Part B, issued January 1965] to dates of observations) for Explorers 4, 7 and 12 observations are ~ 4.4, 5.5 - 6.7 and 7.4 years, respectively, and are during the descending portion of the solar activity cycle as indicated by smoothed sunspot numbers. Temporal variations in proton $E_p > 34$ Mev intensities by a factor of ~ 10 at higher L-values $L \gtrsim 2.5$ during a geomagnetic storm in September 1963 have been reported by McIlwain [1965] [see also Gabbe and Brown, 1965]. Observations during the next few years of increasing geomagnetic activity will be of fundamental importance toward identifying and understanding the predominant loss and acceleration mechanisms for inner zone protons.

A secondary maximum of proton ($40 < E_p < 110$ Mev) unidirectional intensities, $j_\perp$, at $L \sim 2.2$ on the magnetic equator was observed with Explorer 15 in late 1962 [McIlwain, 1963]. Explorer 12 measurements of the omnidirectional intensities of protons $E_p > 21$ Mev and > 70 Mev at the geomagnetic equator as summarized in Figures 7 and 8, respectively, show only a change of slope in the equatorial intensity versus L profiles in the region $2.1 \lesssim L \lesssim 2.4$. Observations of this secondary peak with

Explorer 12 were perhaps precluded by the omnidirectional nature of these observations and the extrapolations of observed intensities from $\lambda_m \simeq 15°$ to the magnetic equator over these L-values.

The Explorer 12 observations reported here provide an unique opportunity to obtain upper limits for the intensities of natural electrons $E_e > 1.6$ Mev from $L \simeq 1.2$ to $L \simeq 2.4$ at the magnetic equator prior to the Starfish nuclear burst on 9 July 1962. Solid upper limits for these natural electron $E > 1.6$ Mev intensities in the inner radiation zone can be obtained by assuming the detector response is wholly due to penetrating electrons and multiplying the equatorial 302 G.M. tube counting rates displayed in Figure 7 by a factor of 10 [Frank, Van Allen and Hills, 1964]. Representative upper limits for the omnidirectional intensities of electrons $E_e > 1.6$ Mev are given in Table III.

Table III

Upper Limits for the Omnidirectional Intensities of Electrons $E_e > 1.6$ Mev at the Geomagnetic Equator Prior to The Starfish Nuclear Burst

L	$J_o(E_e > 1.6$ Mev) $(cm^2\text{-sec})^{-1}$
1.2	$\leq 10^4$
1.25	$\leq 4 \times 10^4$
1.3	$\leq 10^5$
1.4	$\leq 2 \times 10^5$
1.5	$\leq 2.5 \times 10^5$
1.6	$\leq 2 \times 10^5$
1.8	$\leq 8 \times 10^4$
2.0	$\leq 4 \times 10^4$
2.2	$\leq 2.5 \times 10^4$
2.4	$\leq 1.5 \times 10^4$

Acknowledgements

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Figure Captions

Figure 1. Counting rates of the Explorer 12 302 G.M. tube plotted as a function of B (gauss) for selected values of L. The ordinate scales for each successive L-shell have been separated by one decade.

Figure 2. Continuation of Figure 1 for L = 1.8 to 2.4.

Figure 3. Counting rates of the Explorer 12 SPB G.M. tube plotted as a function of B (gauss) for selected values of L. The ordinate scales for each successive L-shell have been separated by one decade.

Figure 4. Continuation of Figure 3 for L = 1.8 to 2.3.

Figure 5. Contours of constant counting rate for the Explorer 12 302 G.M. tube in B-L coordinates.

Figure 6. Contours of constant counting rate for the Explorer 12 SPB G.M. tube in B-L coordinates.

Figure 7. Responses of the 302 G.M. tube plotted as a function of L at the magnetic equator.

Figure 8. Responses of the SPB G.M. tube plotted as a function of L at the magnetic equator.

Figure 9. Comparisons of observations of the omnidirectional intensities of protons $E_p > 21$ Mev with Explorer 12 in August-September 1961 and Telstar 2 in summer 1963.

Figure 10. Comparisons of observations of the omnidirectional intensities of protons $E_p > 70$ Mev with Explorer 12 in August-September 1961 and 1964-45A in August 1964.

Figure 11. Contours of constant counting rates in B-L coordinates for the 302 G.M. tubes on Explorer 4 (August-September, 1958) and Explorer 12 (August-September, 1961).

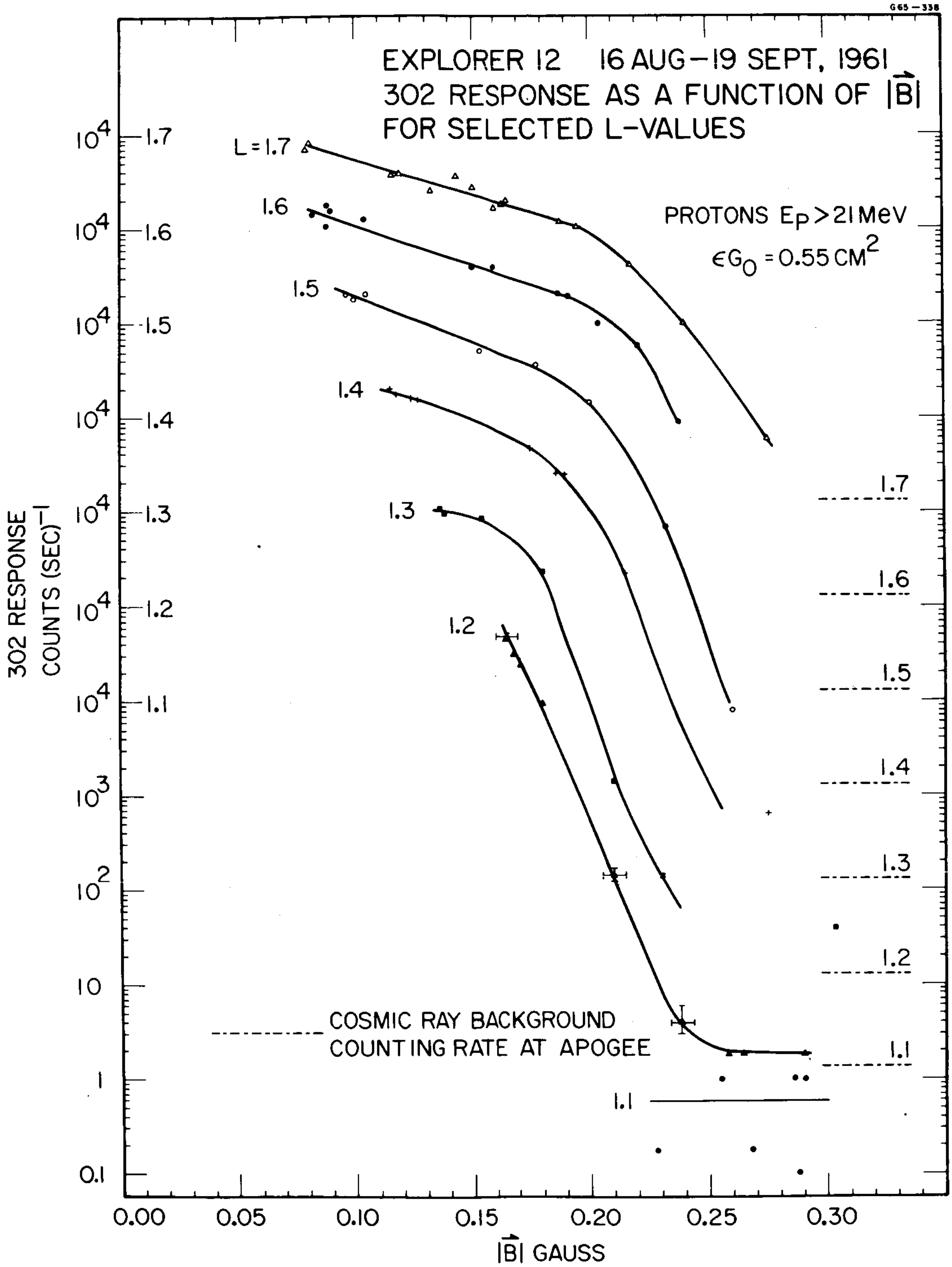

G65-338
EXPLORER 12 16 AUG-19 SEPT, 1961
302 RESPONSE AS A FUNCTION OF |B|
FOR SELECTED L-VALUES
PROTONS EP > 21 MeV
ϵG0 = 0.55 CM2
L = 1.7
1.6
1.5
1.4
1.3
1.2
1.1
COSMIC RAY BACKGROUND
COUNTING RATE AT APOGEE
302 RESPONSE
COUNTS (SEC)-1
|B| GAUSS
0.00
0.05
0.10
0.15
0.20
0.25
0.30

Figure 1

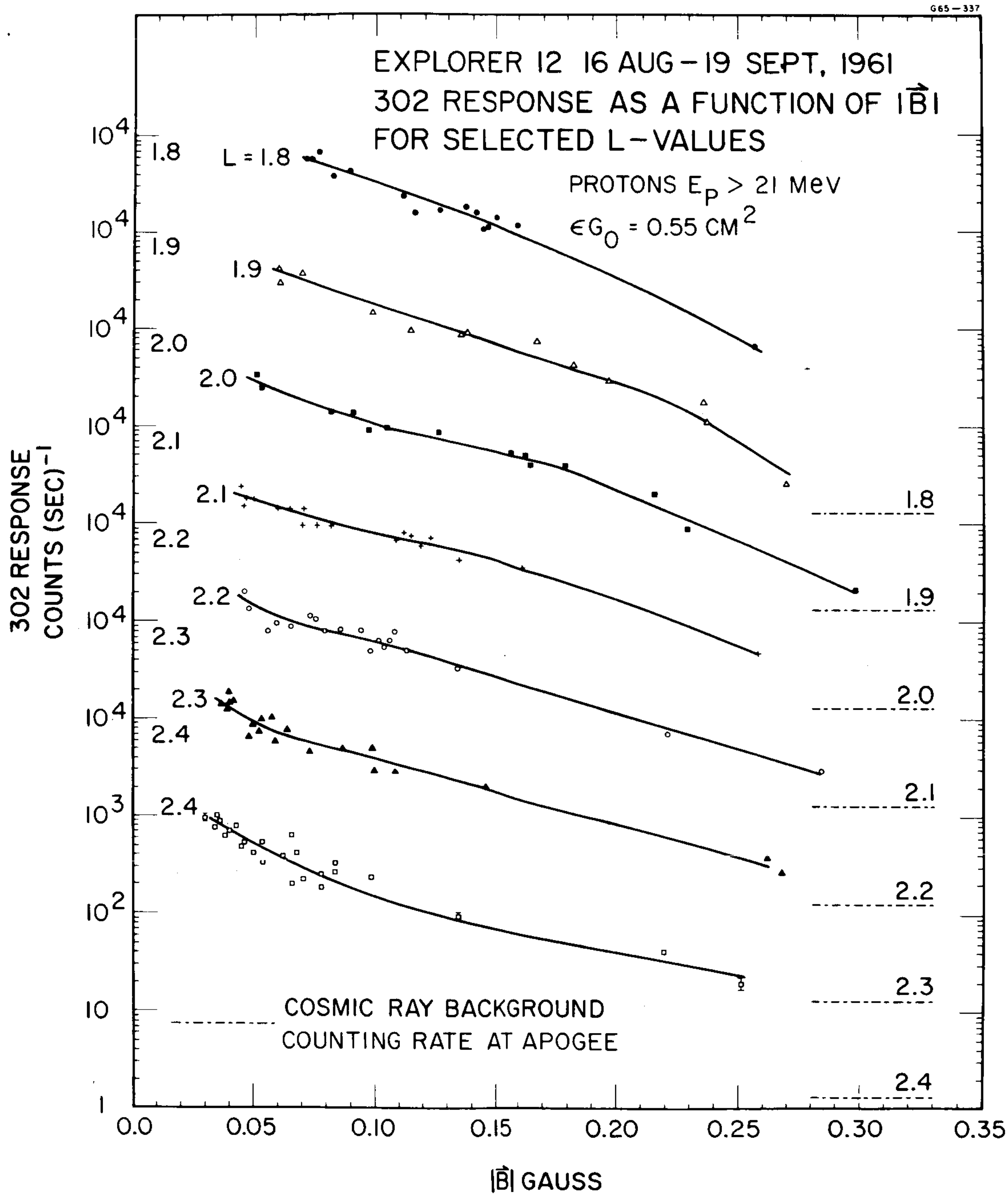

G65-337
EXPLORER 12 16 AUG - 19 SEPT, 1961
302 RESPONSE AS A FUNCTION OF |B|
FOR SELECTED L-VALUES
PROTONS E_P > 21 MeV
ϵG_0 = 0.55 CM^2
L = 1.8
1.9
2.0
2.1
2.2
2.3
2.4
COSMIC RAY BACKGROUND
COUNTING RATE AT APOGEE
302 RESPONSE
COUNTS (SEC)$^{-1}$
|B| GAUSS

Figure 2

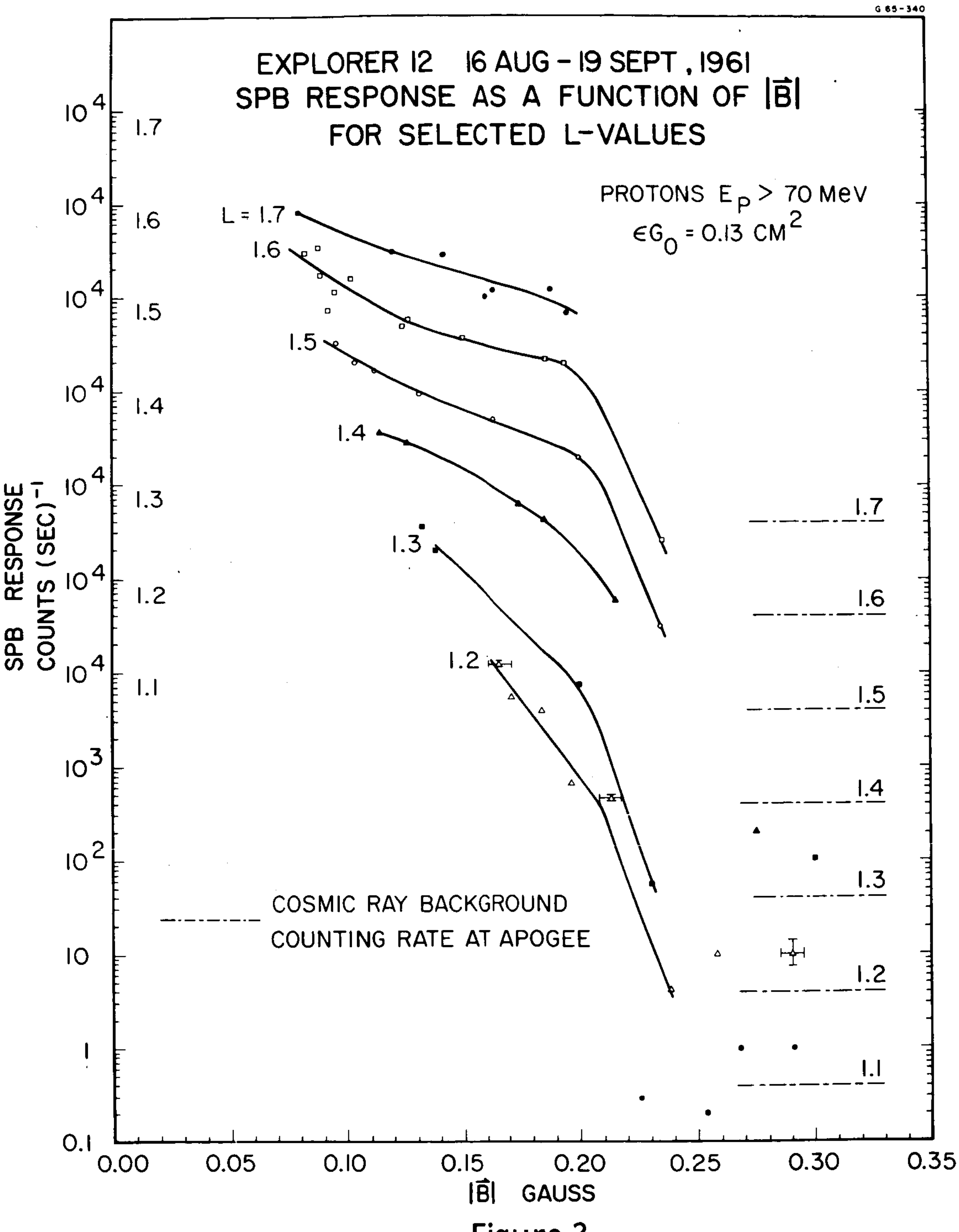

G 65-340
EXPLORER 12 16 AUG - 19 SEPT, 1961
SPB RESPONSE AS A FUNCTION OF |B⃗|
FOR SELECTED L-VALUES
PROTONS E_P > 70 MeV
ϵG_0 = 0.13 CM^2
SPB RESPONSE
COUNTS $(SEC)^{-1}$
L = 1.7
1.6
1.5
1.4
1.3
1.2
1.1
COSMIC RAY BACKGROUND
COUNTING RATE AT APOGEE
|B⃗| GAUSS
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
10^4
10^3
10^2
10
1
0.1

Figure 3

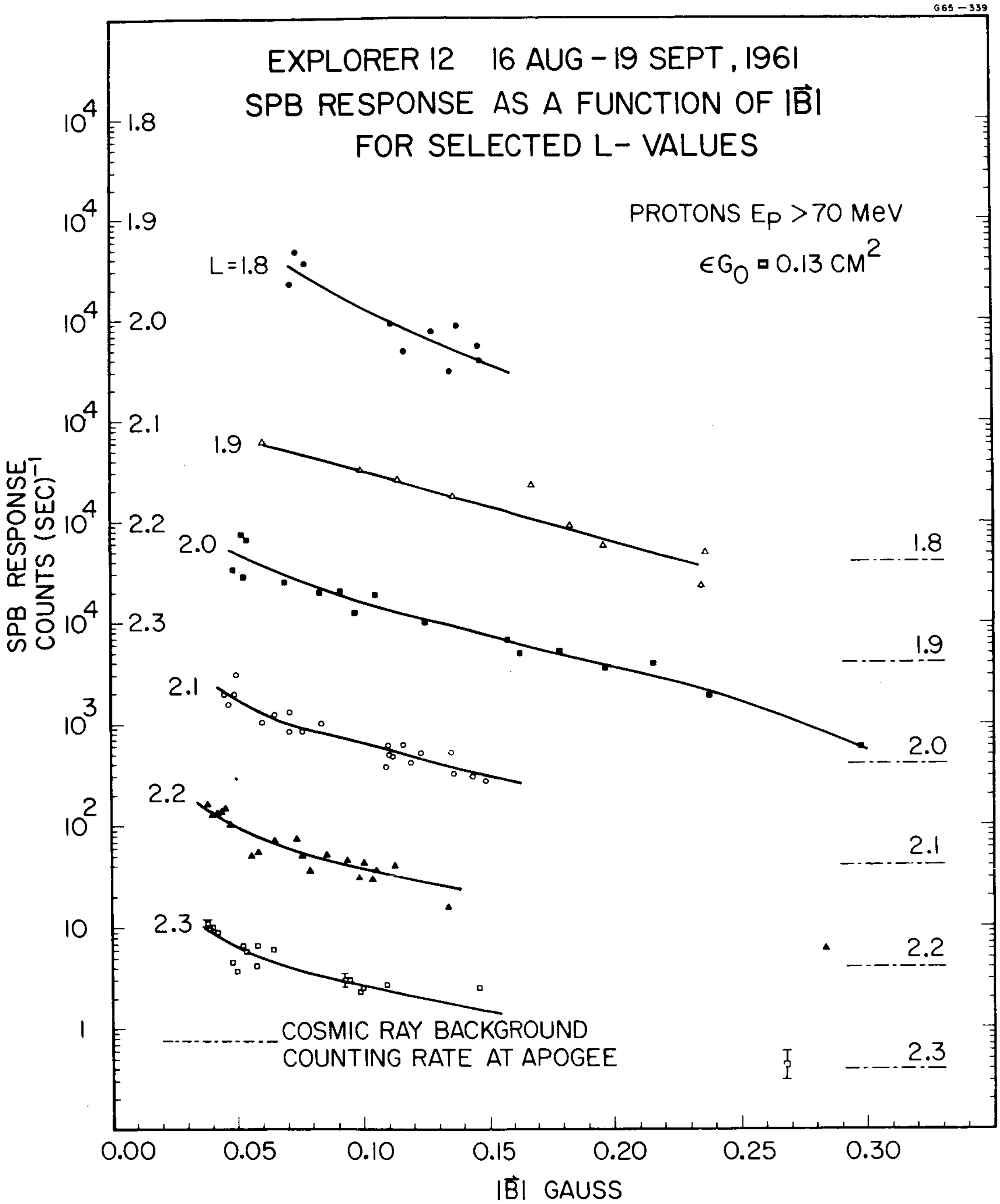

G65—339
EXPLORER 12 16 AUG - 19 SEPT, 1961
SPB RESPONSE AS A FUNCTION OF |B|
FOR SELECTED L- VALUES
PROTONS Ep > 70 MeV
εGo ≈ 0.13 CM2
L=1.8
1.9
2.0
2.1
2.2
2.3
COSMIC RAY BACKGROUND
COUNTING RATE AT APOGEE
SPB RESPONSE
COUNTS (SEC)-1
|B| GAUSS
0.00
0.05
0.10
0.15
0.20
0.25
0.30

Figure 4

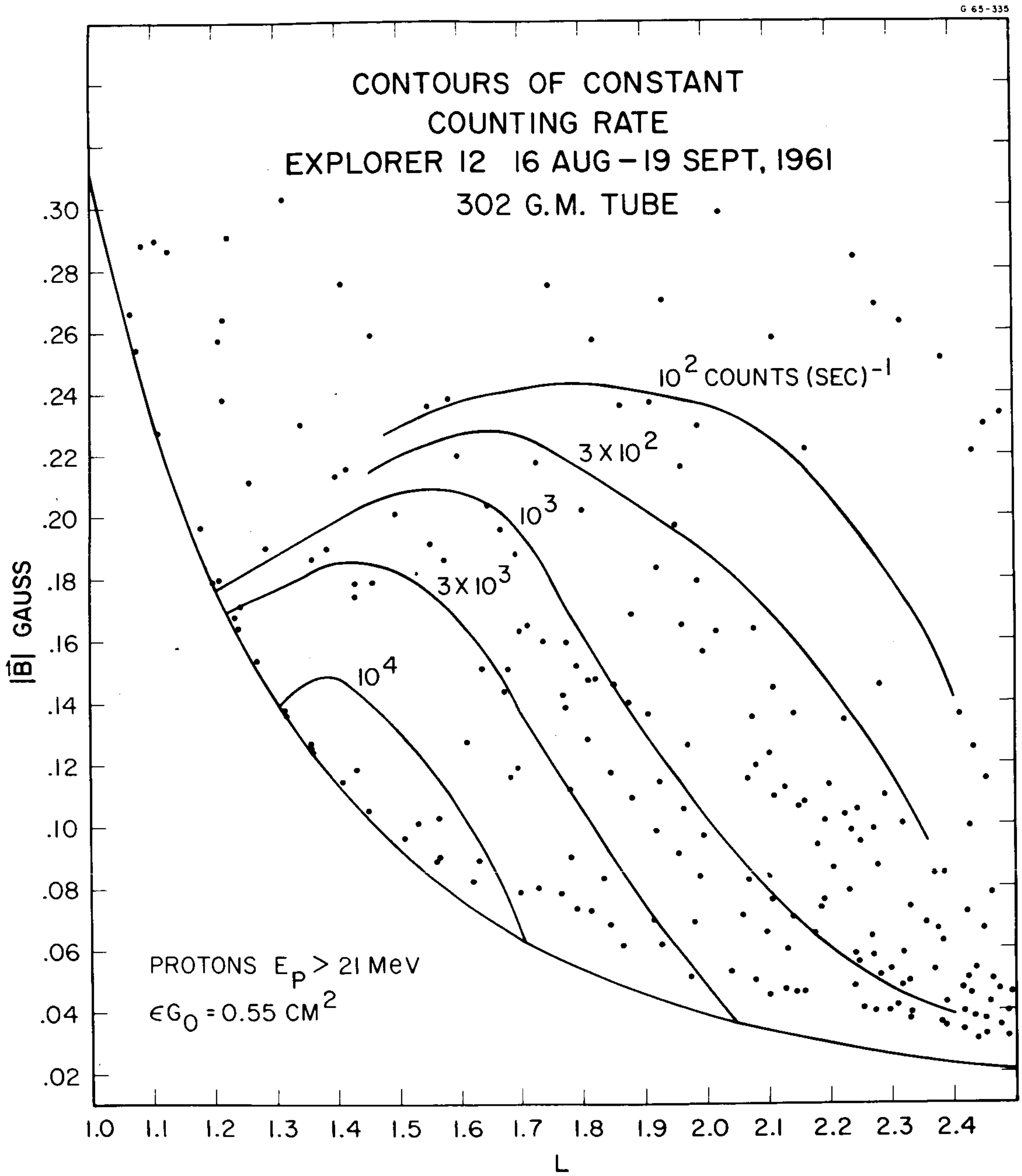
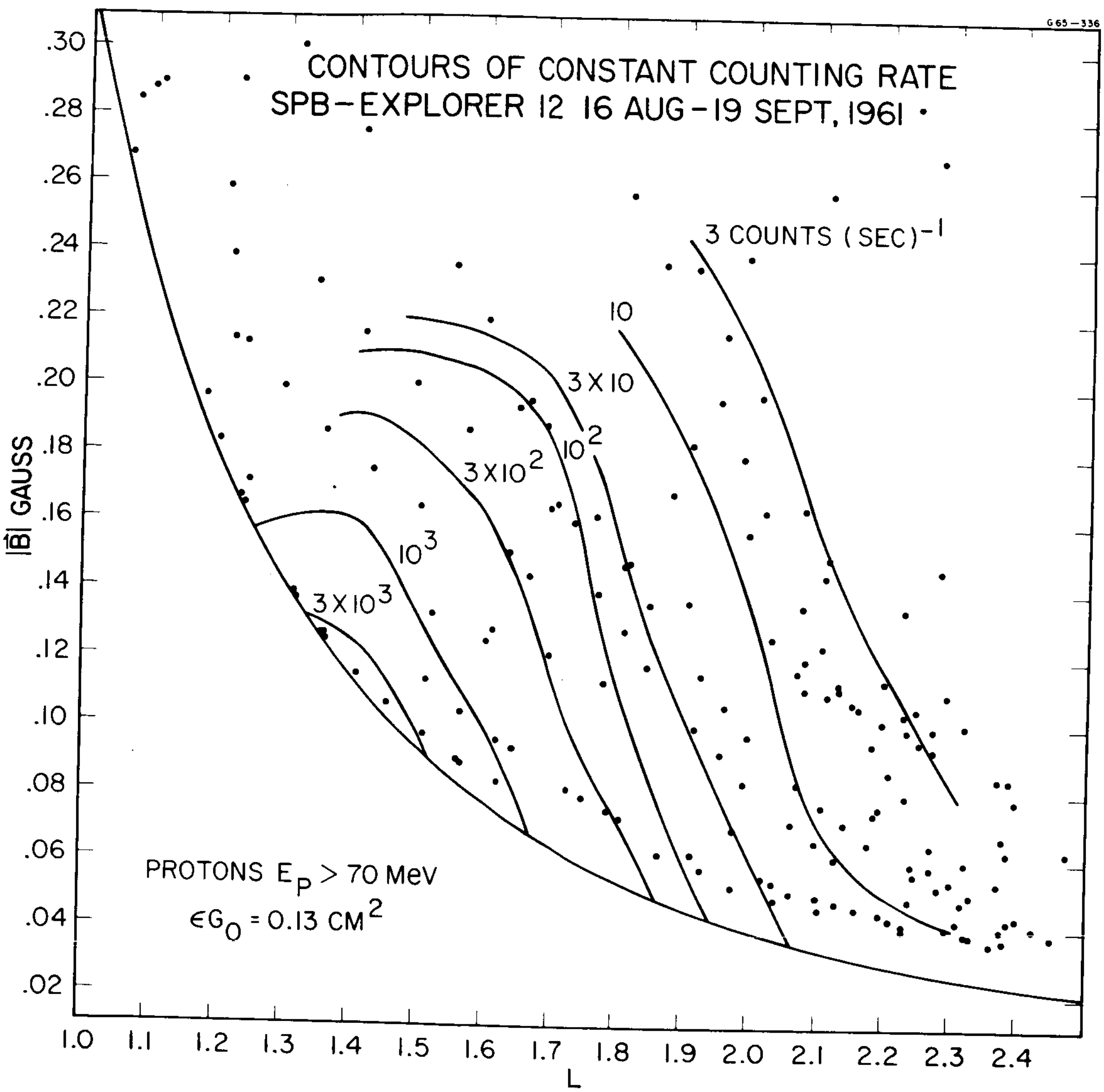

G 65-335
CONTOURS OF CONSTANT
COUNTING RATE
EXPLORER 12 16 AUG – 19 SEPT, 1961
302 G.M. TUBE
10^2 COUNTS $(SEC)^{-1}$
3×10^2
10^3
3×10^3
10^4
PROTONS $E_P > 21$ MeV
$\epsilon G_0 = 0.55$ CM^2
|B| GAUSS
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
L

Figure 5



G65-336
CONTOURS OF CONSTANT COUNTING RATE
SPB-EXPLORER 12 16 AUG-19 SEPT, 1961
3 COUNTS (SEC)$^{-1}$
10
3 X 10
10^2
3 X 10^2
10^3
3 X 10^3
PROTONS $E_P > 70$ MeV
$\epsilon G_0 = 0.13$ CM^2
|B| GAUSS
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
L

Figure 6

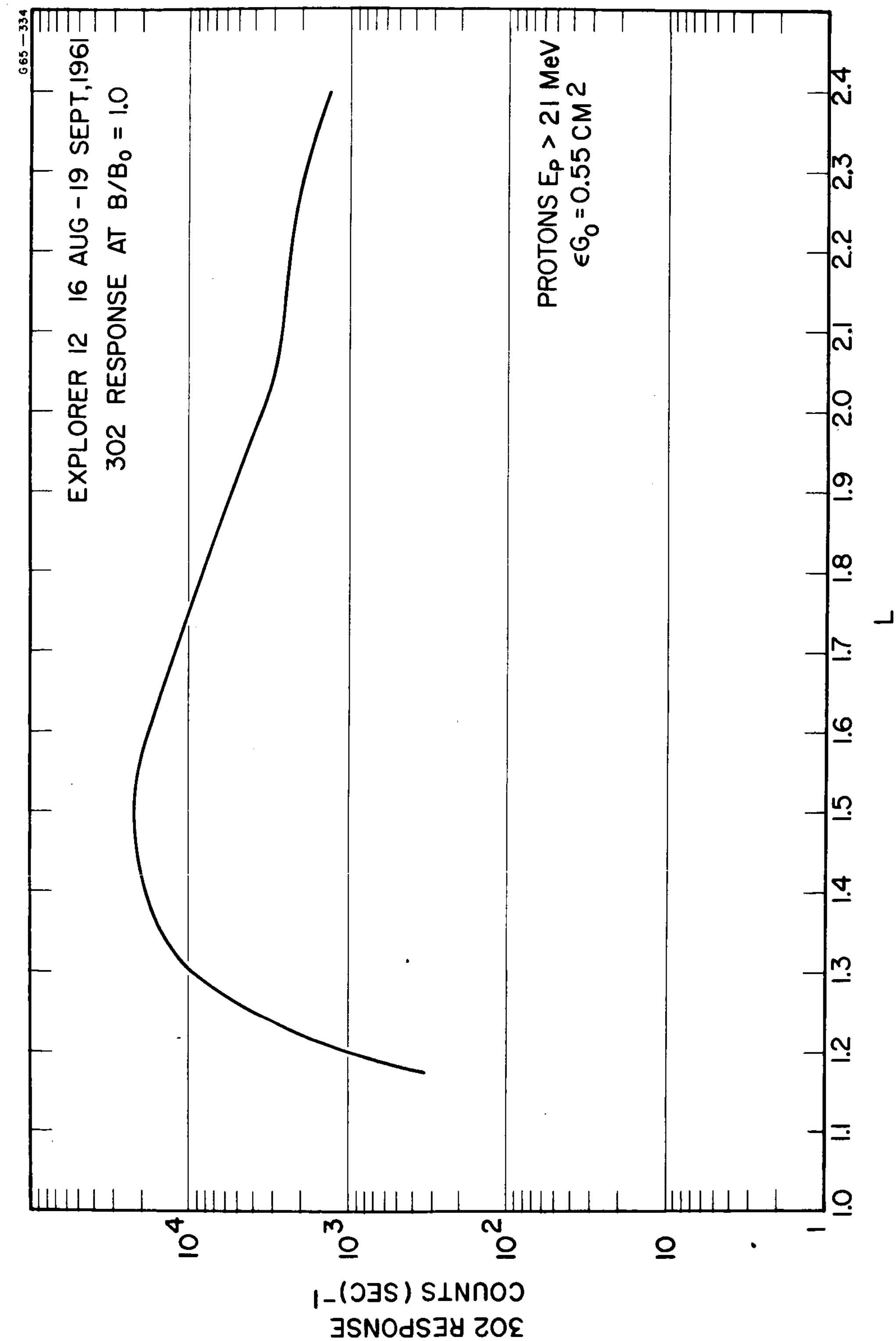

G65 — 334
EXPLORER 12 16 AUG - 19 SEPT, 1961
302 RESPONSE AT B/B_o = 1.0
PROTONS E_p > 21 MeV
ϵG_o = 0.55 CM^2
10^4
10^3
10^2
10
1
302 RESPONSE
COUNTS $(SEC)^{-1}$
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
L

Figure 7

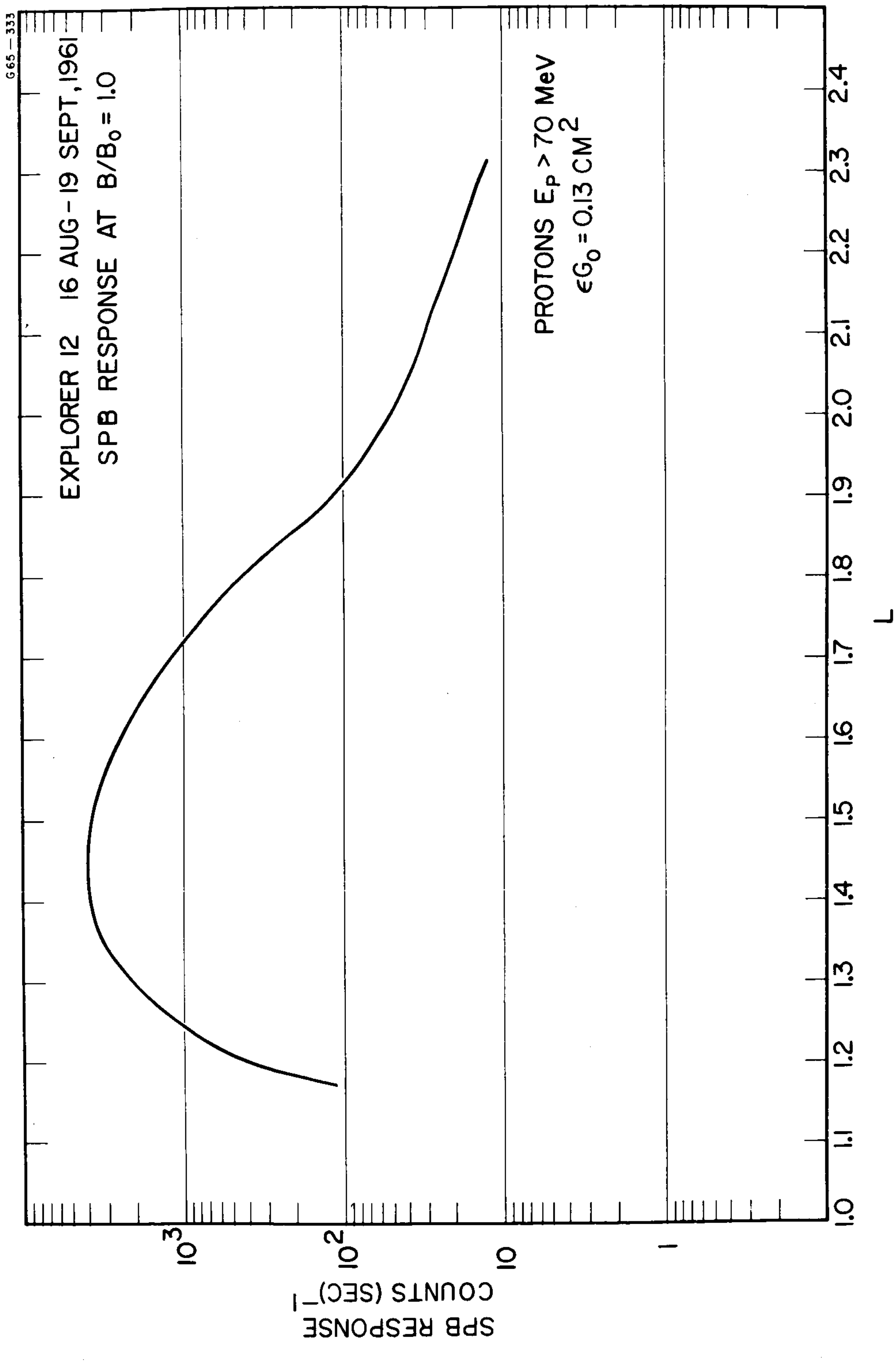
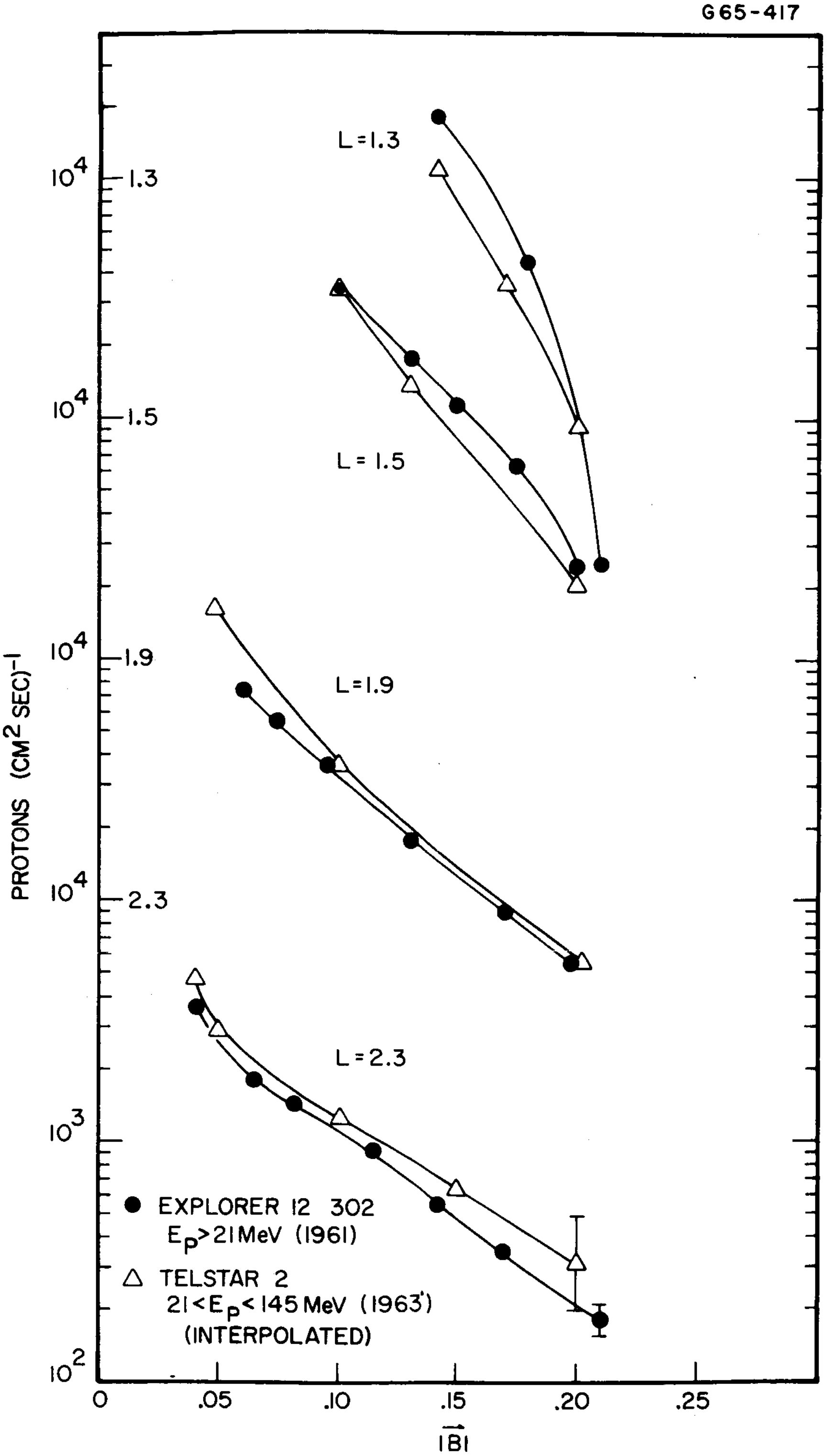

G65 — 333
EXPLORER 12 16 AUG - 19 SEPT, 1961
SPB RESPONSE AT $B/B_0 = 1.0$
PROTONS $E_p > 70$ MeV
$\epsilon G_0 = 0.13$ CM^2
SPB RESPONSE
COUNTS $(SEC)^{-1}$
10^3
10^2
10
1
L
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4

Figure 8



G65-417
L=1.3
L= 1.5
L=1.9
L=2.3
10^4 – 1.3
10^4 – 1.5
10^4 – 1.9
10^4 – 2.3
10^3
10^2
PROTONS $(CM^2 SEC)^{-1}$
0
.05
.10
.15
.20
.25
$|\vec{B}|$
● EXPLORER 12 302
$E_P > 21 MeV$ (1961)
△ TELSTAR 2
$21 < E_P < 145 MeV$ (1963)
(INTERPOLATED)

Figure 9

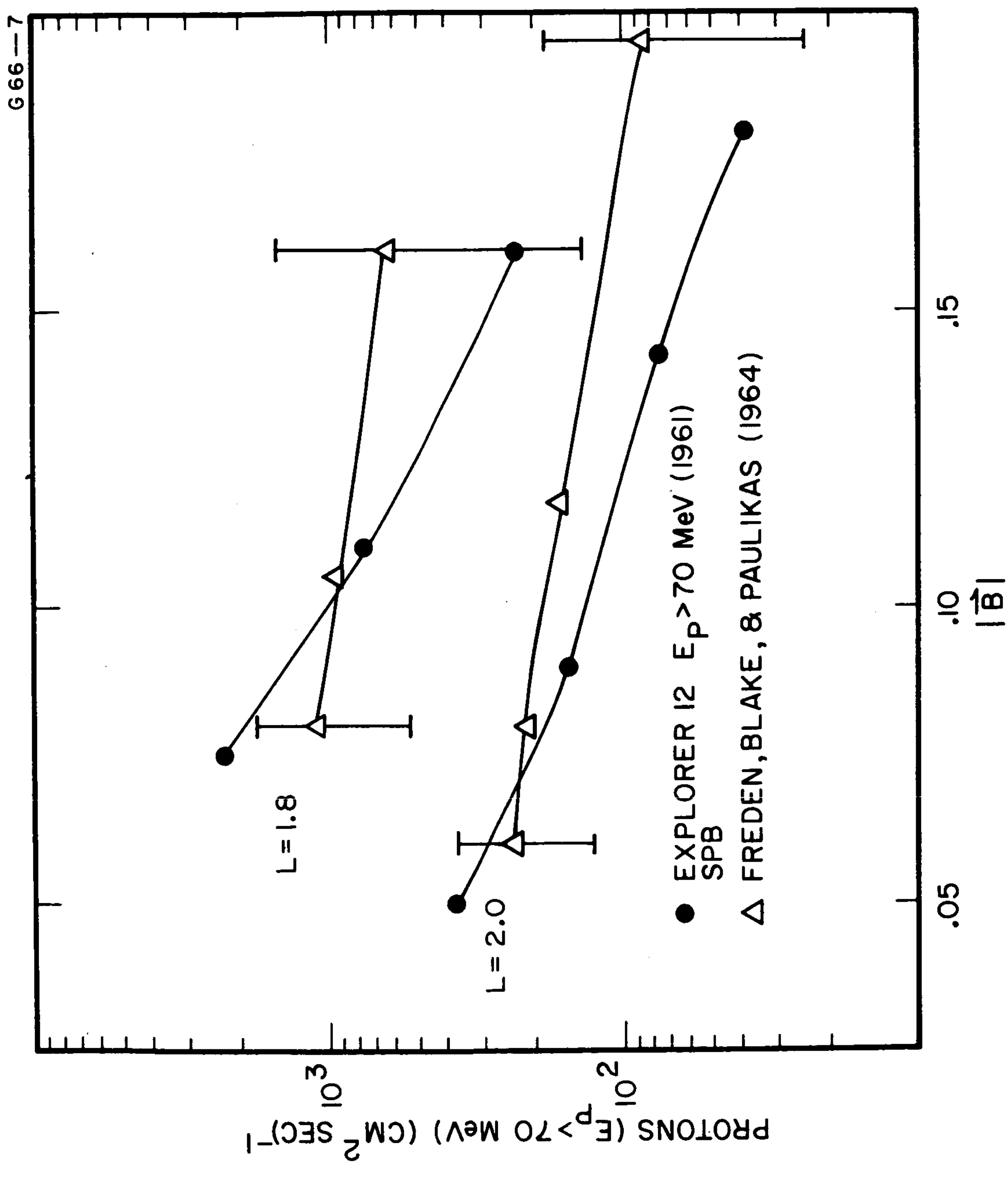
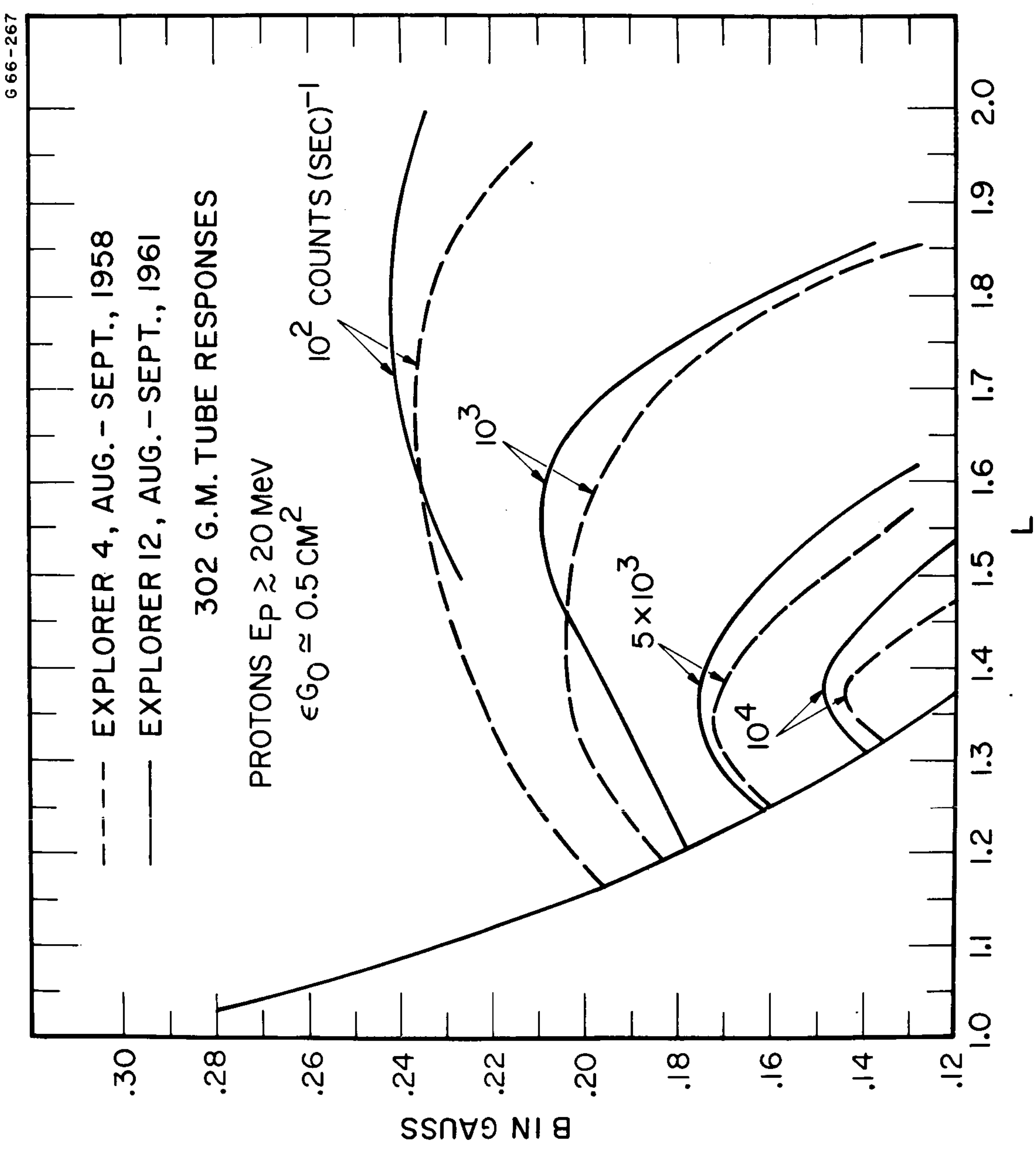

G66—7
L = 1.8
L = 2.0
EXPLORER 12 E_P > 70 MeV (1961) SPB
FREDEN, BLAKE, & PAULIKAS (1964)
.05
.10
.15
|$\vec{B}$|
10^3
10^2
PROTONS (E_P > 70 MeV) (CM^2 SEC)$^{-1}$

Figure 10



G66-267
– – – EXPLORER 4, AUG.-SEPT., 1958
—— EXPLORER 12, AUG.-SEPT., 1961
302 G.M. TUBE RESPONSES
PROTONS $E_P \gtrsim 20$ MeV
$\epsilon G_0 \simeq 0.5$ CM^2
10^2 COUNTS (SEC)$^{-1}$
10^3
5×10^3
10^4
B IN GAUSS
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
L
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0

Figure 11

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) University of Iowa, Department of Physics and Astronomy	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

Explorer 12 Observations of Charged Particles in the Inner Radiation Zone

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Progress

5. AUTHOR(S) (Last name, first name, initial)

Ackerson, K. L. and L. A. Frank

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1966	40	25

8a. CONTRACT OR GRANT NO. Nonr-1509(06) b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) U. of Iowa 66-13 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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13. ABSTRACT

Measurements of energetic charged particles in the inner radiation zone with two shielded, omnidirectional Geiger-Mueller tubes flown on Explorer 12 have been used to construct B-L contours of the omnidirectional intensities of protons $E_p > 21$ Mev and $E_p > 70$ Mev for the period 16 August to 19 September, 1961, prior to the Starfish high-altitude nuclear burst on 9 July 1962. The values of proton ($E_p > 21$ Mev) omnidirectional intensities are in substantial agreement with the post-Starfish values from Telstar 2 and with other observations. Upper limits for the omnidirectional intensities of electrons $E_e > 1.6$ Mev at the geomagnetic equator before the Starfish test are $J_o \le 10^4$ (cm^2-sec)$^{-1}$ at L = 1.2, $\le 4 \times 10^4$ (cm^2-sec)$^{-1}$ at L = 1.25, $\le 2.5 \times 10^5$ (cm^2-sec)$^{-1}$ at L = 1.5, $\lesssim 8 \times 10^4$ (cm^2-sec)$^{-1}$ at L = 1.8 and $\le 1.5 \times 10^4$(cm^2-sec)$^{-1}$ at L = 2.4.

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Inner radiation zone						
Starfish						
Radiation zones						

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