VOYAGER OBSERVATIONS OF VERY HIGH ENERGY (> 20 MEV/NUCLEON) OXYGEN IONS IN THE INNER JOVIAN MAGNETOSPHERE

H. Breneman

SRL Internal Report #90
September 20, 1983

This document was produced in July 1983 as a result of an attempt to extend Voyager LET data on energetic oxygen in the inner Jovian magnetosphere to much higher energies than previously reported (Gehrels et al. 1981). The purpose was to help assess the potential danger posed by very high energy charged particles in the vicinity of Io (4.9 - 5.3 R_J) to the electronics of the Galileo Jupiter spacecraft scheduled for launch in 1986.

The accompanying figures document the efforts made to extend to higher energies the Voyager CRS data on the oxygen flux in the inner Jovian magnetosphere.

Figs. 1a - 1f display the detector energy losses for the high-energy oxygen events observed by Voyager 1 LETs B and D during the time period 1979:064:0936 to 1979:064:1405, corresponding to distances of 4.9 - 5.3 R_J from Jupiter. The "track" due to oxygen events is apparent, along with a superimposed theoretical track; the broadening of the data track is due mainly to coincidences with protons. Numbers along the track indicate the corresponding incident energy in MeV/nuc. The boxes along the track from 13.15 to 200 MeV/nuc are energy regions used to extend the LET energy coverage beyond the previously published data.

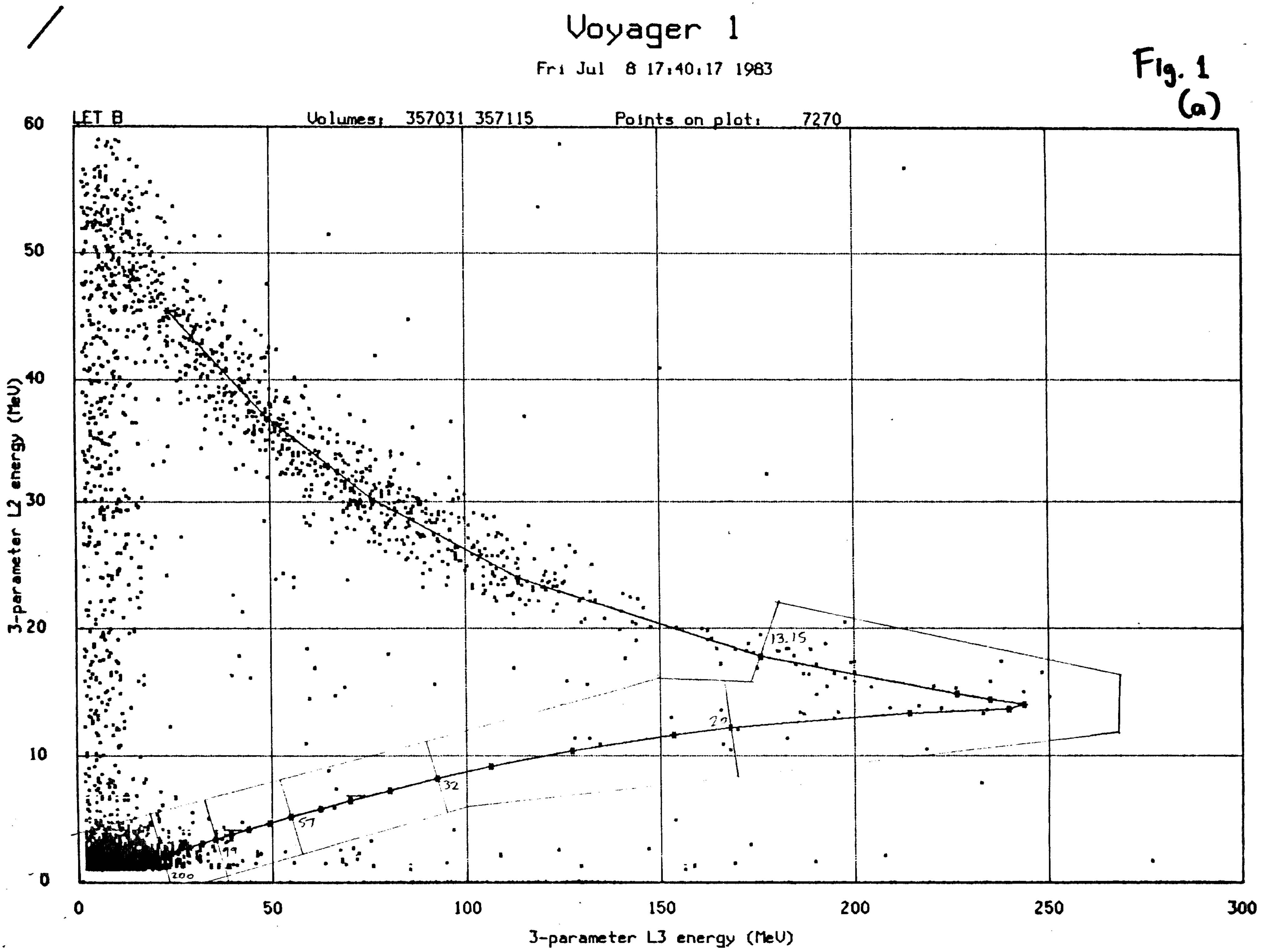
From the L2 vs. L3 plots (Figs. 1a, 1b), it can be seen that background effects become severe above about 100 Mev/nuc. However, most of this background can be removed by requiring L1 to be within the proper range, as is apparent from Figs. 1e and 1f. The second set of scatterplots (Figs. 2a - 2f) are analogous to those in the first set, but with a restriction imposed on the L1 vs. L2 plot. This removes most of the background and provides event totals for the boxes, which were used to extend the differential energy spectrum to higher energies.

Fig. 3 is the differential energy spectrum of oxygen as observed by Voyager 1 LET B at around 5.3 R_J from Jupiter. It corresponds closely to the previously published spectrum (Gehrels et al. 1981). To make the most of poor event statistics at higher energies than these, we wished to combine the data from both operating LETs (B and D) and include radial distances down to closest approach at about 4.9 R_J. In addition, the previously published data imposed no contraints on the L1 energy loss, which is frequently excessively large due to accidental coincidences; but such a constraint was found to be necessary for optimum removal of background at very high energies, as described above. Therefore two additional low-energy spectra were produced to provide the proper normalization for these different event selection criteria. Fig. 4 is the spectrum for LETs B and D combined, from 4.9 to 5.3 R_J, but still with no L1 constraint, like Fig. 3. Fig. 5 is like Fig. 4 but with the L1 constraint imposed, and corresponds to the event selection criteria used for the higher energies; data points at these higher energies, obtained from Figs. 2a and 2b, have been added to Fig. 5. The difference between the spectra in Figs. 3 and 5 amounts to about a factor of 1.5. The least-squares-fit power-law spectral index of Fig. 5 (ignoring the lowest energy point where the spectrum begins to roll over) is 5.55 ± 0.19.

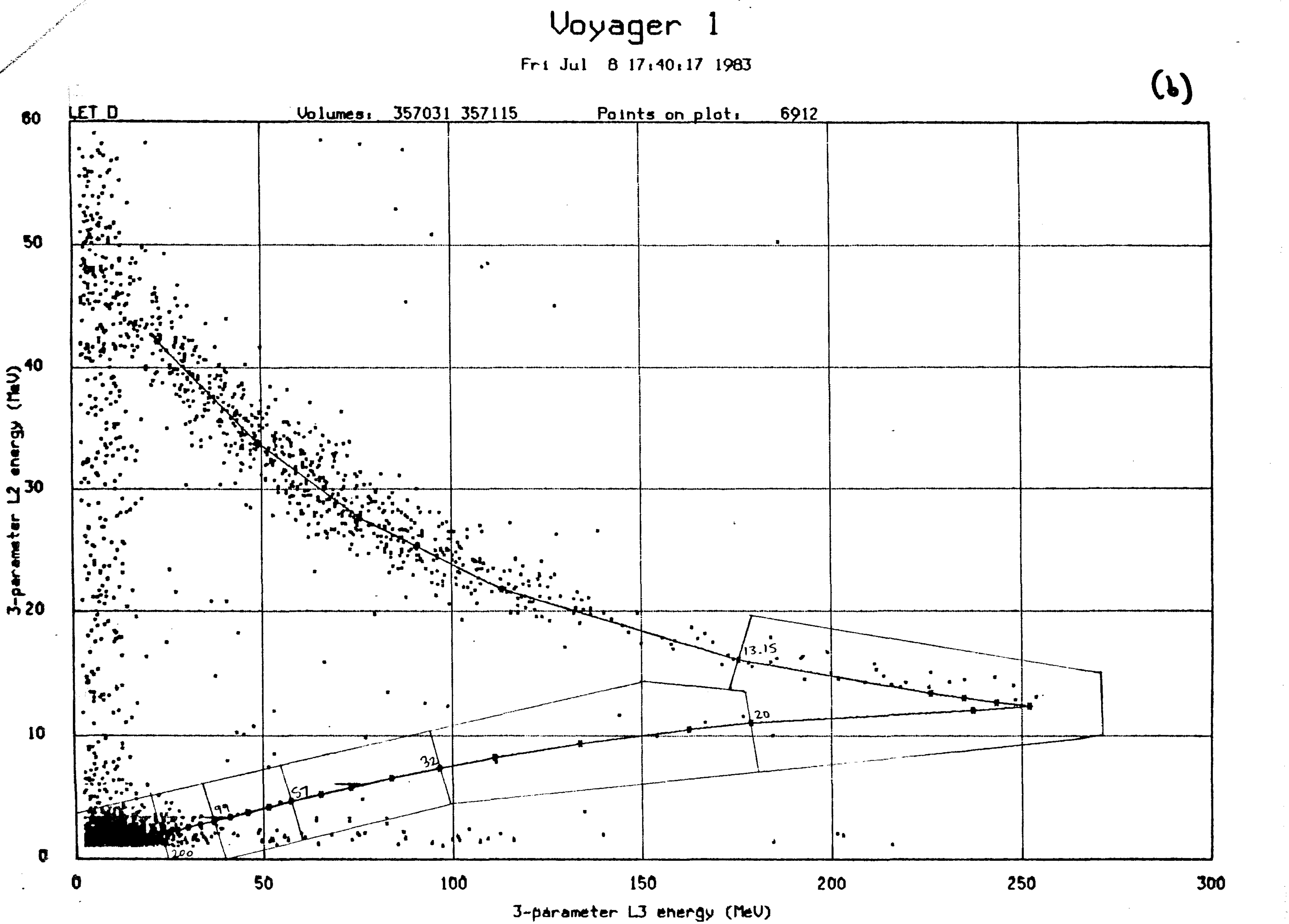
The upper limits shown in solid lines for the two highest energy intervals are based on eight events observed in these intervals. However, we consider these to be most likely background events based on their location on an L1 vs. L2 plot (Figs. 1e, 1f). There is a background distribution concentrated at L2,L3 $< \sim 5$ MeV and L1 $> \sim 10$ MeV; these are caused by oxygen events stopping in L1 in coincidence with a proton in L2 and L3, resulting in a small signal in the latter two detectors. The few events near the L1 vs. L2 oxygen track above 57 MeV/nuc incident energy are almost certainly part of this background distribution rather than the distribution of events on the oxygen track. This interpretation is further supported by the observation that all eight candidate events above 57 MeV/nuc occur in LET D, with none in LET B, although the data in the lower energy ranges is divided nearly equally between the two telescopes. With the assumption, then, that actually no real oxygen events above 57 MeV/nuc were seen, the applicable upper limits in Fig. 5 are as shown in the dotted lines.

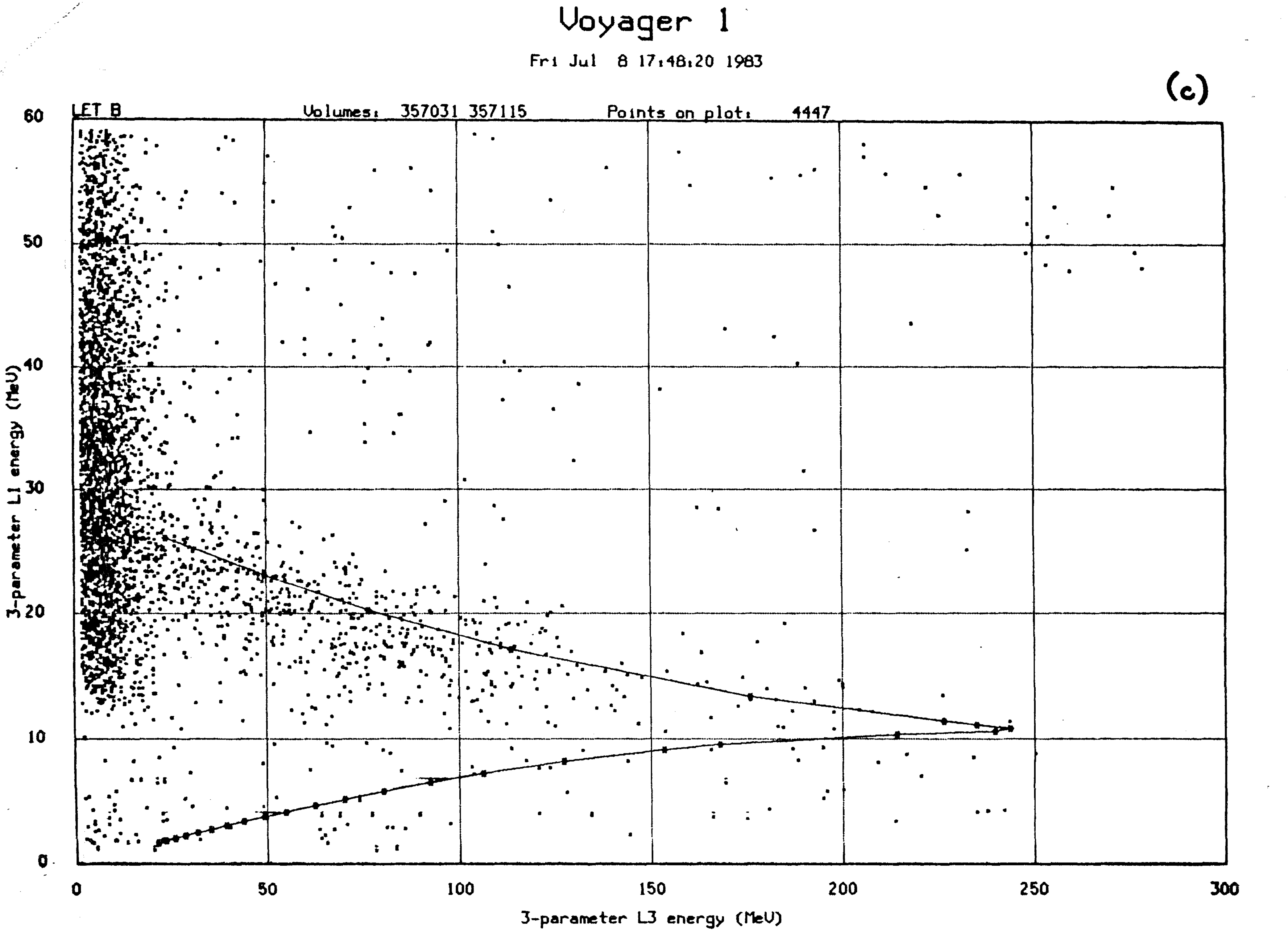
An integral energy spectrum (Fig. 6) was generated from Fig. 5, applying the normalization factor of 1.5 referred to earlier. It has a least-squares spectral index (again ignoring the lowest-energy point) of 4.26 ± 0.17 and predicts about an order of magnitude less flux above 70 Mev/nuc than does the extrapolated spectrum in Fig. 3 of (McKibben 1983).

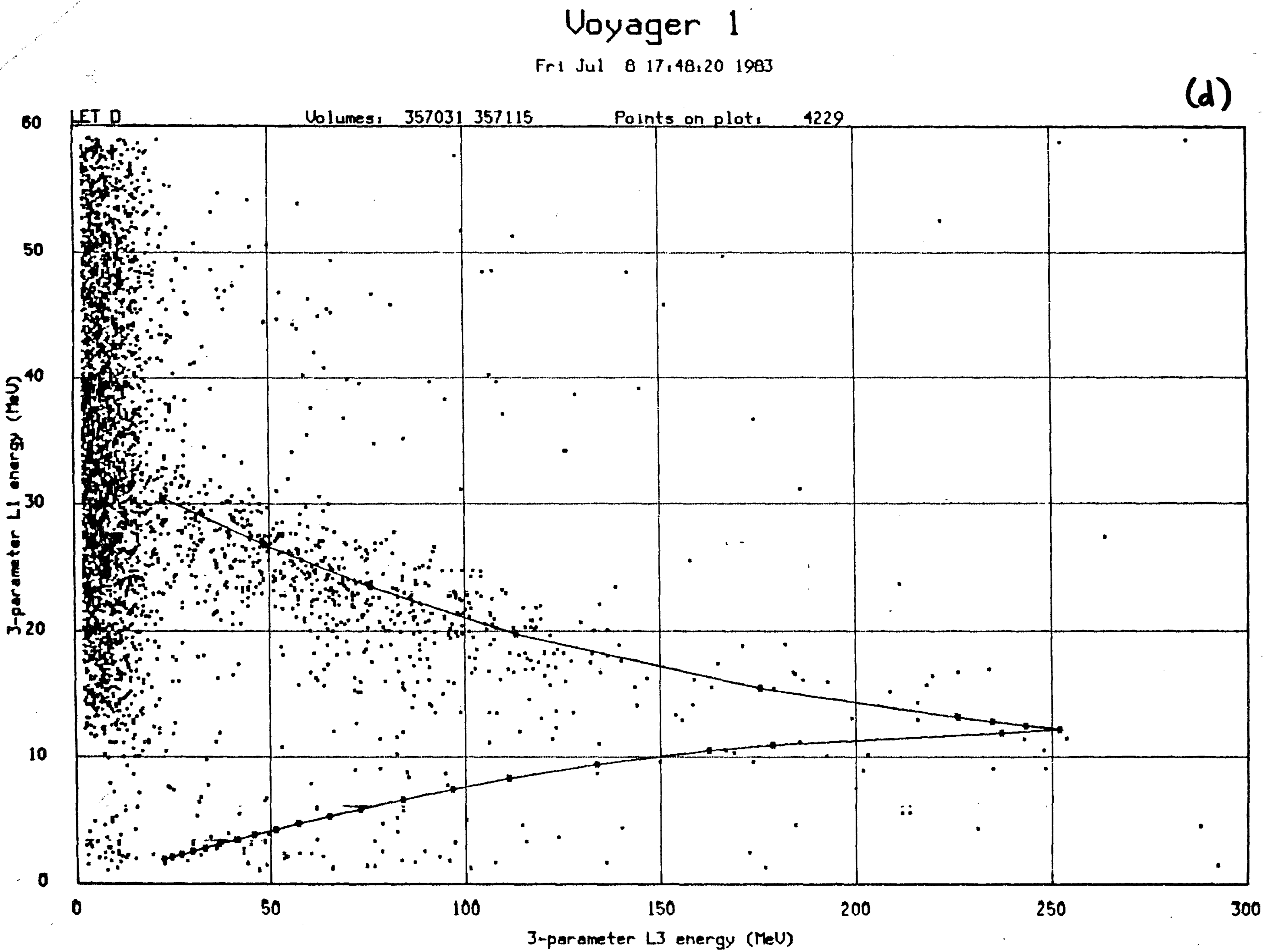
H. H. Breneman
July 11, 1983

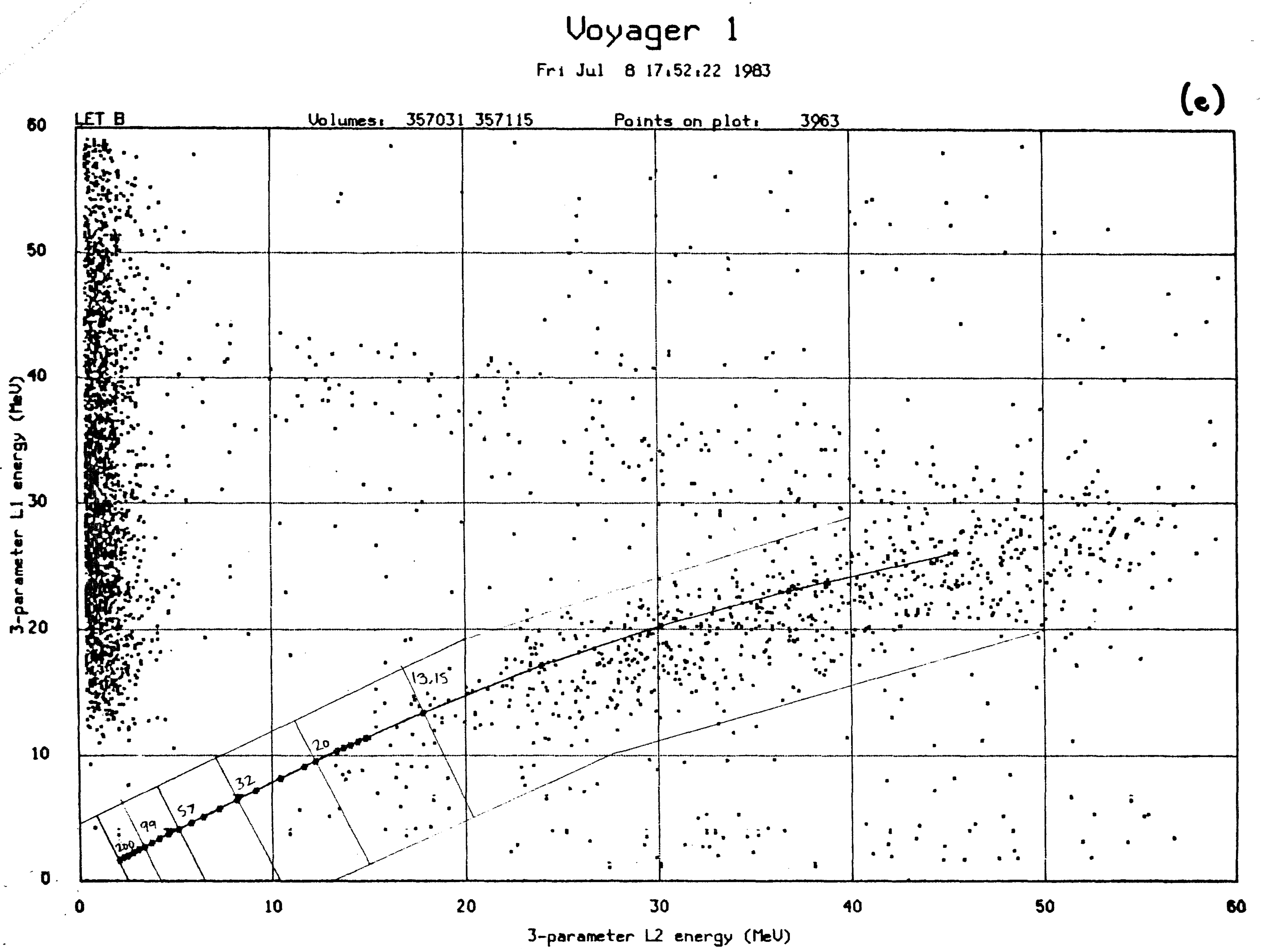


Voyager 1
Fri Jul 8 17:40:17 1983
Fig. 1
(a)
LET B
Volumes: 357031 357115
Points on plot: 7270
3-parameter L2 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
0
50
100
150
200
250
300
13.15
32
57
200


Voyager 1
Fri Jul 8 17:40:17 1983
(b)
LET D
Volumes: 357031 357115
Points on plot: 6912
3-parameter L2 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
0
50
100
150
200
250
300
13.15
20
32
57
99
200


Voyager 1
Fri Jul 8 17:48:20 1983
(c)
LET B
Volumes: 357031 357115
Points on plot: 4447
3-parameter L1 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
0
50
100
150
200
250
300

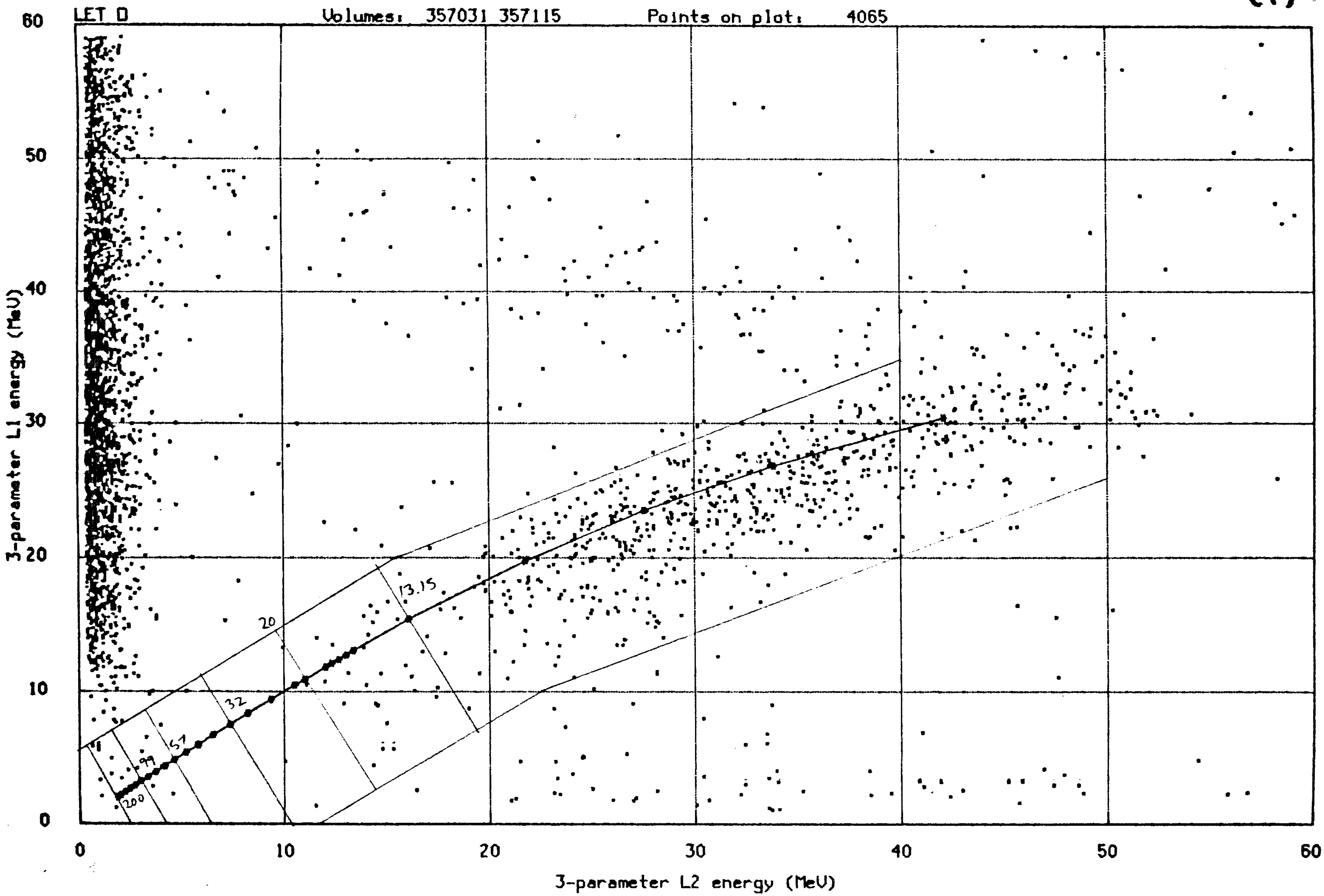

Voyager 1
Fri Jul 8 17:48:20 1983
(d)
LET D
Volumes: 357031 357115
Points on plot: 4229
3-parameter L1 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
0
50
100
150
200
250
300

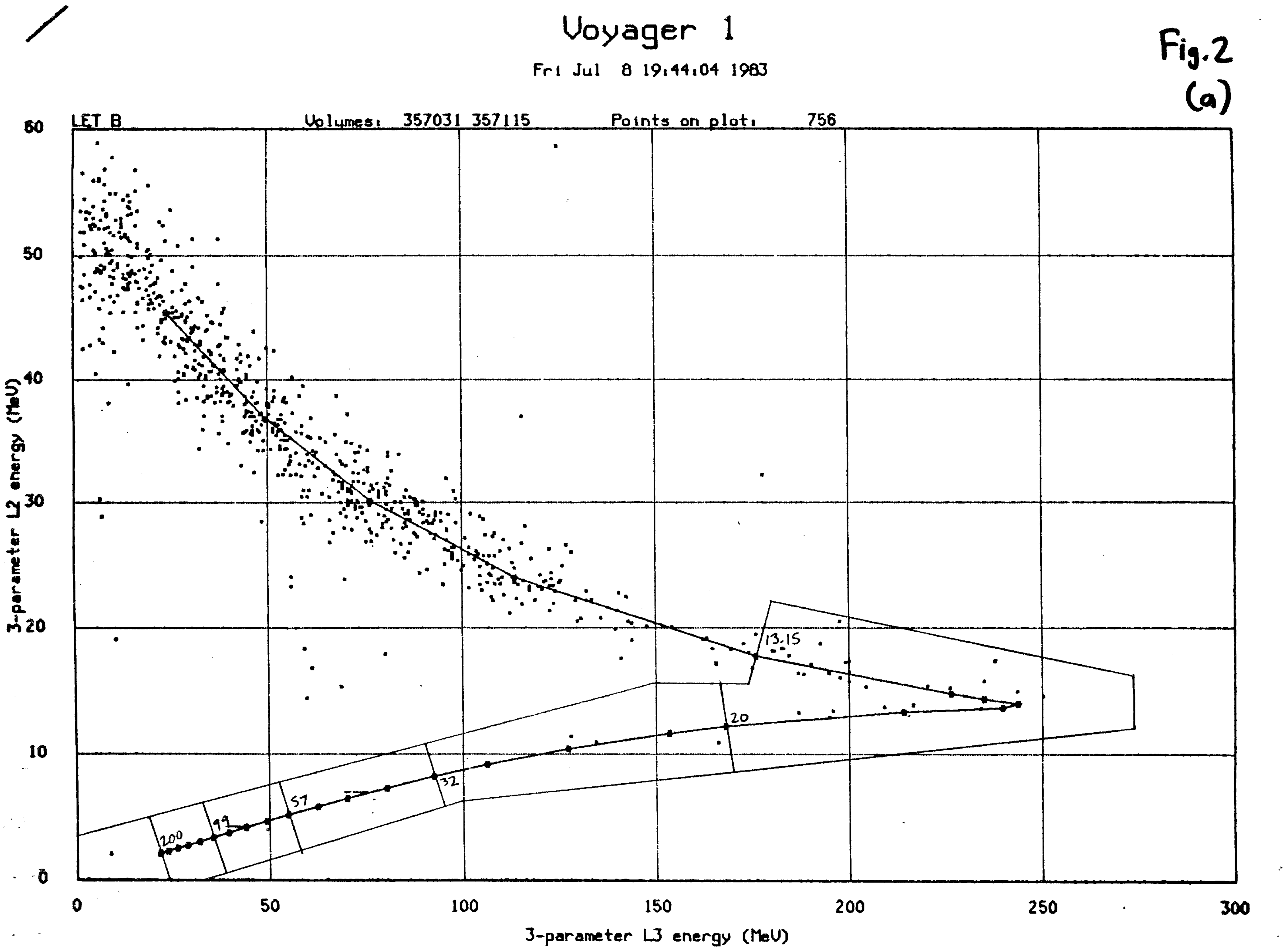

Voyager 1
Fri Jul 8 17:52:22 1983
(e)
LET B
Volumes: 357031 357115
Points on plot: 3963
3-parameter L1 energy (MeV)
3-parameter L2 energy (MeV)
0
10
20
30
40
50
60
200
99
57
32
20
13.15

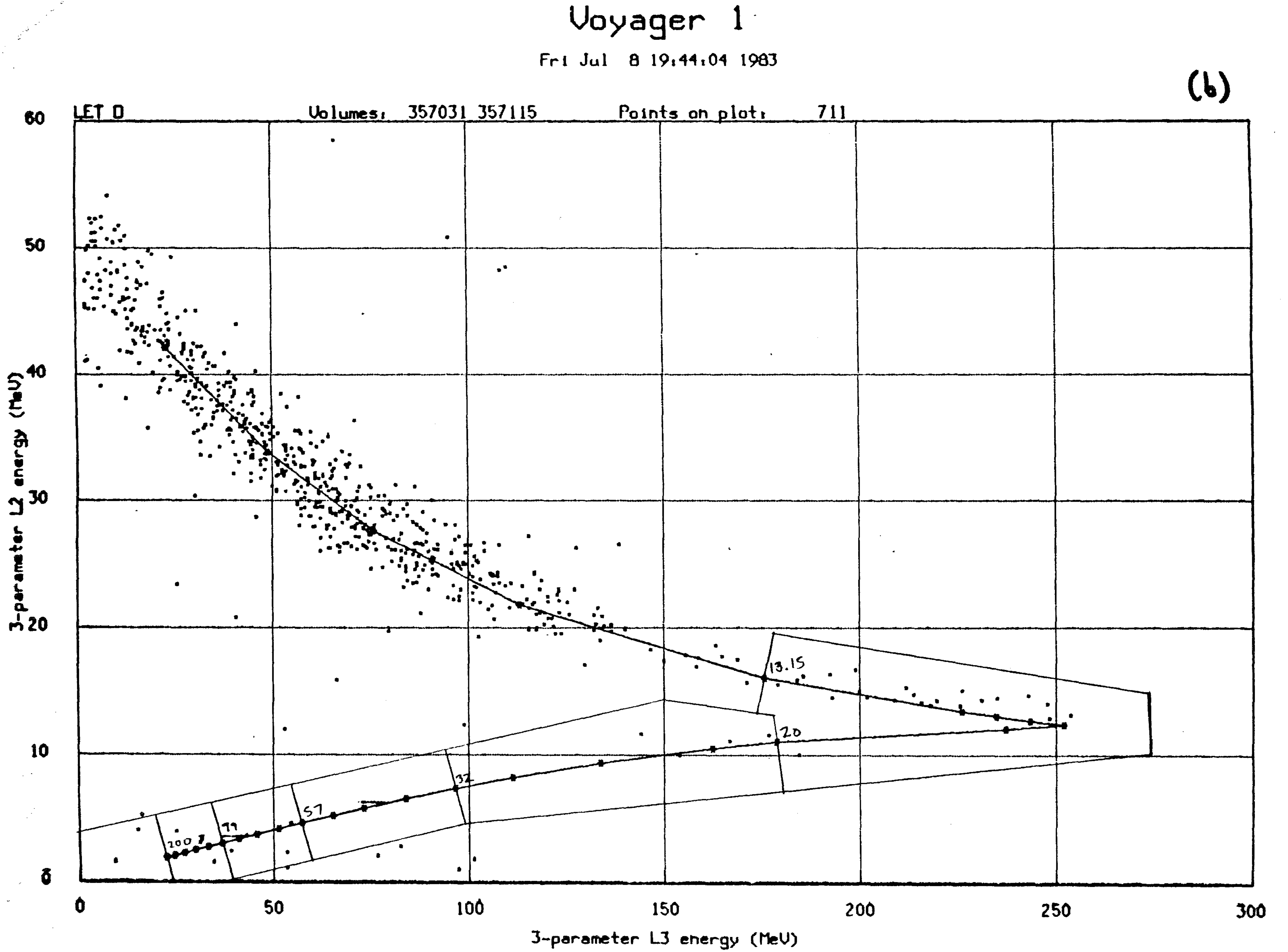
Voyager 1

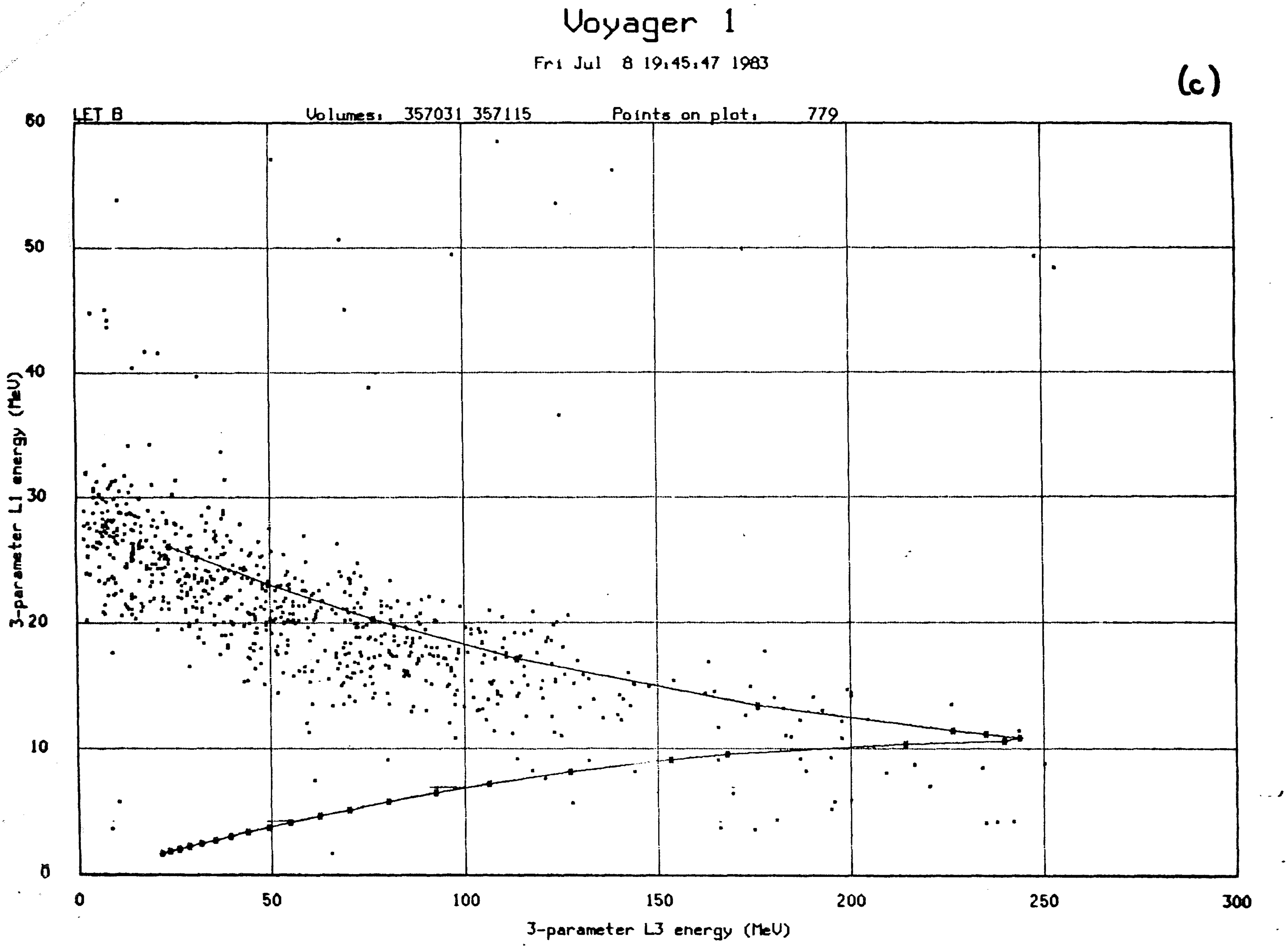
Fri Jul 8 17:52:22 1983

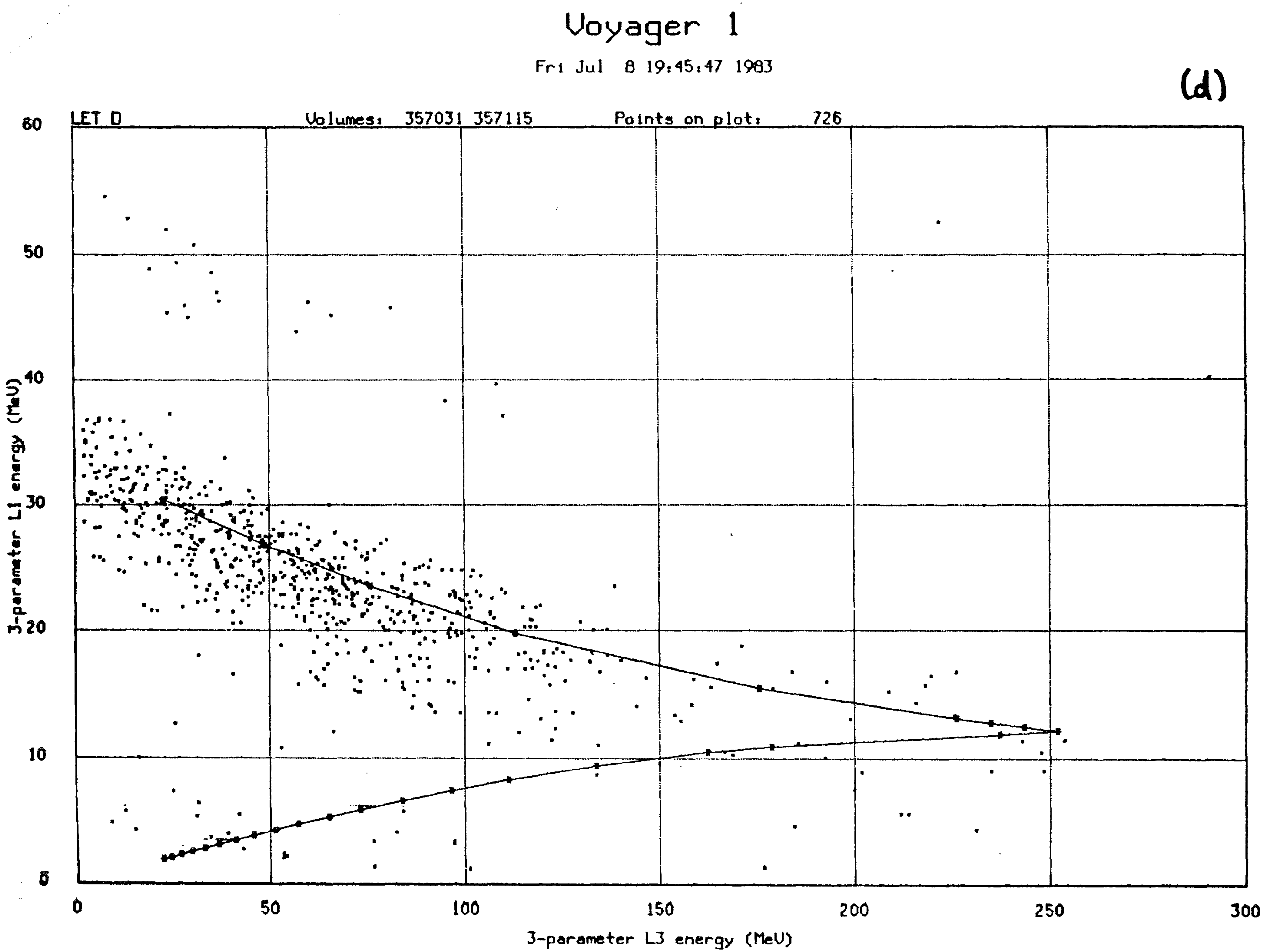
(f)

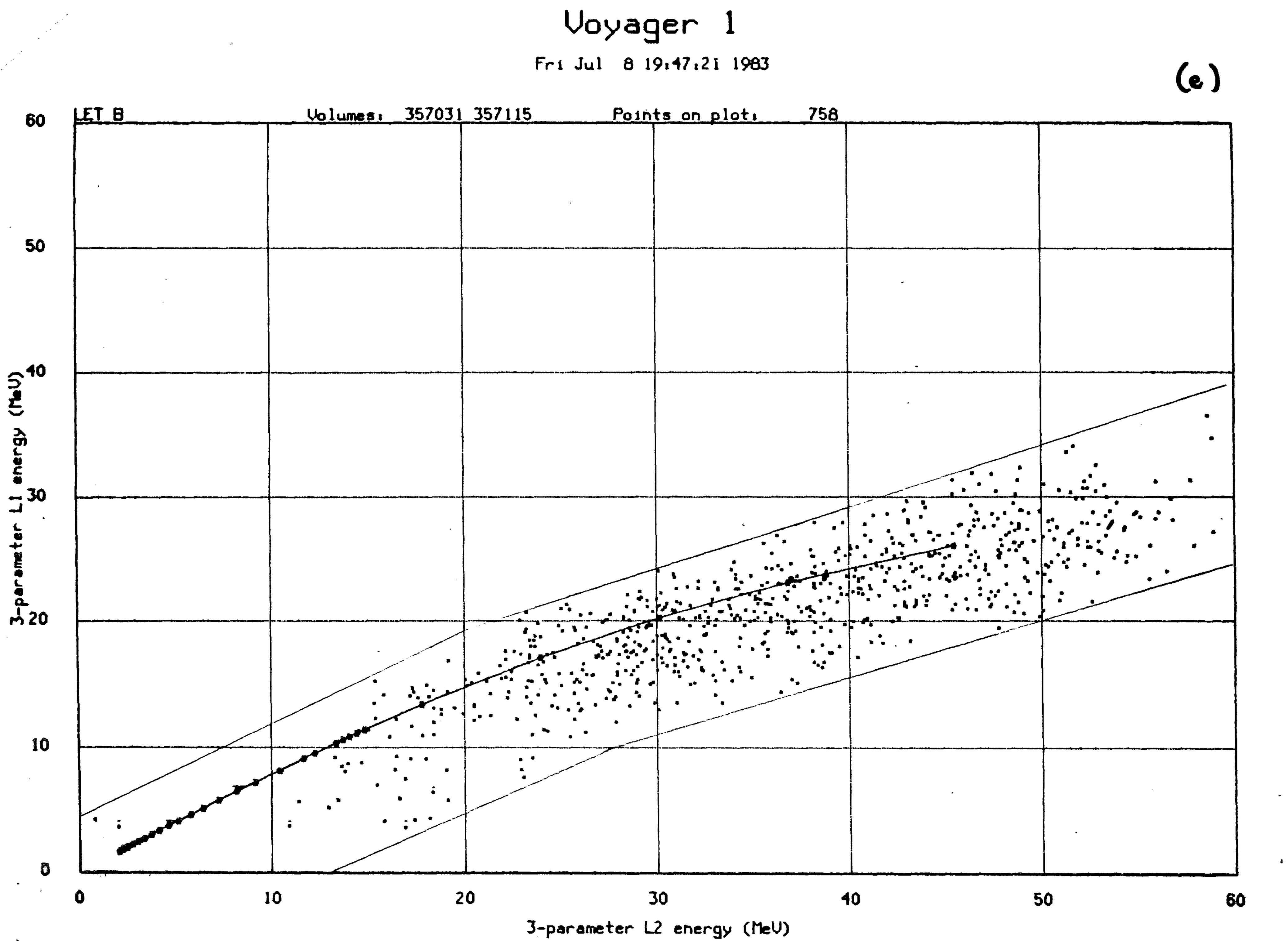



Voyager 1
Fri Jul 8 19:44:04 1983
Fig.2
(a)
LET B
Volumes: 357031 357115
Points on plot: 756
3-parameter L2 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
50
100
150
200
250
300
200
99
57
32
20
13.15


Voyager 1
Fri Jul 8 19:44:04 1983
(b)
LET D
Volumes: 357031 357115
Points on plot: 711
13.15
20
32
57
79
200
0
50
100
150
200
250
300
10
20
30
40
50
60
3-parameter L2 energy (MeV)
3-parameter L3 energy (MeV)


Voyager 1
Fri Jul 8 19:45:47 1983
(c)
LET B
Volumes: 357031 357115
Points on plot: 779
3-parameter L1 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
0
50
100
150
200
250
300


Voyager 1
Fri Jul 8 19:45:47 1983
(d)
LET D
Volumes: 357031 357115
Points on plot: 726
3-parameter L1 energy (MeV)
3-parameter L3 energy (MeV)
0
10
20
30
40
50
60
0
50
100
150
200
250
300


Voyager 1
Fri Jul 8 19:47:21 1983
(e)
LET B
Volumes: 357031 357115
Points on plot: 758
0
10
20
30
40
50
60
3-parameter L1 energy (MeV)
3-parameter L2 energy (MeV)

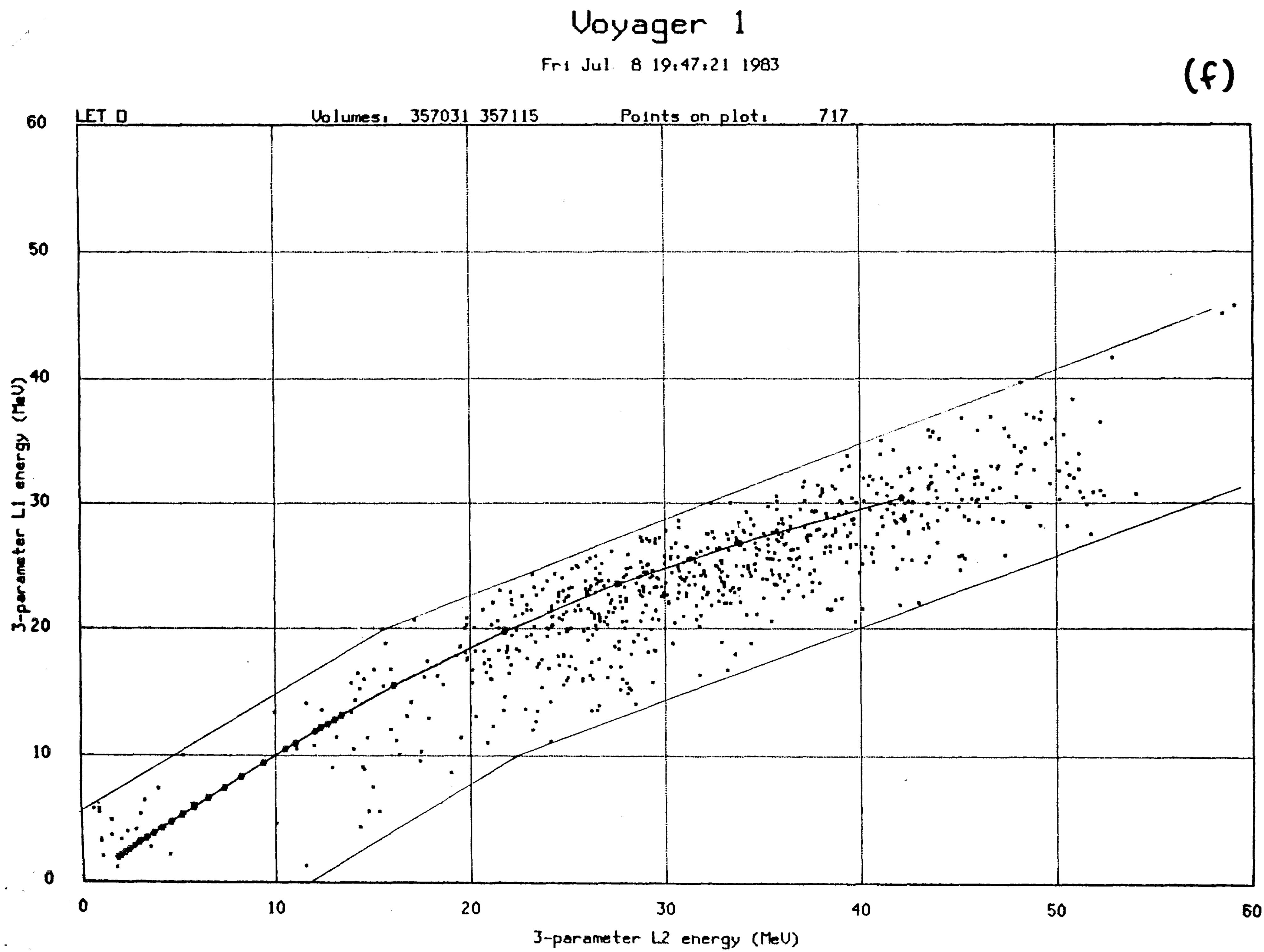

Voyager 1
Fri Jul 8 19:47:21 1983
(f)
LET D
Volumes: 357031 357115
Points on plot: 717
3-parameter L1 energy (MeV)
3-parameter L2 energy (MeV)
0
10
20
30
40
50
60

Fig. 3

Voyager 1

Sat Jul 9 18:03:26 1983

1979:64.40 to 1979:64.59

Overall time period : [redacted]

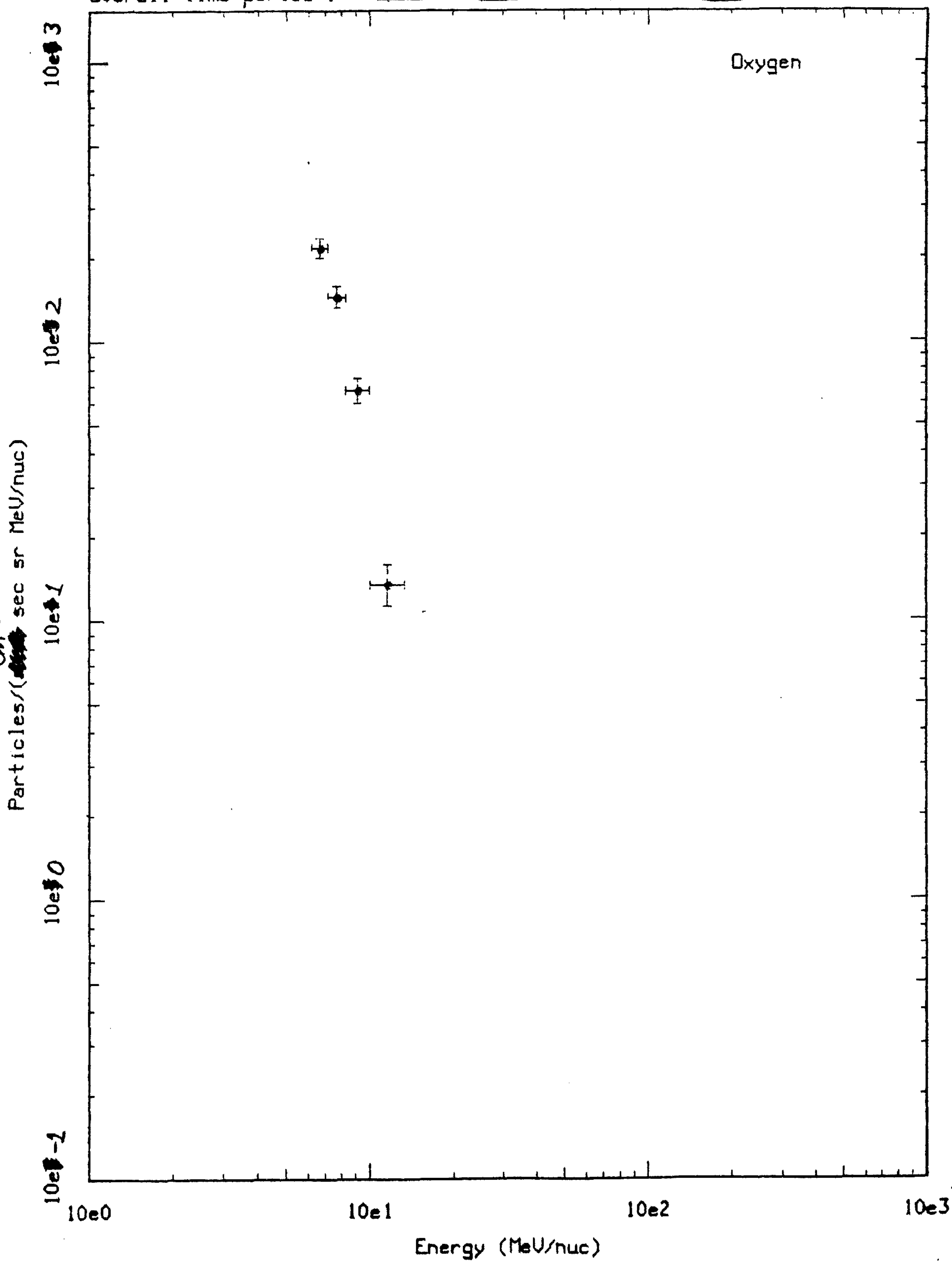


Fig. 4

Voyager 1

Sat Jul 9 18:05:55 1983

1979:64.40 to 1979:64.59

Overall time period : [redacted]

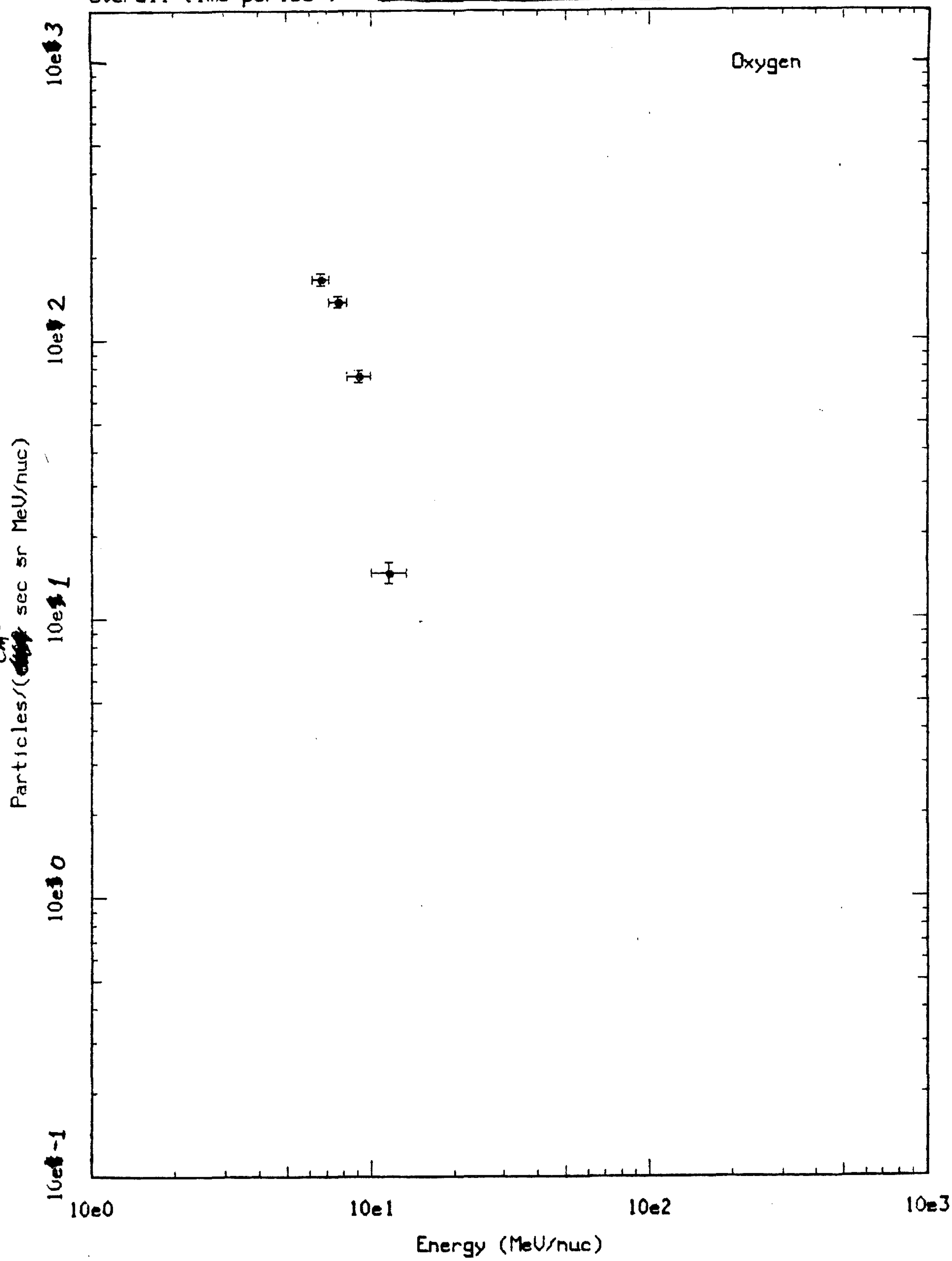


Fig. 5

Voyager 1

Sat Jul 9 19:17:39 1983

1979: 64.40 to 1979: 69.59

Overall time period : [redacted]

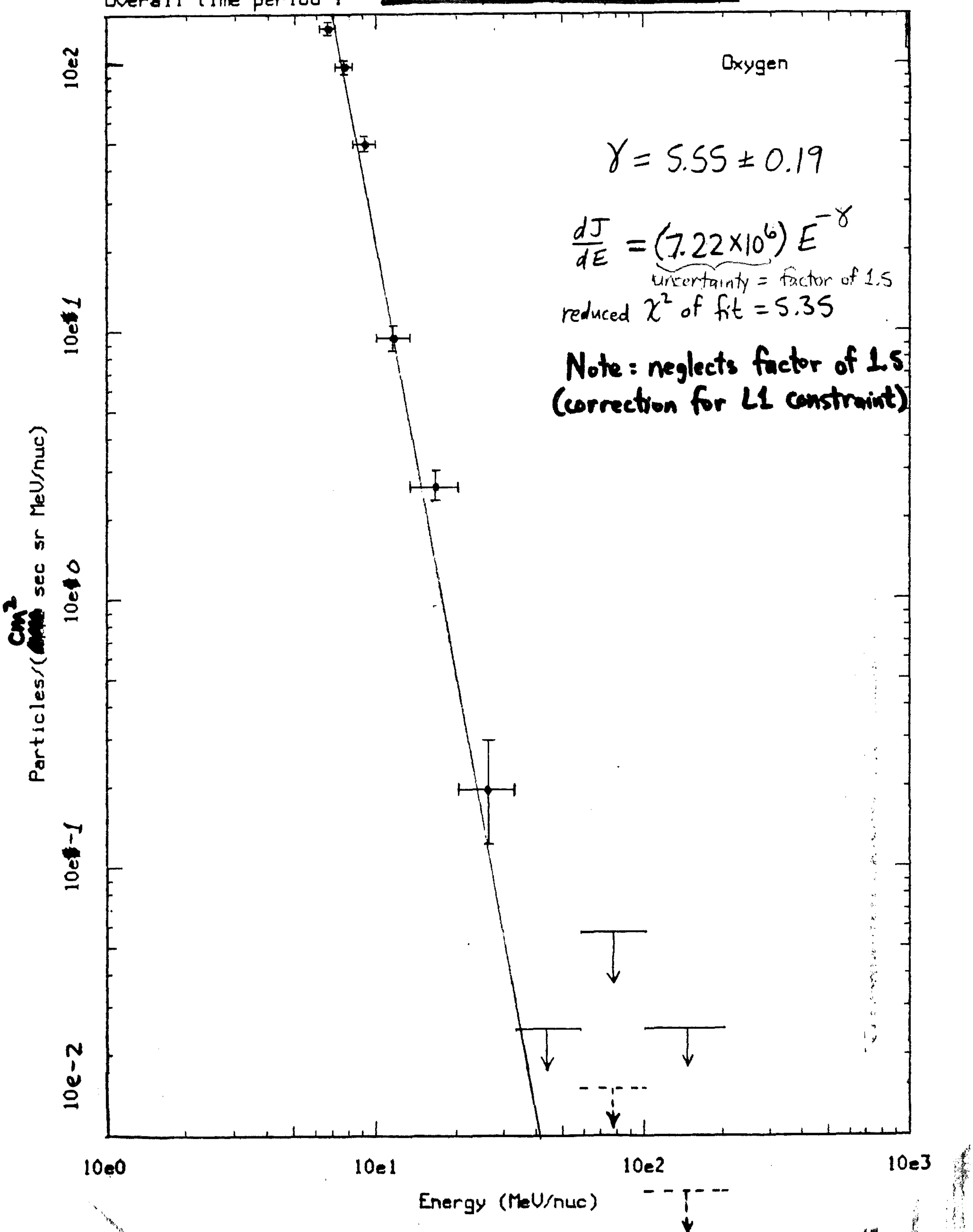
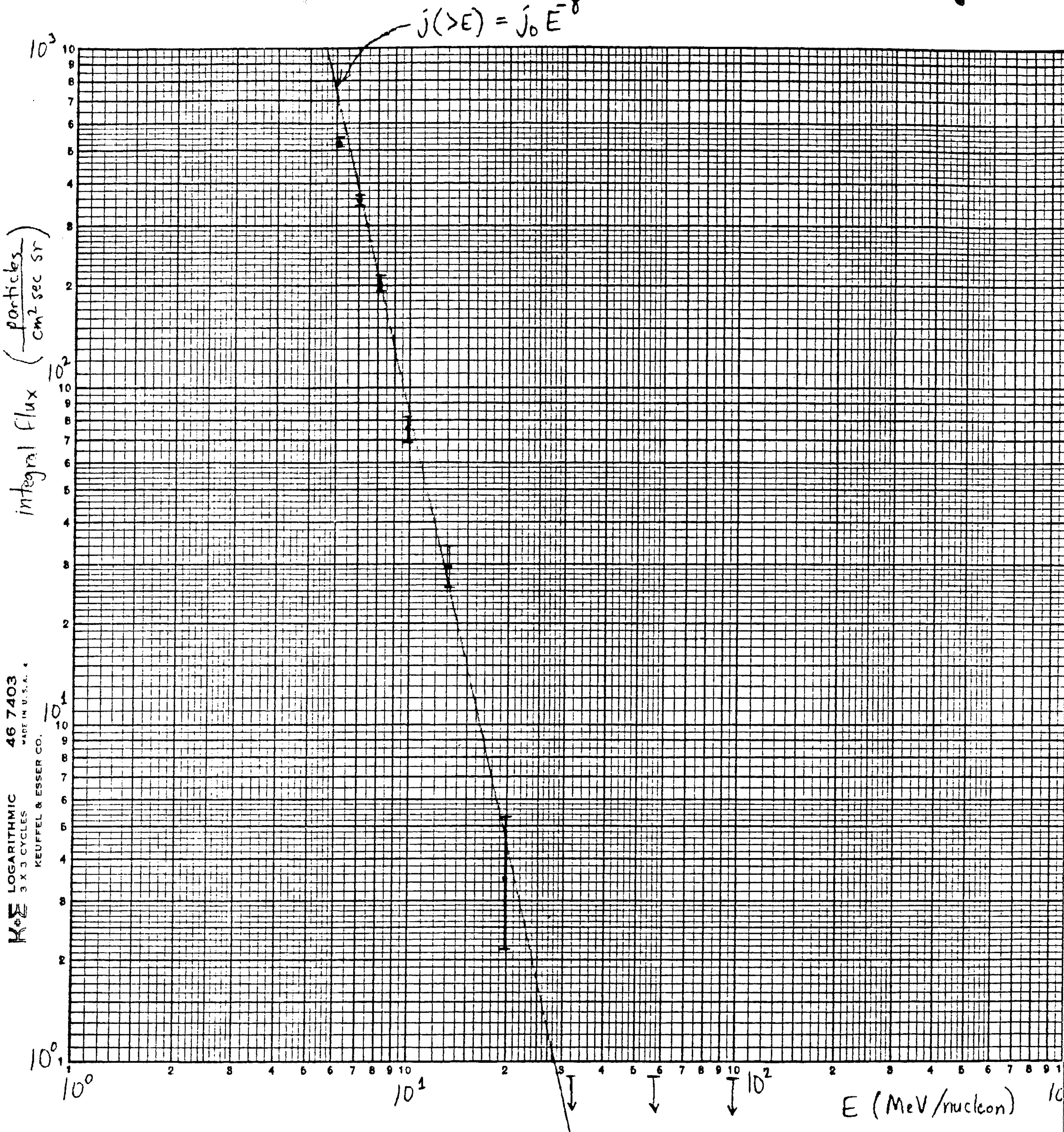


Fig. 6



omitting lowest-energy point from fit

$j_0 = 1.475 \times 10^6$, j_0 uncertainty = factor of 1.4

$\gamma = 4.26 \pm 0.17$

reduced χ^2 of fit = 1.53