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THE FEBRUARY 5, 1965 SOLAR PROTON EVENT: 1. TIME HISTORY AND SPECTRUMS OBSERVED AT 1100 KM

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The February 5, 1965 Solar Proton Event:

1. Time History and Spectrums Observed at 1100 km

by

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Applied Physics Laboratory

and

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January 1967

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ABSTRACT

The solar proton event of February 5, 1965 was observed in the polar regions with detectors aboard 1963 38C. The initial detection of protons occurred during the pass at 1914 UT, February 5 and the maximum intensity of 115 $cm^{-2}sec^{-1}$ for $E_p \geq 25$ Mev was seen during the pass at 2103 UT, February 5. The time history of the low energy protons ($E_p \geq 1$ to 2 Mev) was considerably more complex than that of the higher energy particles. The maximum observed intensity ($E_p \geq 2$ Mev) was equal to 775 $cm^{-2}sec^{-1}$ at 0232 UT, February 6 and a second maximum was observed following the onset of the magnetic storm on February 6. The detailed discussion of the low energy proton behavior is taken up in the companion paper. For the higher energies the particle flux decayed approximately exponentially in time with the shorter "lifetimes" associated with the higher energies. An attempt to fit the time history with diffusion theory using a diffusion coefficient of the form $D = Mr^{\beta}$ was moderately successful for $E_p \geq 25$ Mev. The spectrum showed a (nearly) monotonic softening with time and a power law generally provided a better approximation to the spectrum than did an exponential form.

INTRODUCTION

The importance 2 solar flare which occurred at 1750 UT on February 5, (Solar-Geophysical Data, 1965) produced solar protons which were observed by satellite 1963 38C and by a number of other spacecraft including IMP 2 (O'Gallagher and Simpson, 1966; F. B. McDonald, personal communication), 1964 45A (Paulikas et al, 1966) and Mariner 4 and INJUN 4 (S. M. Krimigis and J. A. Van Allen, 1967). In the present paper the temporal development of the event as seen by 1963 38C in the polar regions is described and comparisons with other observations are made. Particular attention is paid to the energy dependence of the time history but with emphasis on the higher energy (> 10 Mev) particles. The detailed discussion of the low energy (~ 1 Mev) protons is reserved for the following paper (Williams and Bostrom, 1967) where comparisons with Mariner 4 data show significantly different time histories and possible explanations are put forth.

The results are presented following a description of the satellite and of the detectors used in this work.

INSTRUMENTATION

Satellite 1963 38C was launched into a nearly circular, polar orbit at ~1100 km altitude on September 28, 1963. It is magnetically stabilized to within ~5° of the local magnetic field direction and has been described in some detail by Williams and Smith (1965). The detectors used in this study were only mentioned briefly in the above reference, however, so that a discussion is in order here.

Among the instruments in the satellite are two proton spectrometers, one looking perpendicular ($\theta = 90°$) and one parallel ($\theta = 180°$) to the magnetic alignment axis. The parallel unit looks away from the earth in the northern hemisphere.

Each spectrometer consists of two fully depleted surface barrier solid state detectors (500 micron thick x 50 mm^2 area) arranged as shown in Figure 1. The minimum shielding in any direction (excepting the aperture) is sufficient to stop a 50 Mev proton. Additional shielding is provided to prevent protons with $E < 100$ Mev from entering the telescope in the reverse direction. The permanent magnet which serves as part of the collimator prevents electrons of energy less than ~200 kev from reaching detector A. A sheet of 0.0005" mylar, aluminized on both sides, serves as a light shield.

The operation of the spectrometer is best explained by reference to Figure 2 which shows the (ideal) response of the detectors, as a function of energy, to protons incident parallel to the telescope axis. Discriminator levels at 700 kev, 2 Mev, and 8.5 Mev provide two pulse height windows for each detector (A and B). By observing detector A, both singly and in coincidence with B, we obtain four energy intervals, namely, 0.7-2.0 Mev, 2.0-8.2 Mev (8.2 Mev is the energy at which a proton penetrates detector A with sufficient remaining energy to trigger the 700 kev level on detector B), 8.2-25 Mev, and 25-100 Mev. The effect of the aluminized mylar is noticeable only on the lowest energy thresholds and Table 1 gives the energy intervals including this effect. Although only the 700 kev level on B is used in determining the presence of a coincidence, the singles rates in the "windows" (0.7-2.0 Mev, 2.0-8.5 Mev) on B are also recorded. Since only particles entering through the shielding produce singles counts in B, the B singles rates provide a measure of the omnidirectional background in the low energy channels P1 and P2. The background measurement is not precisely 1:1 because of small differences in shielding and electronics for detectors A and B, and depends somewhat on the angular distribution of the penetrating particles. Channels 1 and 5 (see Table 1) are also susceptible to background from electrons with energy $\gtrsim$ 700 kev. The electron detection efficiency is low ($\lesssim$ 5%) but must be considered in some situations. For the present study, the electron spectrometer (Williams and Smith, 1965) aboard indicates that electrons do not contribute to the proton spectrometer counting rate.

The sensitive (aperture) area for channels 1 to 4 is 0.31 cm^2 and the acceptance cone has a half-angle of 10.1° for channels 1 and 2 ($\bar{A}B$) and 6.9° for channels 3 and 4 (AB), yielding the geometric factors given in Table 1.

The other detectors used in this work are a set of three omni-directional detectors each consisting of a Li-drifted solid state detector in the form of a cube 1.4 mm on a side and a hemispherical absorber. The three detectors are mounted on the end of the spacecraft with a clear view over 2π steradians, symmetrical about θ = 180° (i.e., upward in the northern hemisphere). The minimum shielding over the remaining hemisphere will stop protons with E > 50 Mev, in fact considerably greater when the satellite structure is taken into account.

The electronics associated with each detector consists of a charge-sensitive preamplifier, voltage amplifier, and an integral discriminator set at ~250 kev. Thus, except for edge effects, the detectors are sensitive to all particles above the threshold set by the combination of absorber thickness and discriminator level. The pertinent facts are presented in Table 1 for each detector along with the calculated geometric factor.

The average galactic cosmic ray counting rates obtained from four passes ($L \geq 10$) on February 4, 1965 for detectors A, B, and C, were 0.237 ± 0.019, 0.214 ± 0.025, and 0.212 ± 0.025 counts per second respectively. Using the calculated geometric factor one obtains a cosmic ray flux ($E_p > 25$ Mev) of ~7.3 $cm^{-2}sec^{-1}$. The near earth flux is actually the sum of the primary cosmic ray flux and direct and reentrant albedo. It is questionable whether reentrant albedo should be considered in the polar regions but since the two are not easily separated, we follow the example of Lin et al (1963) in which they measured the albedo to be 0.59 J_p, where J_p is the planetary cosmic ray flux taking into account the shielding of the earth. At 1100 km $J_p \cong 0.77\ J_{IP}$, where J_{IP} is the flux in interplanetary space. The value of J_{IP} for this period of time was measured by Mariner 4 (H. R. Anderson, personal communication) to be approximately 4.2 $cm^{-2}sec^{-1}$. Applying the above albedo conversion factor and earth shielding correction to the Mariner 4 measurement yields for an 1100 km altitude $J_p \approx 3.2\ cm^{-2}sec^{-1}$ and a total (1.59 J_p) flux of ~5.1 $cm^{-2}sec^{-1}$. We consider this 43 percent discrepancy between our measured value and the corrected interplanetary flux to be indicative of the uncertainty in the geometric factor, and in fact, feel that the absolute omnidirectional fluxes of solar protons are known only to within a factor of two. Neither the proton spectrometer nor the omnidirectional detectors can distinguish protons from other heavy ions.

DATA REDUCTION

In this section we describe the methods of selecting and correcting the data used to obtain the fluxes given later. Figure 3 shows the omnidirectional detector A ($E_e \geq 280$ kev, $E_p \geq 2.0$ Mev) counting rate plotted vs. L for three passes of satellite 1963 38C. The first pass, at 1959 UT, February 4 shows a typical quiet-time observation of the outer radiation zone at 1100 km altitude. Note that the counting rate drops to that attributed to galactic cosmic rays for $L > 9.8$. The second pass at 0232 UT, February 6, is the one during which the maximum low energy proton flux is observed. The outer zone profile has changed and the high latitude counting rate clearly increased by a factor of ~150 showing the presence of solar cosmic rays in the polar regions. The shift in the position of the outer zone peak is apparently real and not the result of solar protons penetrating to L's of 6 or 7. The proton spectrometer does not indicate a high intensity of solar protons at these L values, and the electron spectrometer does show a similar distribution for trapped electrons. The increase in intensity by more than a factor of 2 between L = 32 ($\Lambda \approx 78°$) and L = 38 ($\Lambda \approx 80°$) is discussed in Williams and Bostrom (1967). The third pass is from

February 7 at 0730 UT some 17 hours after the sudden commencement on February 6. This pass illustrates the large increase in outer zone intensity which typically follows certain types of magnetic activity (Williams and Smith, 1965). Because counting rates in all detectors are very low, all fluxes presented are averages over the polar regions, defined in most cases as $L \geq 10$ ($\Lambda \geq 70°$). Figure 3 shows that this procedure is generally valid, and in all cases the full complement of detectors has been used to verify that the averages are not contaminated by (outer zone) electrons.

The first step in correcting the data is the subtraction of the average counting rate due to galactic cosmic rays in all channels, as determined from quiet-time passes preceding and following the event. For proton spectrometer channels 3 and 4 and for the omnidirectional detectors, this is the only background correction required. Channels 1 and 2 of the proton spectrometer, however, must be corrected for omnidirectional, penetrating background. The quiet-time cosmic ray data were used to obtain the ratios of P1 to P5 and P2 to P6 for each (90° and 180°) spectrometer. P1 and P2 are singles rates in detector A and P5 and P6 are singles rates in detector B. Then these ratios, together with the P5 and P6 counting rates were used to correct the low energy channels for each pass. In all the fluxes presented here the statistical uncertainties shown include the error introduced by the background subtractions, but do not include uncertainties in geometric factor because these amount to a scale uncertainty and do not significantly affect the relative intensities. Other effects such as dead time corrections and corrections for accidental coincidences are negligible for the counting rates involved here.

Data from the two proton spectrometers (θ = 90°, 180°) were analyzed separately and no statistically significant departures from an assumed omnidirectional flux over the upper hemisphere were found. Therefore, the data from the two were averaged to improve statistics. Several passes during this period were observed by the station at Woomera, Australia. These southern hemisphere data appear to fit quite well with the northern hemisphere points, but the 180° proton spectrometer looks toward the earth and cannot be used. The omnidirectional detectors also count lower for the same reason. An altitude of 1100 km in the vicinity of $L \approx 10$ within view of Woomera implies that local pitch angles $\lesssim$ 50° to 55° will not be populated, assuming that particles which penetrate to 100 km are lost in the atmosphere.

Correcting the omnidirectional detectors for this effect introduces a large relative uncertainty because the absolute value of the geometric factor enters the correction. Woomera points are therefore presented both uncorrected and corrected, assuming that the solid angle of acceptance is exactly 2π steradians, the two points being connected by a dashed line.

RESULTS AND DISCUSSION

Time History: A solar flare of importance 2 was observed in Hα to begin at 1750 UT, reach maximum at 1810 UT, and end at 2000 UT on February 5, 1965. The flare position was 8°N, 25°W in McMath Plage

No. 7661 and produced radio emission of several types including type IV (Solar-Geophysical Data, 1965). VLF phase perturbations over the path from Jim Creek, Washington to Thule, Greenland were produced by the flare associated electromagnetic and particle emissions (B. W. Shaw and A. J. Zmuda, personal communication). Energetic Protons were observed in the vicinity of earth by IMP 2 which was in the magnetospheric tail region near the antisolar direction at a distance $\gtrsim$ 12 earth radii and by Mariner 4 which was ~3700 R_e from earth and approximately 9° from the antisolar direction. The onset times for $E_p \gtrsim 30$ Mev were approximately 1840 UT $\pm$ 10 minutes for both IMP 2 (F. B. McDonald, personal communication) and Mariner 4 (Krimigis and Van Allen, 1967). The near earth high latitude satellites 1963 38C, 1964 45A (Paulikas et al, 1966) and Injun 4 (Krimigis and Van Allen, 1967) are unable to establish a precise onset time in the polar regions. The first observation of high energy (> 25 Mev) protons by 1963 38C was during a pass which began at 1914 UT, February 5, 1965. The PCA event was observed by riometers at Vostok (G. C. Reid, personal communication) and McMurdo (A. J. Masley, personal communication) Antarctica to begin at about 1900 UT.

The fluxes observed by 1963 38C are presented in Figure 4 along with the PCA data from McMurdo and Vostok and 3 hour Kp indices for the period. The times of the flare and of the sudden commencement which occurred some 20 hours after the flare are also indicated. For those data points without error bars, the statistical uncertainties are within the size of the symbol. Only detector OA counts significantly above cosmic ray background during February 8 and 9. All flux values are polar cap averages obtained in the manner described previously.

Of particular interest is the very different time behavior of the several energy groups observed. For $E_p > 25$ Mev (detectors OC and P4) the maximum flux was observed during the pass at 2103 UT on February 5 and apparently decreased monotonically thereafter, following an approximately exponential decay with a mean life of ~9.6 hours, in quite good agreement with Paulikas et al (1966) who measured 11.6 hours for $E_p > 20$ Mev. Because of relatively infrequent sampling by the near earth satellites the times of maximum intensity cannot be determined exactly in the polar regions. However, according to measurements by IMP 2 (F. B. McDonald, personal communication) the maximum for $E_p > 30$ Mev occurred at ~2130 UT on February 5 and Geiger counters aboard Mariner 4 recorded the peak intensity at about 2200 UT. The IMP 2 data at 15 Mev (F. B. McDonald, personal communication; O'Gallagher and Simpson, 1966) agree on the time of maximum and both experiments show decay on February 6 with a mean life of 9 to 10 hours. The PCA data are informative for the polar regions but because of the complex dependence of absorption on the incident spectrum it is difficult to specify the time of maximum for a particular energy group. The riometer data do indicate that rather severe inhomogeneities can exist at high latitudes for periods of hours.

Detector OB, sensitive to protons with $E_p > 8.4$ Mev, reaches its maximum counting rate during the 0232 UT pass on February 6 and also decays monotonically if one ignores the hint of a second peak at 1647 UT on the same day. The decay time is ~14.4 hours, somewhat faster than the 16.8 hours reported for $E_p > 10$ Mev by Paulikas et al (1965). However, the 8.2-25 Mev detector, P3, gives a clearer indication that a second maximum occurs in the intensity of low energy protons, and it is questionable whether it is meaningful to discuss decay times for ~10 Mev protons. Considering now the lower energies as observed by detectors OA, P1, and P2 we find that the complex time structure, barely evident above 8 Mev, is obvious for $E_p > 2$ Mev. In the 1.2-2.2 Mev channel the second peak at 1647 UT is nearly as intense (~75%) as the first (keeping in mind, however, that we are sampling rather than monitoring continuously).

We have attempted to analyze the temporal behavior within the framework of the diffusion model which has been worked out in detail by Krimigis (1965). In this model, which follows one set forth by Parker (1963), the diffusion coefficient, D is of the form

$$D = Mr^{\beta}$$

where β and M may be energy dependent but are independent of heliocentric radial distance, r. The diffusion equation with D in the above form has been solved by Krimigis (1965) in terms of the directional particle intensity, I, and, without reviewing the details, the solution predicts that a plot of $\ln[I\ t^{(\alpha+1)/(2-\beta)}]$ vs. t^{-1} should yield a family of straight lines corresponding to various choices of $(\alpha+1)/(2-\beta)$. The parameter α specifies the dimensionality of the space being used. The value α = 2 corresponds to spherical symmetry and was the value used by Krimigis in comparisons with experimental data and the one used here. The value of β = 0.5 yielded the best approximation to a straight line for detector OC ($E_p > 25$ Mev), implying that the density of scattering centers falls off as $r^{-1/2}$. The data are shown in Figure 5. This might be compared to the value of 0.66 found by Krimigis (1966) for $E_p \gtrsim 55$ Mev for this event, and values of 0.66 and 1.0 for $E_p > 23$ Mev found for the events of September 28, 1961 and April 15, 1963 (Krimigis, 1965). Attempts to apply this procedure to the other channels were unsuccessful, perhaps because of a paucity of data points and poor statistics, but more likely because the basic assumptions of the model do not hold for the low energy protons in this event.

The time behavior of the low energy protons is reminiscent of observations made in July, 1961 and February, 1962 (Pieper et al, 1962; Zmuda et al, 1963) and in September, 1961 (Van Allen et al, 1962) by the 1.5-15 Mev proton detectors on Injun 1. In all of these events (for which adequate data coverage was obtained) the intensity of the low energy particles increased rather slowly compared to the higher energy particles, and a second influx of low energy particles appeared following the sudden commencement of the magnetic storm. This event does not show this phenomenon to the same extent as the September 28, 1961 event, where, concurrent with the beginning of the storm, an increase by a factor of 40 was seen in the polar regions (Van Allen et al, 1962). Judging from the additional structure seen when Injun 4 data are added to the 1963 38C data for the February 5, 1965 event and comparing these data with Mariner 4 observations, the relatively simple picture of low energy protons being contained in the vicinity of the expanding shock front may not apply here (Williams and Bostrom, 1967).

The maximum intensities observed by the various spacecraft are listed in Table 2 along with the times of peak intensity and the energy intervals of the measurements. The two continuous measurements of high energy protons at large distances from the earth (IMP 2 and Mariner 4) are in good agreement on the time of maximum intensity. The absolute flux values for the IMP 2 high energy channels were not available to us, but there is good agreement between the two measurements at 15 Mev. The discrepancy between the IMP and Mariner fluxes reported by O'Gallagher and Simpson (1966) is attributed (by them) to anisotropy or spatial variations. Their Mariner detector is oriented to look in the antisolar direction. The maximum fluxes measured by the three near earth satellites agree quite well considering that the measurements were not simultaneous and sizable variations can occur over short temporal and/or spatial intervals at low energies (Williams and Bostrom, 1967) and even at energies greater than 10 Mev (Paulikas et al, 1965).

We must also consider that the low energy measurements of 1963 38C and Mariner 4 agree quite well for the first peak early on February 6. Unfortunately, we do not have data during the time of the maximum 0.5 - 11 Mev intensity seen by Mariner 4 at 0900 UT on February 7, 1965, but the Injun 4 data available do not show a similar maximum (Williams and Bostrom, 1967).

The Spectrum: For convenience in discussion, we have plotted the omnidirectional detector data in Figure 6 to show the integral energy spectrum for each of five passes during the event. The passes selected are:

2103 UT, February 5 - when the maximum intensity is observed for $E_p \geq 25$ Mev;

0232 UT, February 6 - when the maximum intensity is observed for $E_p \geq 2$ Mev;

1331 UT, February 6 - just prior to the sudden commencement at 1414 UT;

1647 UT, February 6 - the time of the second maximum for low energy particles; and

0730 UT, February 7 - some 36 hours after the first observation of particles in the polar region.

These spectrums are similar to those presented by Paulikas et al (1966), except that they extend lower in energy and show the spectral changes which occur after the sudden commencement. In general, the spectrums cannot be described by a simple function but the results of deriving values for γ from the equation

$$J(E > E_i) = \int_{E_i}^{\infty} J_o E^{-\gamma} dE$$

are shown in Figure 7 for the passes given in Figure 4. Detectors OA and OB were used to obtain γ_1 and detectors OB and OC to obtain γ_2. In all cases γ_2 is greater than γ_1, indicating a spectrum steeper than power law. The more rapid decay of the higher energy particles is evident from the increase in the value of γ with time.

Detector	Energy Sensitivity Protons	Electrons	Mode	Absorber mg/cm^2 Al	Geometric Factor
Proton Spectrometer					
P1	1.2 - 2.2 Mev	--	$A\bar{B}$		0.030 ± 0.008 cm^2ster
P2	2.2 - 8.2 Mev	--	$A\bar{B}$		
P3	8.2 - 25 Mev	--	AB		0.014 ± 0.004 cm^2ster
P4	25 - 100 Mev	--	AB		
P5	Channel 1 Bkgd.	--	$\bar{A}B$		---
P6	Channel 2 Bkgd.	--	$\bar{A}B$		---
Omnidirectional Detectors					
OA	$\gtrsim$ 2.0 Mev	$\gtrsim$ 0.28 Mev	--	10.3 ± 3.5	0.030 cm^2
OB	$\gtrsim$ 8.4 Mev	$\gtrsim$ 0.54 Mev	--	123 ± 7	0.030 cm^2
OC	$\gtrsim$ 25 Mev	$\gtrsim$ 1.98 Mev	--	857 ± 7	0.030 cm^2

TABLE 1: Detector Characteristics

Observer	Energy Interval (Mev)	Time of Maximum Intensity	Maximum Intensity $cm^{-2}sec^{-1}$	$cm^{-2}sec^{-1}ster^{-1}$
IMP 2	> 60 Mev	~2130 UT 5 Feb	---	---
(F. B. McDonald,	> 30 Mev	2130 UT 5 Feb	---	---
personal communication)	15 - 75 Mev	0027 UT 6 Feb	---	~14
IMP 2 (O'Gallagher and Simpson, 1966)	> 15 Mev	~0030 UT 6 Feb	---	~15
Mariner 4 (O'Gallagher and Simpson, 1966)	> 15 Mev	~0130 UT 6 Feb	---	~6
Mariner 4	> 55 Mev	2200 UT 5 Feb	80	---
(Van Allen et al, 1965)	0.5 - 11 Mev	0500 UT 6 Feb	---	100
		0900 UT 7 Feb	---	130
Injun 4	0.52 - 4.2 Mev	0608 UT 6 Feb	---	110
(Krimigis and Van Allen,	0.52 - 4.2 Mev	1635 UT 6 Feb	---	210
1967)	0.90 - 2.1 Mev	0608 UT 6 Feb	---	40
	0.90 - 2.1 Mev	1635 UT 6 Feb	---	52
1964 45A	> 80 Mev	2200 UT 5 Feb	5	---
(Paulikas et al, 1966)	> 40 Mev	2200 UT 5 Feb	98	---
	> 20 Mev	2200 UT 5 Feb	240	---
	> 10 Mev	0020 UT 6 Feb	370	---
1963 38C	> 25 Mev	2103 UT 5 Feb	115	---
	> 8.4 Mev	0232 UT 6 Feb	305	---
	> 2.0 Mev	0232 UT 6 Feb	775	---
	25 - 100 Mev	2103 UT 5 Feb	---	30
	8.2 - 25 Mev	0232 UT 6 Feb	---	31
	2.2 - 8.2 Mev	0232 UT to	---	57
	1.2 - 2.2 Mev	0730 UT 6 Feb	---	40
	2.2 - 8.2 Mev	1647 UT 6 Feb	---	34
	1.2 - 2.2 Mev	1647 UT 6 Feb	---	32

TABLE 2: Maximum Intensities Observed During the February 5, 1965 Solar Proton Event

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FIGURE CAPTIONS

Figure 1: Cross-sectional view of the 1963 38C proton spectrometer. Two of these units are aboard the satellite, one each at 90° and 180° to the magnetic alignment axis.

Figure 2: Response of 500μ Si detectors, arranged as shown in Figure 1, to normally incident protons.

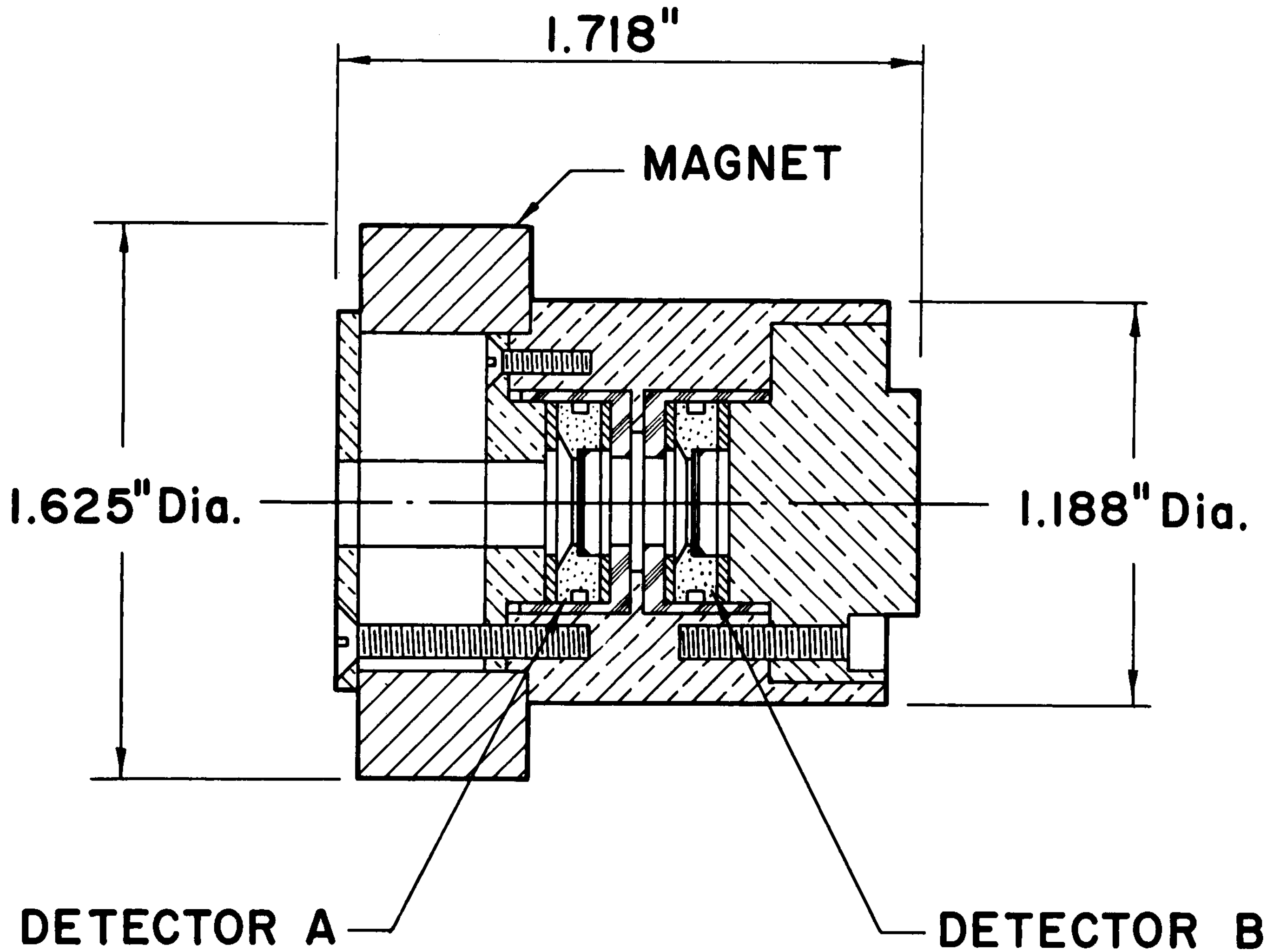
Figure 3: Detector OA counting rates for three high latitude passes. The horizontal lines above L = 10 represent the average polar cap counting rates.

Figure 4: Average fluxes of solar particles observed above L = 10 during February 5-9, 1965. Detector characteristics are given on the figure and PCA data from Vostok and McMurdo are included.

Figure 5: Comparison of data from detector OC ($E_p \geq 25$ Mev) with diffusion theory (Krimigis, 1965). The value $\beta = 0.5$ provides the best fit to the data.

Figure 6: Integral spectrums derived from the omnidirectional detector fluxes averaged over $L \geq 10$ for five passes during the February 5, 1965 solar proton event.

Figure 7: The spectral parameter γ, in an assumed power law spectrum, as derived from the pairs of detectors OA-OB and OB-OC is shown for nine passes during February 5-7, 1965.



(Detectors surrounded by copper)

APL PROTON SPECTROMETER

Figure 1

PROTON SPECTROMETER

Energy deposited in detectors A and B (each 500μ Si) for protons incident normally on A, as a function of proton energy.

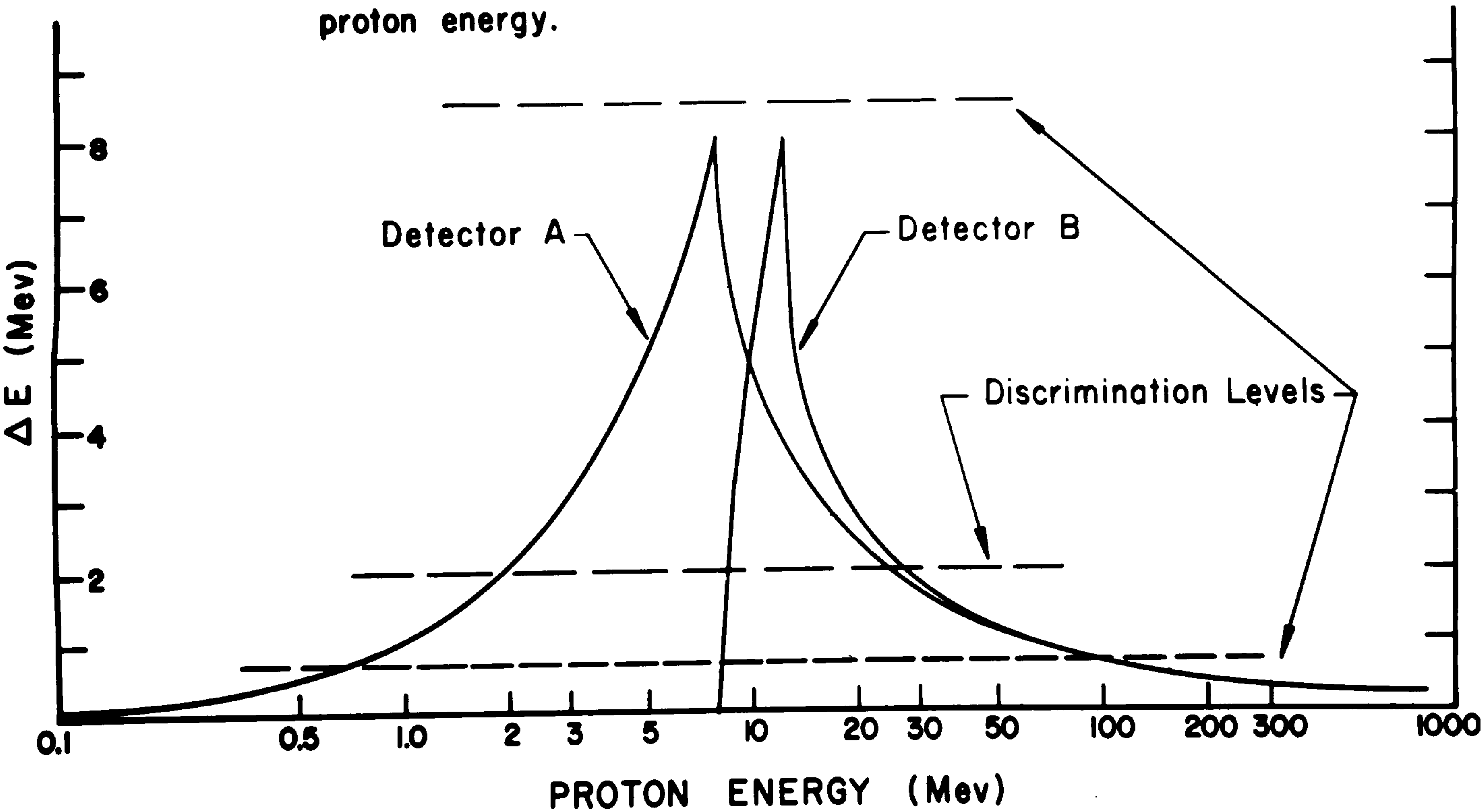


Figure 2

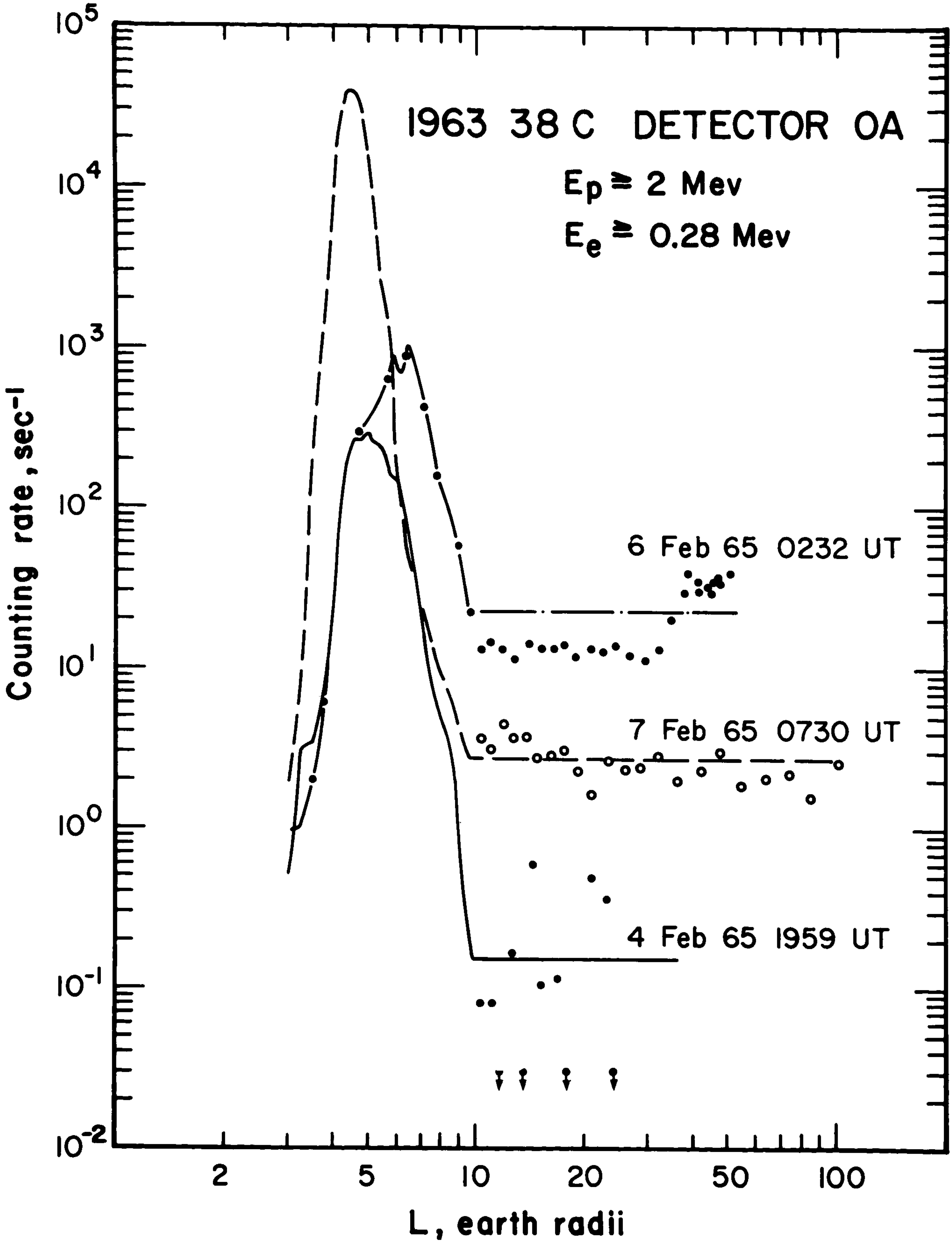
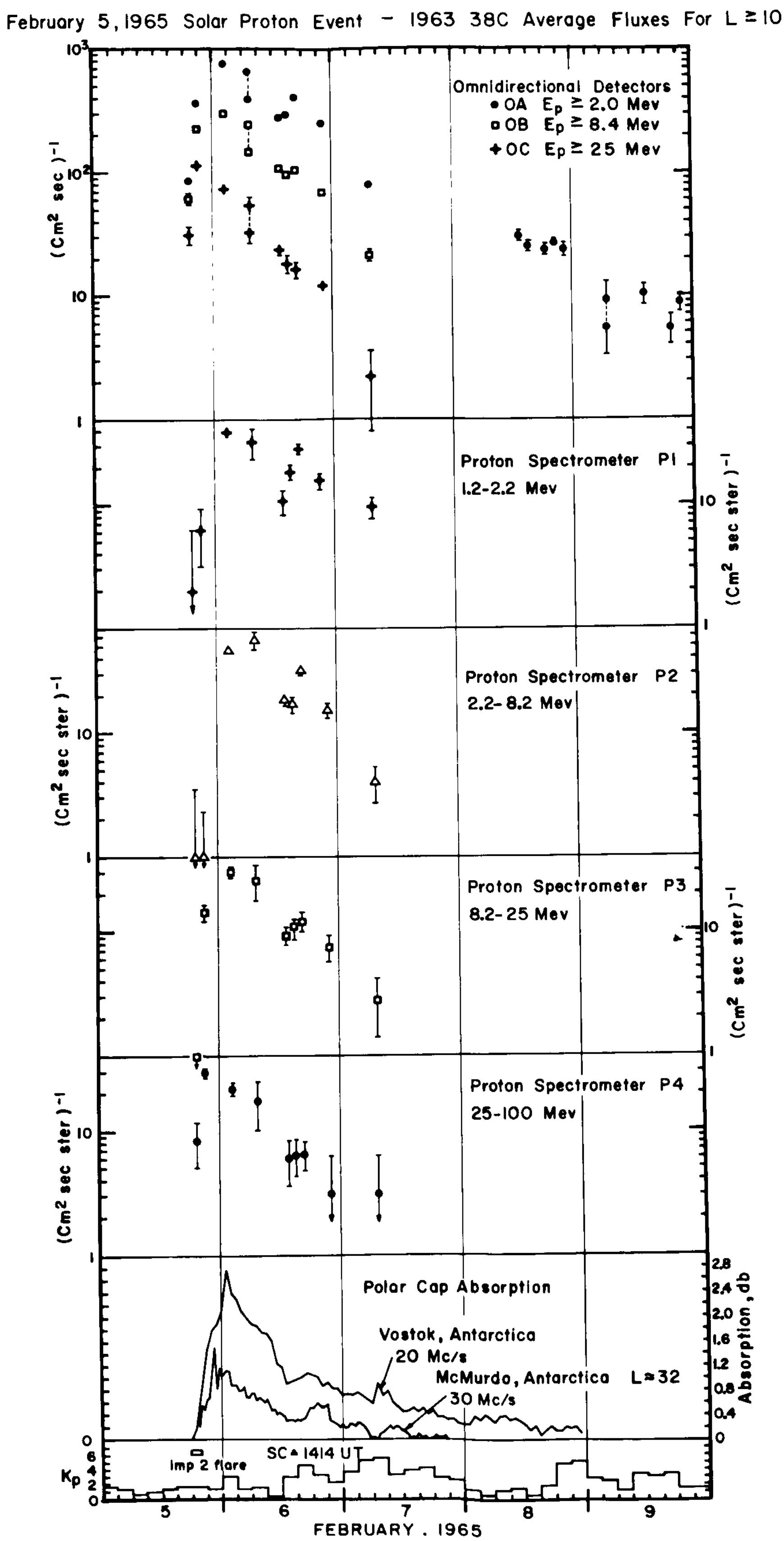
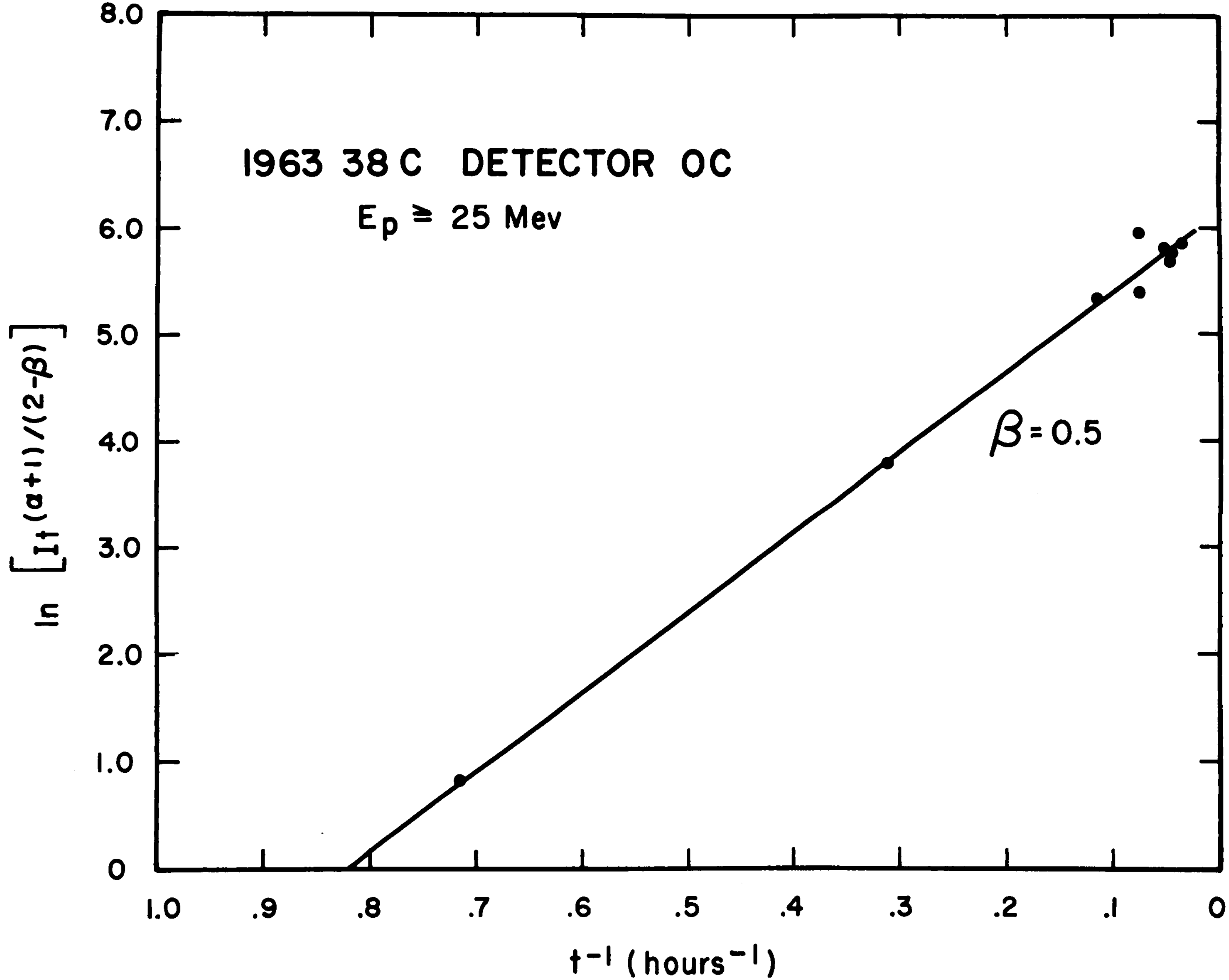

1963 38 C DETECTOR OA
$E_p \geq 2$ Mev
$E_e \geq 0.28$ Mev
6 Feb 65 0232 UT
7 Feb 65 0730 UT
4 Feb 65 1959 UT
Counting rate, sec^{-1}
L, earth radii
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
2
5
10
20
50
100

Figure 3



February 5, 1965 Solar Proton Event - 1963 38C Average Fluxes For L ≥ 10
Omnidirectional Detectors
• OA Ep ≥ 2.0 Mev
▫ OB Ep ≥ 8.4 Mev
✚ OC Ep ≥ 25 Mev
(Cm² sec)⁻¹
Proton Spectrometer P1
1.2-2.2 Mev
Proton Spectrometer P2
2.2-8.2 Mev
Proton Spectrometer P3
8.2-25 Mev
Proton Spectrometer P4
25-100 Mev
(Cm² sec ster)⁻¹
Polar Cap Absorption
Vostok, Antarctica
20 Mc/s
McMurdo, Antarctica L≈32
30 Mc/s
Absorption, db
Imp 2 flare
SC ▲ 1414 UT
Kp
FEBRUARY . 1965

Figure 4



1963 38 C DETECTOR OC
$E_p \geq 25$ Mev
$\beta = 0.5$
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
$\ln \left[I_t (\alpha+1)/(2-\beta) \right]$
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
t^{-1} (hours^{-1})

Figure 5

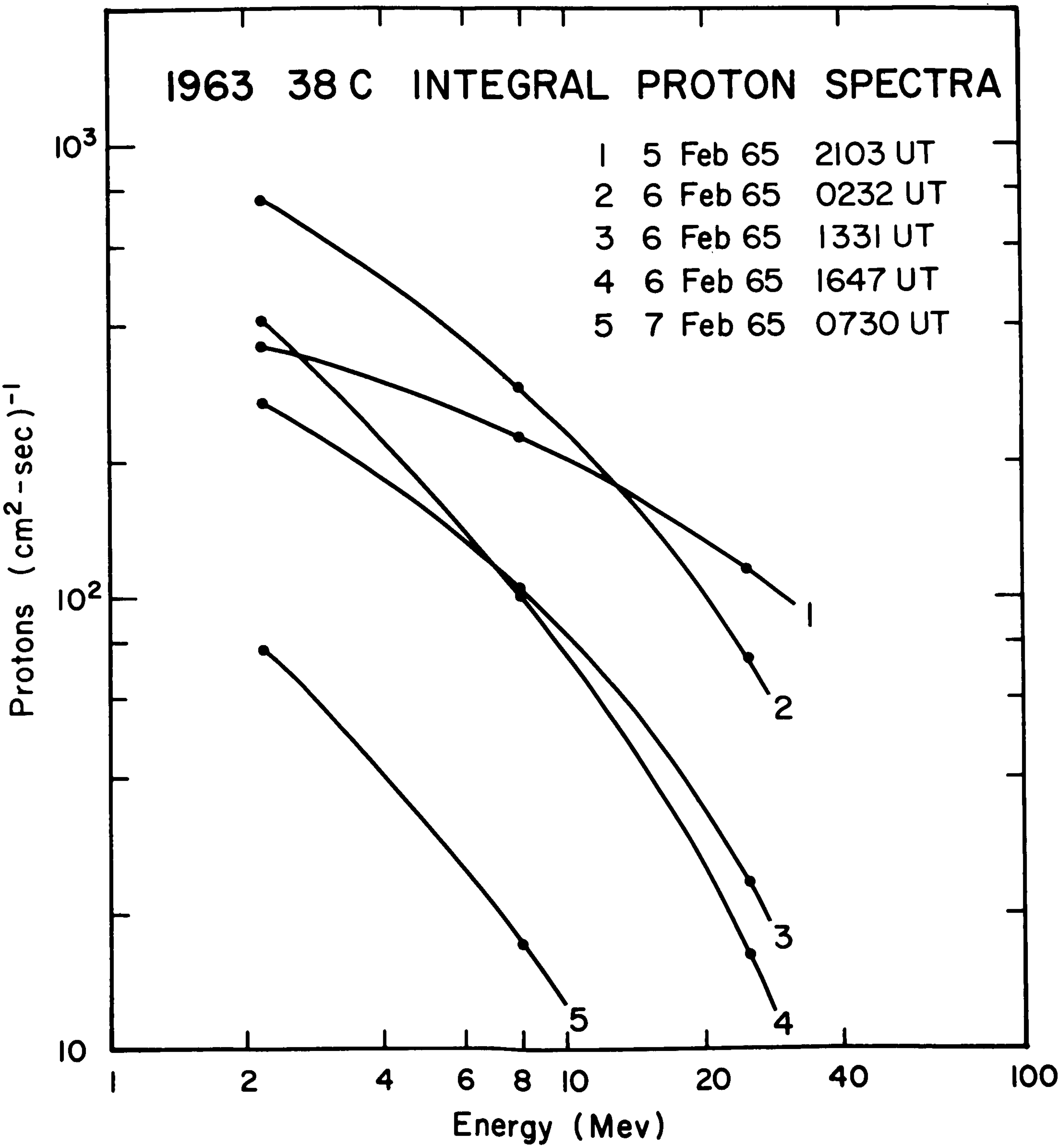
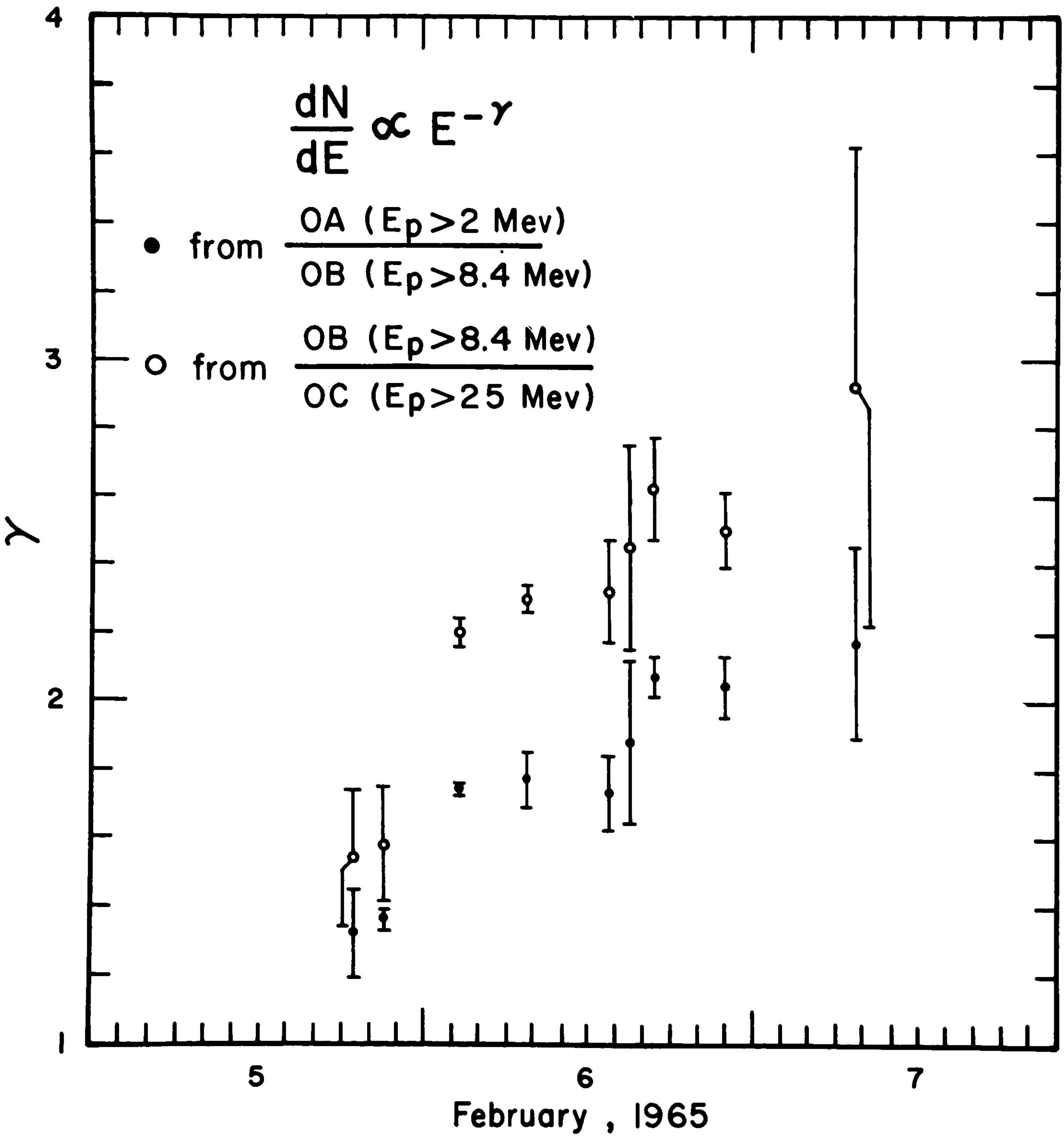

1963 38 C INTEGRAL PROTON SPECTRA
1 5 Feb 65 2103 UT
2 6 Feb 65 0232 UT
3 6 Feb 65 1331 UT
4 6 Feb 65 1647 UT
5 7 Feb 65 0730 UT
Protons (cm^2-sec)$^{-1}$
10^3
10^2
10
1
2
4
6
8
10
20
40
100
Energy (Mev)
1
2
3
4
5

Figure 6



$\frac{dN}{dE} \propto E^{-\gamma}$
● from $\frac{\text{OA } (E_p > 2 \text{ Mev})}{\text{OB } (E_p > 8.4 \text{ Mev})}$
○ from $\frac{\text{OB } (E_p > 8.4 \text{ Mev})}{\text{OC } (E_p > 25 \text{ Mev})}$
4
3
2
1
γ
5
6
7
February , 1965

Figure 7