TM-661
2972.000

350 GeV/c DICHROMATIC NEUTRINO TARGET TRAIN

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INTRODUCTION

This report summarizes design studies of new dichromatic neutrino beams to replace the old dichromatic target train[1] which was used primarily for experiments by the CIT-Fermilab Group. The old train could run for hadron momentum below 170 GeV/c. Its targetting angle was 6 mrad with a solid angle acceptance of 12 μsr. The primary design goal for the new train is to raise the hadron momentum to 350 GeV/c in order to utilize the accelerator operation at 400/500 GeV/c, to reduce wide band and wrong sign backgrounds by orders of magnitude, and to improve momentum definition.

We will discuss two new designs, Train N-30 and Train Q-30. For comparison, we will also discuss a "hypothetical" old train which can run at 300 GeV/c (for convenience, the horizontal and vertical planes are interchanged with respect to the actual old train). Train N-30 and Train Q-30 employ conventional iron magnets and have point-to-parallel focussing in both horizontal and vertical planes. They fit in the present target tube of 200 feet in length. Other focussing modes, such as point-point-parallel[2], do not seem to be feasible without lengthening the target tube. Details about optical properties for the new trains will be described elsewhere[3].

HYPOTHETICAL OLD TRAIN

Details about the old train are discussed in Reference 1. Beam parameters are summarized in Table I. Some properties are shown here in order to stress clearly some improvements made for the new train. Figures 1 and 2 show computed fluxes[4] of neutrinos and antineutrinos for a detector of 1 m radius. The train is set to 300 GeV/c for primary protons of 500 GeV. Collimators are set to the normal open conditions. Wide band backgrounds and wrong sign backgrounds are also shown.

Figure 3 shows the momentum acceptance computed by the TURTLE program[5] which assumes input particles with a uniform momentum distribution. It has a tail on the higher momemtum side. A two dimensional plot of x versus $\Delta p/p$ at the end of the train is shown in Figure 4. In order to reduce the flux of particles with higher momenta, an angle slit was closed at the negative angle side in some of the actual runs. The poor momentum definition is a severe disadvantage of this train.

N-30 TRAIN

Figure 5 shows a schematic drawing of the N-30 Train. The targetting angles are 11.737 and 1.283 mrad in the horizontal and vertical directions, respectively. Beam properties are summarized in Table I. The first five quadrupole magnets are horizontally defocussing and are displaced to give negative bends as indicated. Bending magnets, D1, D2 and D3 are rotated about their longitudinal axis by 30^{o} C.W., 24.38^{o} C.W. and 20^{o} C.C.W., respectively, in order to give vertical deflections. All the bending magnets, D1-D5 are

are Main Ring B1 magnets (10 or 20 feet long) and quadrupole magnets are also Main Ring quadrupole magnets (7 or 4 feet long). Table II gives operational parameters for the magnets. Excitation currents are 5000 A or less at 350 GeV/c.

The first bending magnet, D1, is very effective in suppressing the wrong sign background. The vertical deflection is introduced to reduce the wide band background.

Figures 6 and 7 show computed neutrino and antineutrino fluxes for a detector of 1 m radius. The momentum of the train is set to 300 GeV/c for primary protons of 500 GeV. Wide band and wrong sign backgrounds from the two-body decay are also computed and shown.

To illustrate how the wide band background has been reduced, neutrino fluxes and wide band backgrounds for two earlier versions, Train K and Train N, are shown in Figures 8 and 9, respectively. Train K does not have any vertical deflection; otherwise it is exactly the same as Train N-30. Train N is identical to Train N-30 except for 30^{o} rotation of the first bending magnet in the latter.

Figure 10 shows a computed momentum acceptance. A uniform momentum distribution is assumed for input particles. Two dimensional plots of correlations between horizontal and vertical production angles ($\dot{x}_o$ and $\dot{y}_o$) and momentum ($\Delta p/p$) are shown in Figures 11 and 12. A strong correlation between $\dot{x}_o$ and $\Delta p/p$ is seen. Particles with higher momenta correspond to large negative production angles. Since the production cross section for these particles at high energies is very small, a long tail at the high momentum side is suppressed.

This is also true at the low momentum side. Therefore, an effective momentum acceptance is considerably smaller than that shown in Figure 10. No correlation between $\dot{y}_o$ and $\Delta p/p$ is seen. Particle distributions for the horizontal and vertical planes at the upstream end of Enclosure 100 are shown in Figures 13 and 14. Figure 15 shows a correlation between the two distributions.

TRAIN Q-30

A schematic drawing of Train Q-30 is shown in Figure 16. Magnets with large apertures, 6-3-120 Beam Line Dipole magnets and 4Q120 Beam Line Quadrupole magnets are used for a triplet focus arrangement. The narrow vertical aperture of Main Ring B1 magnets (1.5") precluded a triplet arrangement in Train N-30.

Table I summarizes beam properties of Train Q-30. One of the advantages of the triplet arrangement of this train is that beam optics can be made symmetric in the horizontal and vertical planes. Magnifications at Enclosure 100 can be matched to allow a reasonable muon beam in the Muon Laboratory. A larger aperture gives more neutrino flux and it is particularly advantageous at lower energies where production cross sections of mesons have a wider angular spread.

Figures 17 and 18 show computed neutrino and antineutrino fluxes for a detector of 1 m radius. The momentum of the Train is set to 300 GeV/c for the primary protons of 500 GeV. Intensities and spectra are essentially identical to those for Train N-30. Wide band and wrong sign backgrounds from the two-body decay are also shown. The wrong sign background is effectively reduced by the first bending

magnet as in Train N-30. The wide band background is reduced mostly by vertical bends which are provided by rotations of the first six bending magnets.

Large cross sectional dimensions of the magnets, 70 cm H x 65.4 cm V, make such arrangements extremely difficult inside the target tube of 180 cm in diameter.

Train Q-30 represents the extreme limit of rotations and displacements of these magnets within the confines of the target tube, though some modifications in bed plates and changes in the beam line in the Neuhall are still required. Momentum acceptance is shown in Figure 19. The distribution has a sharper fall off at the high momenta than that for Train N-30. This is a result of the smaller value of the 1, 2 component of the transfer matrix for the triplet in the horizontal plane when compared with the doublet.

Figures 20 and 21 show two dimensional plots of $\dot{x}_o$ versus $\Delta p/p$ and $\dot{y}_o$ versus $\Delta p/p$. Horizontal and vertical particle distributions and correlation between the two distributions are shown in Figures 22, 23 and 24.

CONCLUSION

Train N-30 seems to be preferable to Train Q-30 for the following reasons:

1. The wide band backgrounds are much smaller for Train N-30.
2. Neutrino flux gain due to the large aperture magnets in Train Q-30 is at most, 10% at higher energies ($\gtrsim$300 GeV/c) and only about 30% at lower energies.

3. Train N-30 requires minimum changes in Neuhall for the 500 GeV accelerator operation. On the other hand, Train Q-30 requires sizable beam steering in both the horizontal and vertial planes in Neuhall.
4. Costs of the magnets with two spare magnets (one quad and one bend) are $100K and $406K for Train N-30 and Train Q-30, respectively.
5. Mechanical construction might be more difficult for Train Q-30 because it uses heavier and larger magnets.

Some of the disadvantages with Train N-30 are:

1. A large magnification in the vertical plane at Enclosure 100 reduces muon intensity in the Muon Laboratory.
2. No spaces are available for beam absorbers before the end of the fifth quadrupole magnet. Therefore, the beam must be dumped inside the magnets on fixed aperture collimators. One of the significant advantages of Q-30 is the flexibility derived from the remotely controlled, variable aperture collimators.
3. At sufficiently low energies, fluxes fall off due to the limited solid angle acceptance of the train. However, in any event, other train systems are more advantageous in the low energy region[6].
4. Coupling between momentum and solid angle acceptances in worse than with Train Q-30.

Since the primary beam must be dumped near the target, very localized and fast heating problems must be solved.

REFERENCES

1. P. Limon, et al., Nucl. Inst. and Meth. 116, 317 (1974)

2. L. Stutte, Dichromatic Neutrino Beams, December 1974 (unpublished).

3. D. Edwards and F. Sciulli , TM660.

4. Neutrino fluxes were computed by the computer program NUADA which has been developed and modified by D.C. Carey. See D.C. Carey and V.A. White, NUADA, June 1, 1975, Fermilab. The Wang spectra were used as the momentum and angle spectra for meson production.

5. D.C. Carey, TURTLE, NAL-64,2041.000 (December 1971).

6. C. Baltay and D. Cohen, Two Horn Narrow Band Neutrino Beams (beam design report for FNAL EXP #380).

TABLE I

SUMMARY OF BEAM PROPERTIES

TRAIN	OLD	N-30	Q-30
Nominal Maximum Momentum (GeV/c)	170	350	350
Production Angle (mrad)	0	0	0
Targetting Angles (mrad)			
Bend Plane	6	11.7	9.7
Non-Bend Plane	0	1.3	2.3
Angular Acceptance* for $\Delta p = 0$ (mrad)			
Bend Plane	1,17	1.31	2.16
Non-Bend Plant	2,34	2.20	1.81
Solid Angle Acceptance for $\Delta p = 0$ (μsr)	11.0	11.5	15.7

* The angular acceptance for $\Delta p = 0$ is defined by the apertures of the bending magnets only.

TABLE II

OPERATIONAL PARAMETERS FOR THE MAGNETS IN TRAIN N-30 AT 350 GeV/c

POWER SUPPLIES	MAGNETS	FIELDS	CURRENTS	POWERS
1	D1 - D4	18.84 KG	5000 A	444 KW (DC)
2	D5	9.1	2400	17
3	Q1 - Q5	248 KG/m	4600	438
4	Q6, Q7	243	4500	182
				1081

(Train Q-30 uses 800 kW(DC) total for 350 GeV/c.)

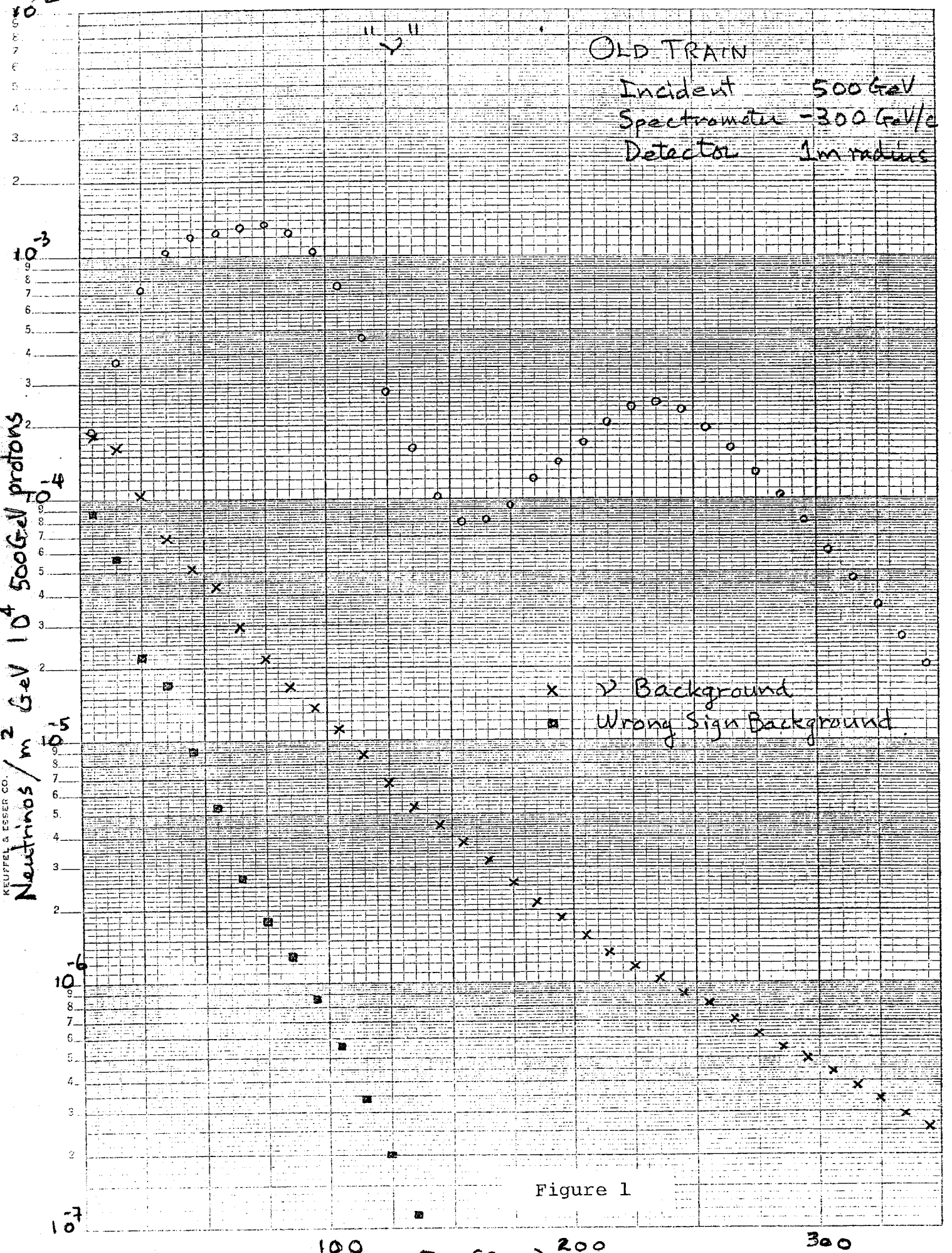

OLD TRAIN
Incident 500 GeV
Spectrometer -300 GeV/c
Detector 1m radius
ν Background
Wrong Sign Background
Neutrinos/m² GeV 10⁴ 500GeV protons
E_ν (GeV)
100
200
300
SEMI-LOGARITHMIC 46 6210
5 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Figure 1

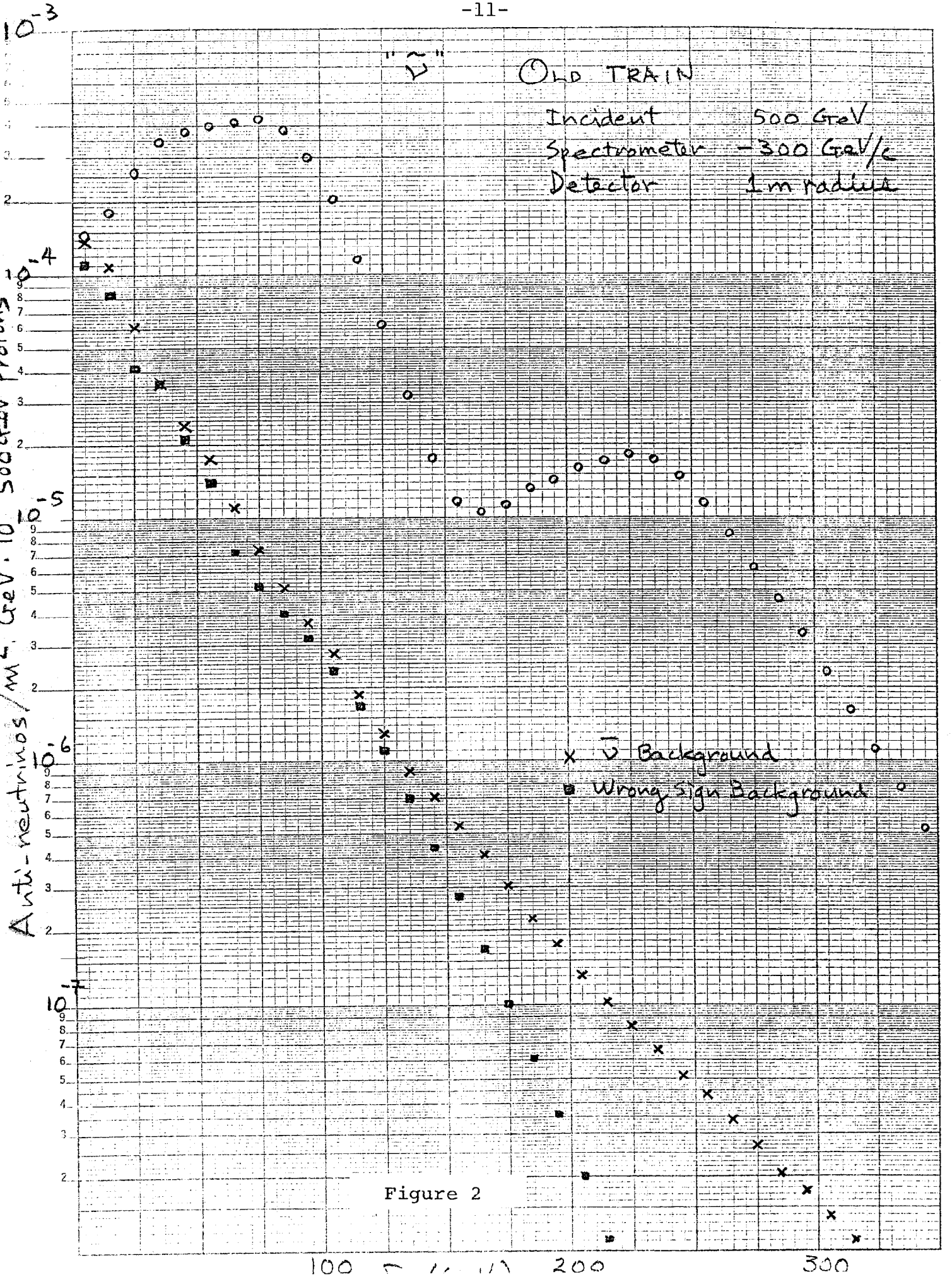
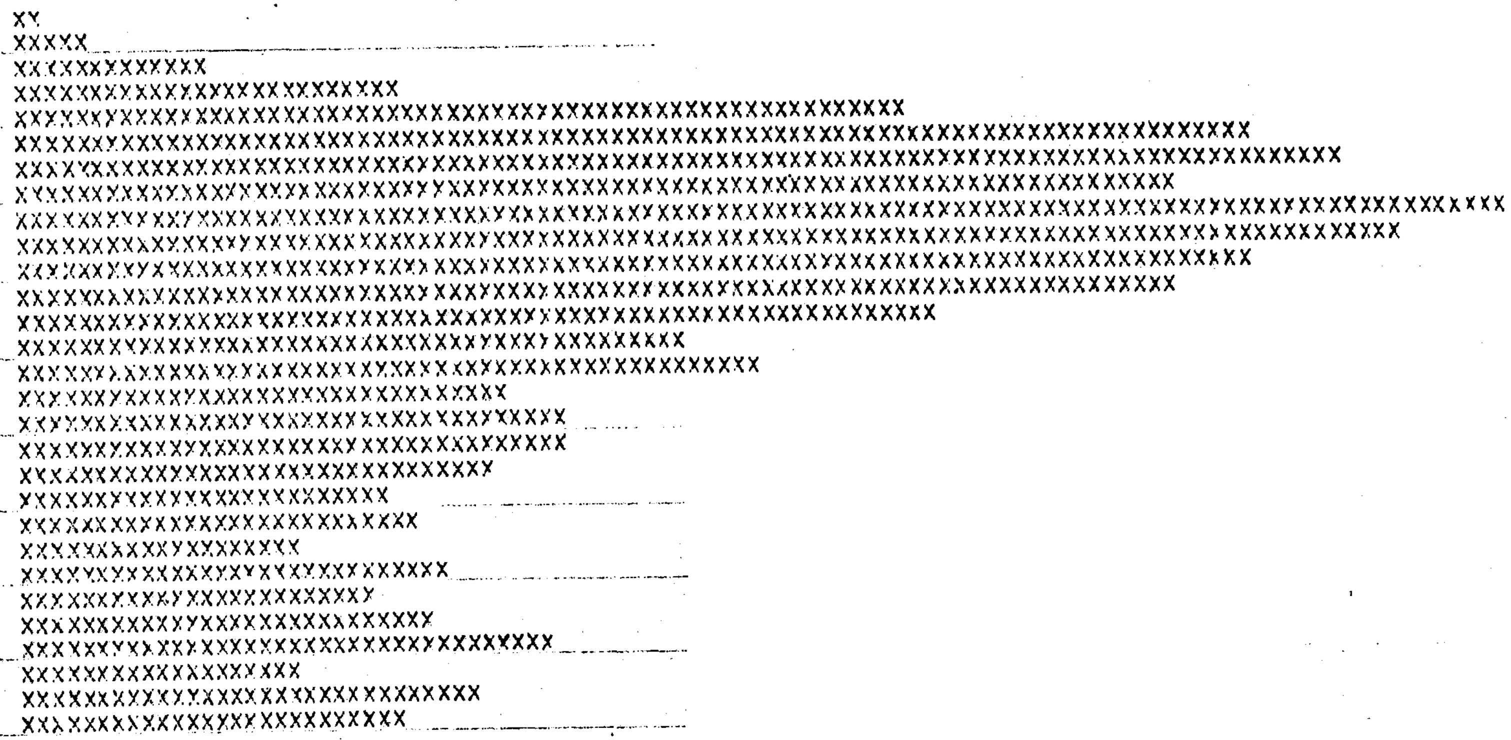

"$\tilde{\nu}$"
OLD TRAIN
Incident 500 GeV
Spectrometer −300 GeV/c
Detector 1 m radius
$\times$ $\bar{\nu}$ Background
■ Wrong Sign Background
Anti-neutrinos/m². GeV. 10^4 500 GeV Protons
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
100
200
300

Figure 2

THE FOLLOWING IS A HISTOGRAM OF DP/P FOR 2580 RAYS

SCALE FACTOR: 100 X'S EQUAL 201 RAYS

INTERVAL	COUNT
LESS THAN -50.000	0
-50.000 TO -45.000	0
-45.000 TO -40.000	5
-40.000 TO -35.000	12
-35.000 TO -30.000	27
-30.000 TO -25.000	54
-25.000 TO -20.000	122
-20.000 TO -15.000	167
-15.000 TO -10.000	180
-10.000 TO -5.000	157
-5.000 TO .000	201
.000 TO 5.000	188
5.000 TO 10.000	167
10.000 TO 15.000	157
15.000 TO 20.000	126
20.000 TO 25.000	91
25.000 TO 30.000	101
30.000 TO 35.000	67
35.000 TO 40.000	75
40.000 TO 45.000	75
45.000 TO 50.000	66
50.000 TO 55.000	51
55.000 TO 60.000	56
60.000 TO 65.000	39
65.000 TO 70.000	59
70.000 TO 75.000	49
75.000 TO 80.000	57
80.000 TO 85.000	74
85.000 TO 90.000	43
90.000 TO 95.000	64
95.000 TO 100.000	53
GREATER THAN 100.000	0



CENTER = 19.481 RMS HALF WIDTH = 34.852

NO 5 OF DP/P IN PC 19.200 FT FROM THE TARGET, FLAG AT 157.000 FT

Figure 3

TWO DIMENSIONAL PLOT OF X VS DP/P

```
                    -50.000      .000     50.000    100.000 TOTALS
                     I**---**---**---**---**---**---**I--------
-3.000 TO   -2.800 I                                        I       0
-2.800 TO   -2.600 I  421                                   I       7
 2.600 TO   -2.400 I 135756744                      24212   I      53
 2.400 TO   -2.200 I  3 18DG4842                    22  2   I      68
 2.200 TO   -2.000 I    66CC799571                 121195   I      93
 2.000 TO   -1.800 I  142884A6799446              13522     I      95
 1.800 TO   -1.600 I  1332G757745A5221            221 1244  I      96
 1.600 TO   -1.400 I  256BA7783787325212 412514533          I     127
 1.400 TO   -1.200 I   56A783977884B36552131222221         I     133
 1.200 TO   -1.000 I   359F8D9885543162325264691 41        I     147
 1.000 TO    -.800 I   146A4766A285212227221 4223          I     101
 -.800 TO    -.600 I    2999976B6476525 21 211412         I     111
 -.600 TO    -.400 I    487788886 13543223132 3121        I     100
 -.400 TO    -.200 I    69C8796344461 341132332155        I     112
 -.200 TO     .000 I    2888378587223252 312115111        I      96
  .000 TO     .200 I     5896A585356327325313323 41       I     112
  .200 TO     .400 I     76A799A5474362723 1346313        I     122
  .400 TO     .600 I     69D8A853244764323 721 112        I     114
  .600 TO     .800 I    2468D65813654342136 21 22         I      97
  .800 TO    1.000 I     4C87EAC428 36 122 32 123         I     106
 1.000 TO    1.200 I     3E7AF876124 626314443342         I     119
 1.200 TO    1.400 I      6697A6655442521222 3141         I      93
 1.400 TO    1.600 I       47A6741624323114138 1 1        I      79
 1.600 TO    1.800 I      29A87462344241 3 2123222        I      83
 1.800 TO    2.000 I       68760674 2345622131112         I      90
 2.000 TO    2.200 I      1566544226323432114 35          I      72
 2.200 TO    2.400 I       4866973545321355211 21         I      81
 2.400 TO    2.600 I       2315C34252532212 1123          I      61
 2.600 TO    2.800 I           111  12112  1 1            I      12
 2.800 TO    3.000 I                                      I       0
                     I**---**---**---**---**---**---**I--------
                     I                                   I
                     I                                   I
                     I      111121111 1                  I
                     I   125268598652906776553545746 5   I
          TOTALS     I 0527427071877611755616999740 43   I    2580
```

TOTAL NUMBER OF ENTRIES = 2580 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	0	0

NO 21 TWO DIMENSIONAL PLOT OF
DP/P IN PC 157.000 FT FROM THE TARGET
X IN IN 157.000 FT FROM THE TARGET

Figure 4

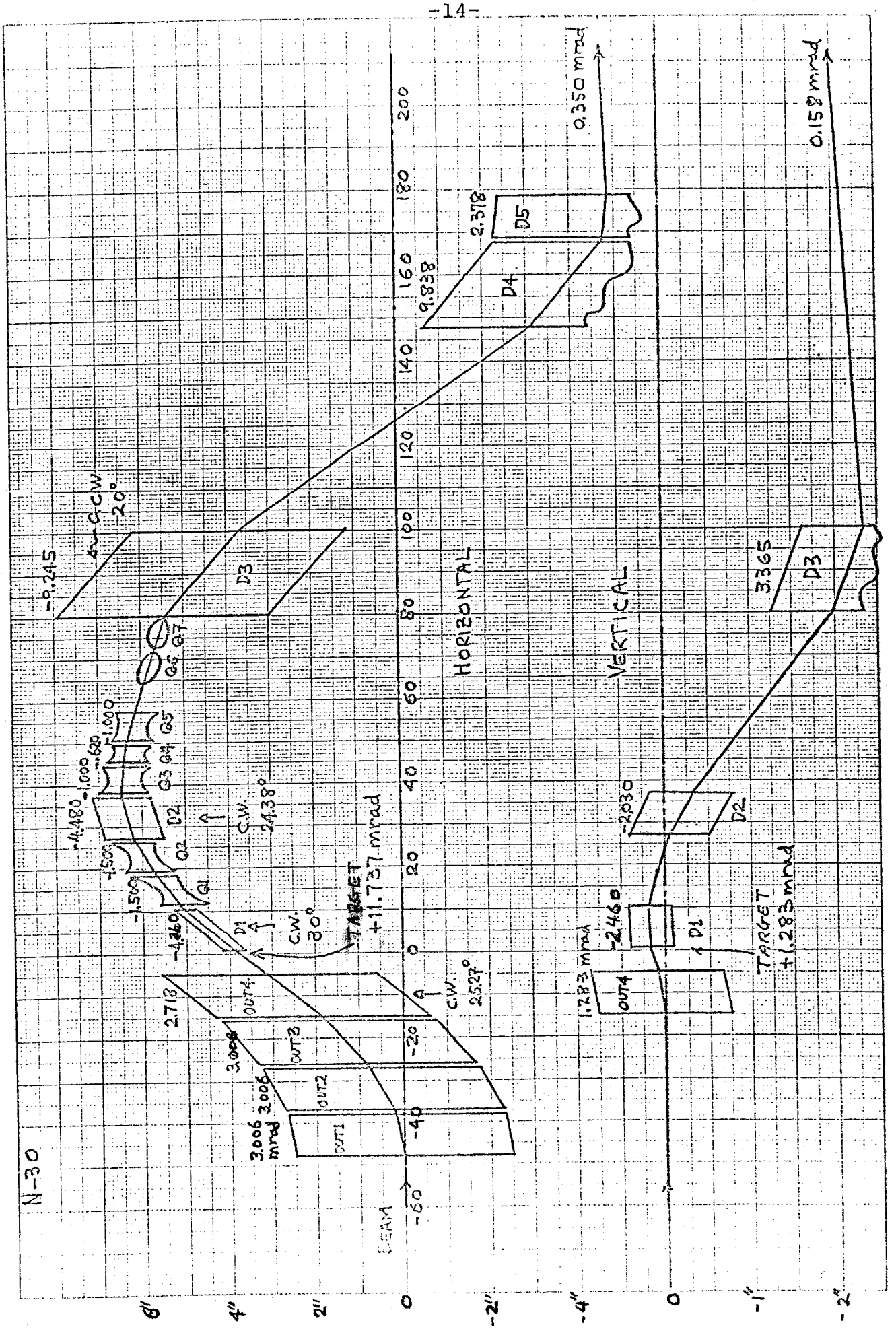

N-30
BEAM
HORIZONTAL
VERTICAL
TARGET
+11.737 mrad
TARGET
+1.283mrad
-9.245
-4.480
-1.000
-1.620
-1.000
+.500
-1.500
-4.460
2.718
3.008
3.006
3.006 mrad
1.282 mrad
-2.460
-2.030
9.838
2.378
3.365
0.350 mrad
0.150 mrad
Q1
Q2
Q3
Q4
Q5
Q6
Q7
D1
D2
D3
D4
D5
OUT1
OUT2
OUT3
OUT4
C.W. 80°
C.W. 14.38°
C.W. 25.27°
A-CCW 20°

Figure 5

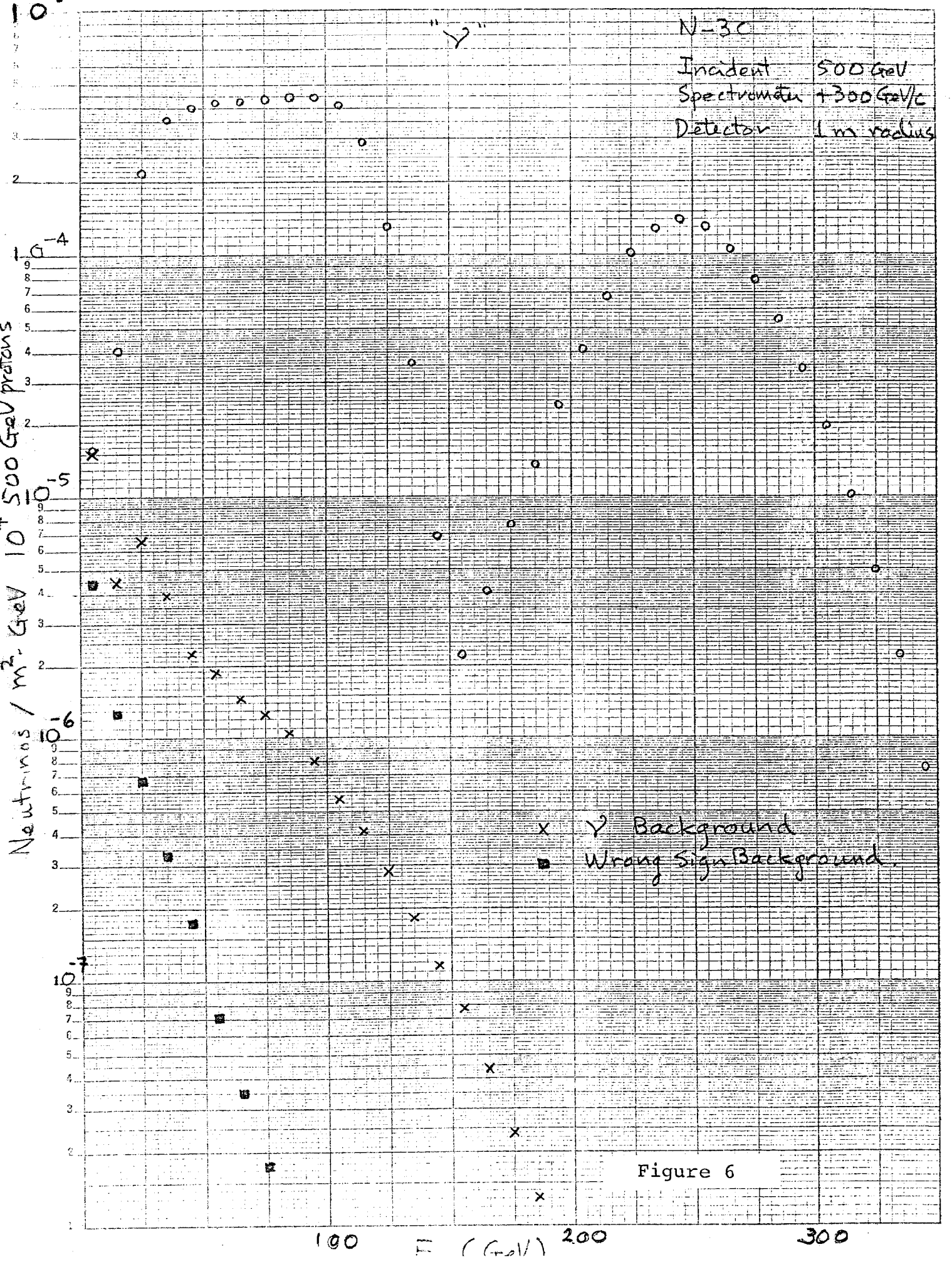

"ν"
N-3C
Incident 500 GeV
Spectrometer ±300 GeV/c
Detector 1m radius
Neutrinos / m² GeV 10⁴ 500 GeV protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
ν Background
Wrong Sign Background
100
200
300
E (GeV)

Figure 6

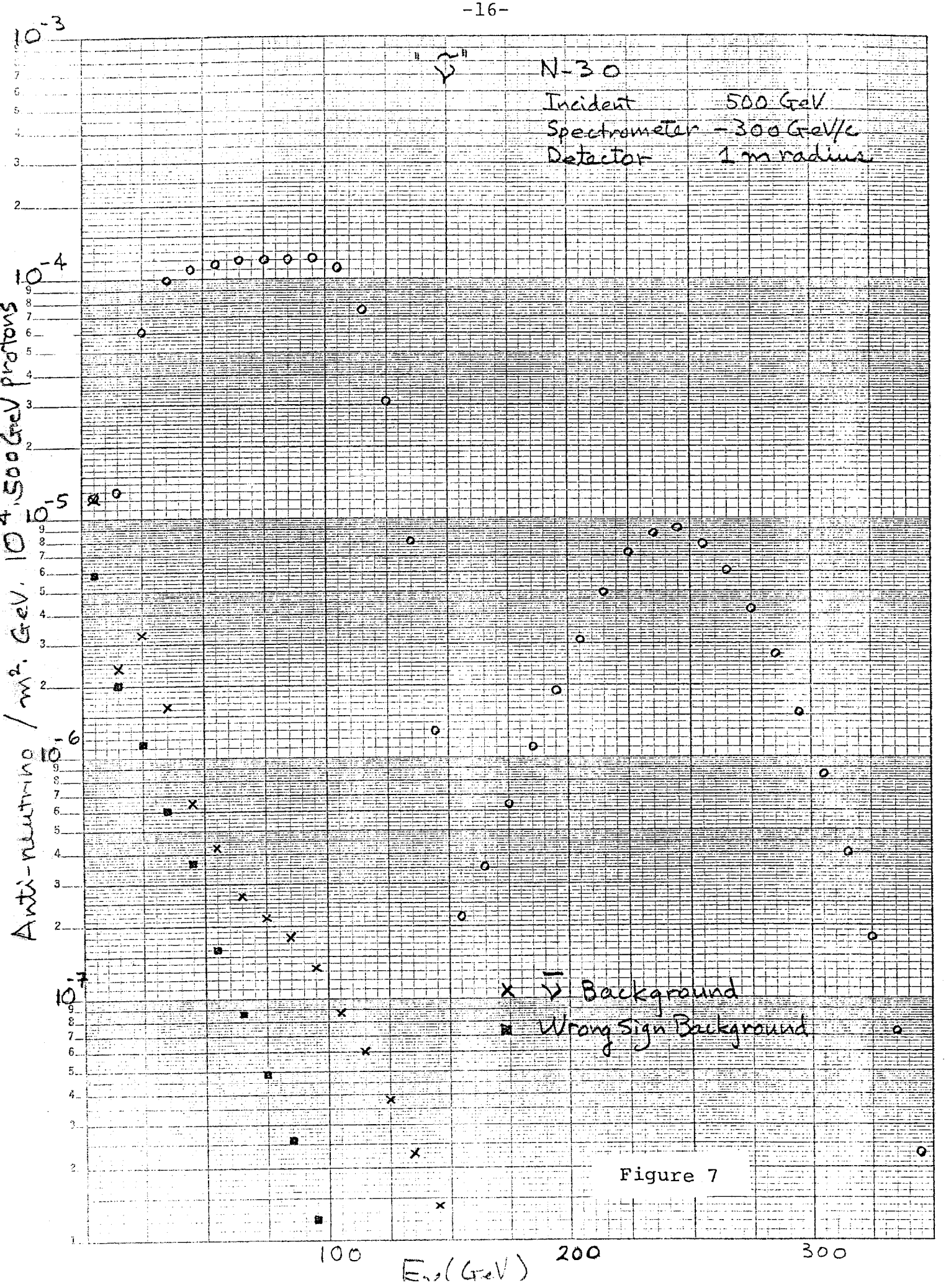

"$\tilde{\nu}$"
N-30
Incident 500 GeV
Spectrometer -300 GeV/c
Detector 1 m radius
Anti-neutrino / m². GeV. 10⁴, 500 GeV protons
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
× $\bar{\nu}$ Background
⊠ Wrong Sign Background
100
200
300
E_{ν} (GeV)

Figure 7

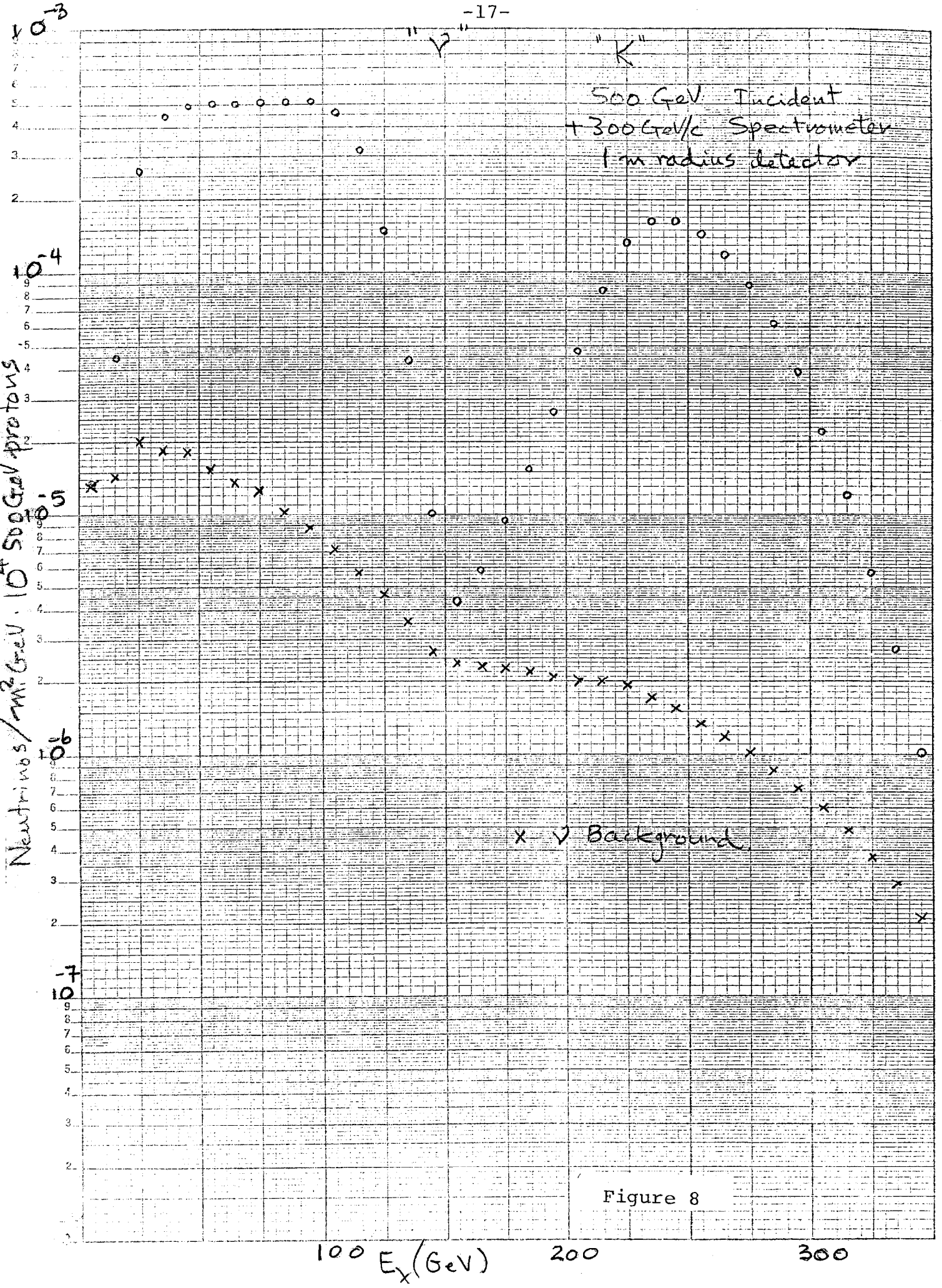

"ν"
"K"
500 GeV Incident
+300 GeV/c Spectrometer
1 m radius detector
ν Background
Neutrinos/m² GeV · 10⁴ 500 GeV protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
100
200
300
E_x (GeV)

Figure 8

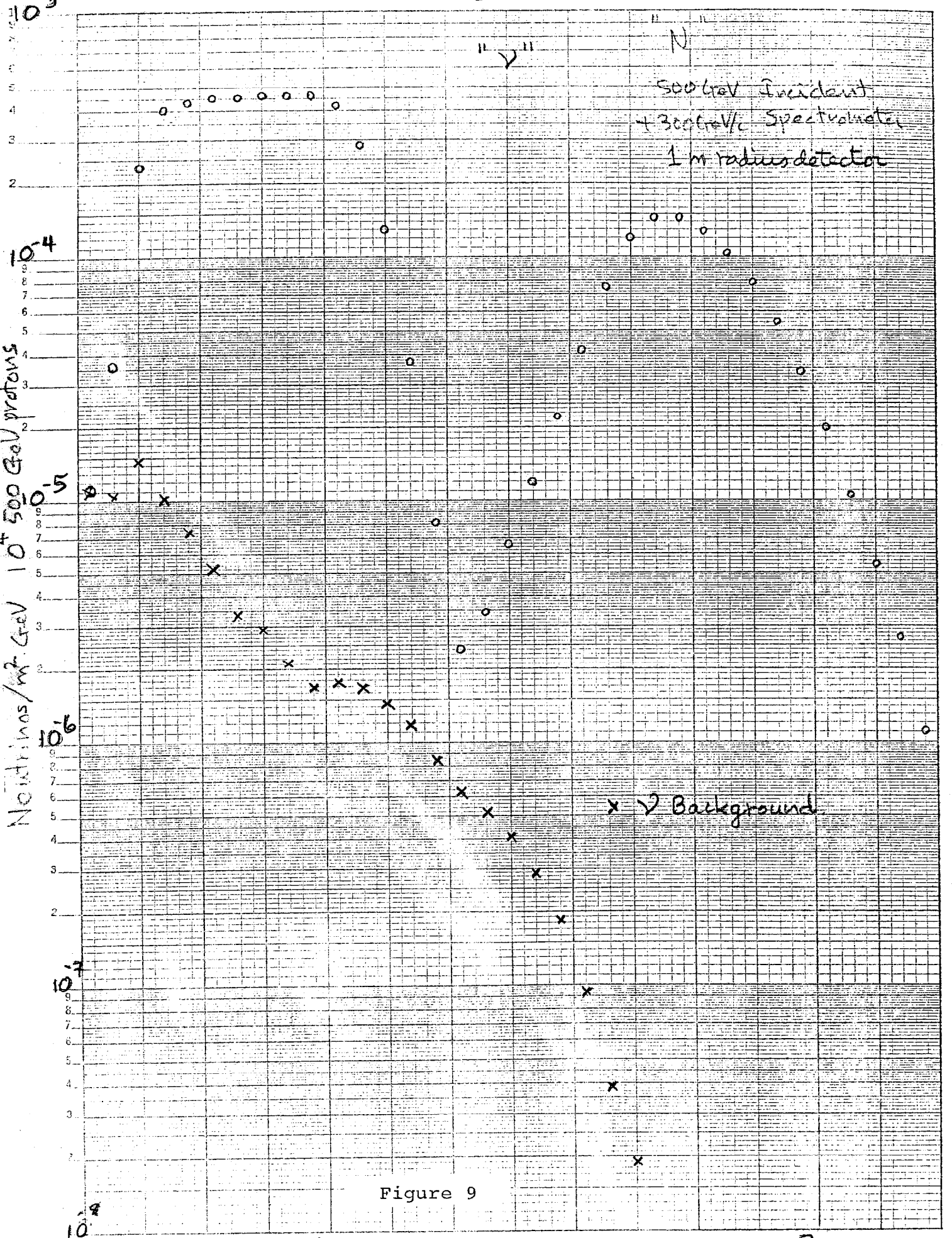

"ν"
"N"
500 GeV Incident
±300 GeV/c Spectrometer
1 m radius detector
× ν Background
Neutrinos/m² GeV 10⁴ 500 GeV protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
100
200
300
Eν (GeV)

Figure 9

THE FOLLOWING IS A HISTOGRAM OF DP/P FOR 2309 RAYS

INTERVAL			SCALE FACTOR: 100 X'S EQUAL 140 RAYS
LESS THAN	-40.000	0	
-40.000 TO	-38.000	0	
-38.000 TO	-36.000	0	
-36.000 TO	-34.000	0	
-34.000 TO	-32.000	0	
-32.000 TO	-30.000	0	
-30.000 TO	-28.000	0	
-28.000 TO	-26.000	0	
-26.000 TO	-24.000	0	
-24.000 TO	-22.000	7	XXXXX
-22.000 TO	-20.000	29	XXXXXXXXXXXXXXXXXXX
-20.000 TO	-18.000	45	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-18.000 TO	-16.000	58	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-16.000 TO	-14.000	87	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-14.000 TO	-12.000	83	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-12.000 TO	-10.000	86	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-10.000 TO	-8.000	119	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-8.000 TO	-6.000	127	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.000 TO	-4.000	120	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.000 TO	-2.000	128	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.000 TO	0.000	140	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.000 TO	2.000	137	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.000 TO	4.000	139	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
4.000 TO	6.000	129	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
6.000 TO	8.000	109	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
8.000 TO	10.000	92	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10.000 TO	12.000	108	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
12.000 TO	14.000	81	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
14.000 TO	16.000	70	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
16.000 TO	18.000	74	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
18.000 TO	20.000	66	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
20.000 TO	22.000	49	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
22.000 TO	24.000	41	XXXXXXXXXXXXXXXXXXXXXXXX
24.000 TO	26.000	34	XXXXXXXXXXXXXXXXXXX
26.000 TO	28.000	28	XXXXXXXXXXXXXXXX
28.000 TO	30.000	32	XXXXXXXXXXXXXXXXXX
30.000 TO	32.000	24	XXXXXXXXXXXXXX
32.000 TO	34.000	14	XXXXXXXX
34.000 TO	36.000	22	XXXXXXXXXXXX
36.000 TO	38.000	18	XXXXXXXXXX
38.000 TO	40.000	13	XXXXXXXX
GREATER THAN	40.000	0	

CENTER = 3.102 RMS HALF WIDTH = 13.467

NO 20 OF DP/P IN PC 178.546 FT FROM THE TARGET

Figure 10

TWO DIMENSIONAL PLOT OF XPR VS DP/P

```
                    -40.000    -20.000      0.000     20.000     40.000 TOTALS
                      I**----**----**----**----**----**----**----**I--------
-2.000 TO   -1.800 I                                 324393669645563 I     74
-1.800 TO   -1.600 I                               2 867B8ABAC2A7333 I    113
-1.600 TO   -1.400 I                              2786F3689854A61    I     98
-1.400 TO   -1.200 I                             19DGBCFBD87632      I    127
-1.200 TO   -1.000 I                            13DEFDFFEHC87        I    147
-1.000 TO    -.800 I                           129C68AHE98A2         I    108
 -.800 TO    -.600 I                           9DBDBDGC87A1          I    124
 -.600 TO    -.400 I                          9F79FF8BFA52           I    121
 -.400 TO    -.200 I                         78BEDK8A987             I    115
 -.200 TO     .000 I                        5GDCDF9NC45              I    127
  .000 TO     .200 I                       3DEGDHKGCD4               I    141
  .200 TO     .400 I                      17CJFAKHA94                I    124
  .400 TO     .600 I                      ECBFBEGLA72                I    133
  .600 TO     .800 I                      8BMACDC992                 I    108
  .800 TO    1.000 I                     K55CBEEG81                  I    106
 1.000 TO    1.200 I                    95B8AAD781                   I     85
 1.200 TO    1.400 I                    89AA9A781                    I     72
 1.400 TO    1.600 I                   989BBG811                     I     74
 1.600 TO    1.800 I                  3C9LAA971                      I     82
 1.800 TO    2.000 I                  8CFDC6                         I     66
                   I**----------**----**----**----**----**----**----**I--------
                                                                     I
                   1                                                 I
                   I                                                 I
                   I                 111111111 1                     I
                   I           13478812224332090866533222 1          I
      TOTALS       I 000000000139726970807999281799945322889 3      I   2145
```

TOTAL NUMBER OF ENTRIES = 2309 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	107	57

NO 11 TWO DIMENSIONAL PLOT OF
DP/P IN PC .770 FT FROM THE TARGET
XPR IN MR .770 FT FROM THE TARGET, FLAG AT 178.546 FT

Figure 11

TWO DIMENSIONAL PLOT OF YPR VS DP/P

```
                    -40.000   -20.000      0.000    20.000    40.000 TOTALS
                      I**---**---**---**---**---**---**---**I--------
-2.000 TO   -1.800 I              2   12 136212152735  12       I     46
-1.800 TO   -1.600 I               3 351186636224321 441 121   I     69
-1.600 TO   -1.400 I              2151599B6A76585114435221 111 I    116
-1.400 TO   -1.200 I          111 32136458A64889563933113 111  I    117
-1.200 TO   -1.000 I           2 443525528666845646132231214   I    113
-1.000 TO    -.800 I          1 451868B765758867146313366 71 52 I    151
 -.800 TO    -.600 I           129A3397997BA6B1954B712333323 4 I    168
 -.600 TO    -.400 I          216649469635A3846555453542323222 I    147
 -.400 TO    -.200 I          121145A878694A964645645632331262 I    153
 -.200 TO     .000 I           45255488DA65197A645774364632511 I    166
  .000 TO     .200 I          134455393AB97A8B68764774121  221 I    161
  .200 TO     .400 I           133539868BB7983568A24441112 1   I    144
  .400 TO     .600 I          1654533887C677762546426 1   1    I    126
  .600 TO     .800 I           1147648758498558D214312         I    116
  .800 TO    1.000 I           366D27799787FA6654253            I    140
 1.000 TO    1.200 I           2324425432B3A41746411            I     80
 1.200 TO    1.400 I            2365496179C764231               I     87
 1.400 TO    1.600 I           223255873635184221               I     72
 1.600 TO    1.800 I              16556595722341                I     61
 1.800 TO    2.000 I              21527432431                   I     34
                   I**---**---**---**---**---**---**---**I--------
                   I                                     I
                   I                                     I
                   I                                     I
                   I              111111111 1            I
                   I          2458781212333209076764432321211 I
     TOTALS        I 000000007956595779766578057834714814428 3 I   2267
```

TOTAL NUMBER OF ENTRIES = 2309 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	27	15

NO 12 TWO DIMENSIONAL PLOT OF
DP/P IN PC .770 FT FROM THE TARGET
YPR IN MR .770 FT FROM THE TARGET, FLAG AT 178.546 FT

Figure 12

```
THE FOLLOWING IS A HISTOGRAM OF     X     FOR    2309 RAYS

      INTERVAL                                   SCALE FACTOR:  100 X+S EQUAL    274 RAYS

LESS THAN       -8.000         0
  -8.000 TO    -7.500          1
  -7.500 TO    -7.000          6   XX
  -7.000 TO    -6.500         15   XXXXX
  -6.500 TO    -6.000         24   XXXXXXXX
  -6.000 TO    -5.500         30   XXXXXXXXXX
  -5.500 TO    -5.000         45   XXXXXXXXXXXXXXXX
  -5.000 TO    -4.500         55   XXXXXXXXXXXXXXXXXXXX
  -4.500 TO    -4.000         74   XXXXXXXXXXXXXXXXXXXXXXXXXXX
  -4.000 TO    -3.500         85   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -3.500 TO    -3.000         77   XXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -3.000 TO    -2.500        100   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -2.500 TO    -2.000        112   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -2.000 TO    -1.500        138   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.500 TO    -1.000        175   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.000 TO     -.500        260   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.500 TO     -.000        274   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.000 TO      .500        190   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .500 TO     1.000        149   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   1.000 TO     1.500        105   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   1.500 TO     2.000        102   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   2.000 TO     2.500         80   XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   2.500 TO     3.000         77   XXXXXXXXXXXXXXXXXXXXXXXXXXXX
   3.000 TO     3.500         51   XXXXXXXXXXXXXXXXXX
   3.500 TO     4.000         40   XXXXXXXXXXXXXX
   4.000 TO     4.500         34   XXXXXXXXXXXX
   4.500 TO     5.000         17   XXXXXX
   5.000 TO     5.500          2
   5.500 TO     6.000          0
   6.000 TO     6.500          0
   6.500 TO     7.000          0
   7.000 TO     7.500          0
   7.500 TO     8.000          0

GREATER THAN    8.000          0

                    CENTER =    -.739   RMS HALF WIDTH =    2.408


NO  23 OF    X IN IN    1318.546 FT   FROM THE TARGET
```

Figure 13

THE FOLLOWING IS A HISTOGRAM OF Y FOR 2309 RAYS

INTERVAL			SCALE FACTOR: 100 X'S EQUAL 190 RAYS
LESS THAN	-8.000	4	XX
-8.000 TO	-7.500	8	XXXX
-7.500 TO	-7.000	7	XXX
-7.000 TO	-6.500	17	XXXXXXXX
-6.500 TO	-6.000	18	XXXXXXXXX
-6.000 TO	-5.500	28	XXXXXXXXXXXXXX
-5.500 TO	-5.000	28	XXXXXXXXXXXXXX
-5.000 TO	-4.500	27	XXXXXXXXXXXXXX
-4.500 TO	-4.000	44	XXXXXXXXXXXXXXXXXXXXX
-4.000 TO	-3.500	57	XXXXXXXXXXXXXXXXXXXXXXXXXXX
-3.500 TO	-3.000	80	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-3.000 TO	-2.500	90	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.500 TO	-2.000	101	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.000 TO	-1.500	143	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.500 TO	-1.000	174	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.000 TO	-.500	175	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-.500 TO	-.000	189	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-.000 TO	.500	158	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.500 TO	1.000	190	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1.000 TO	1.500	163	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1.500 TO	2.000	144	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.000 TO	2.500	118	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.500 TO	3.000	83	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
3.000 TO	3.500	39	XXXXXXXXXXXXXXXXX
3.500 TO	4.000	35	XXXXXXXXXXXXXXXX
4.000 TO	4.500	35	XXXXXXXXXXXXXXXX
4.500 TO	5.000	21	XXXXXXXXXX
5.000 TO	5.500	20	XXXXXXXXX
5.500 TO	6.000	27	XXXXXXXXXXXX
6.000 TO	6.500	14	XXXXXX
6.500 TO	7.000	13	XXXXX
7.000 TO	7.500	14	XXXXXX
7.500 TO	8.000	9	XXX
GREATER THAN	8.000	36	XXXXXXXXXXXXXXXX

CENTER = .003 RMS HALF WIDTH = 2.99

NO 24 OF Y IN IN 1318.546 FT FROM THE TARGET

Figure 14

TWO DIMENSIONAL PLOT OF Y VS X

```
                    -8.000     -3.000      2.000      7.000    TOTALS
                     I*----*----*----*----*----*----*----*--I--------
-8.000 TO   -7.500 I            1  2311                      I       8
-7.500 TO   -7.000 I             1 2111 1                   I       7
-7.000 TO   -6.500 I           2  2322311  1                I      17
-6.500 TO   -6.000 I           2 2 1452  1 1                I      18
-6.000 TO   -5.500 I          21  4216421122                I      28
-5.500 TO   -5.000 I      1         3494411     1           I      28
-5.000 TO   -4.500 I       11   22314462   1               I      27
-4.500 TO   -4.000 I       1   21 5356421  121             I      44
-4.000 TO   -3.500 I        213123548858   3 1             I      57
-3.500 TO   -3.000 I      1112412267F886442221  1          I      80
-3.000 TO   -2.500 I    1 22  23637A9E6762322111            I      90
-2.500 TO   -2.000 I     22 12755586DD6462212414           I     101
-2.000 TO   -1.500 I     1348455575OFFB94247835            I     143
-1.500 TO   -1.000 I  11113863425JDDHCFA7886433 1           I     174
-1.000 TO    -.500 I  2 1324554989CBEGBDB887441            I     175
 -.500 TO    -.000 I  1132448AA883AGBJBEK691352            I     189
 -.000 TO     .500 I   34323366F995GB68AB5B4521            I     158
  .500 TO    1.000 I   11238BA5ACAHIAA889C56662            I     190
 1.000 TO    1.500 I  143123734A8FGHF96AA45 622            I     163
 1.500 TO    2.000 I    33427776888DFAC36C15 4             I     144
 2.000 TO    2.500 I    11335342446AHF7968621 1            I     118
 2.500 TO    3.000 I  1113322422438CF9312122               I      83
 3.000 TO    3.500 I       1  1131236731162 1              I      39
 3.500 TO    4.000 I    1     1  122496421  11             I      35
 4.000 TO    4.500 I    1    2   22169622 11               I      35
 4.500 TO    5.000 I       11121 132252                   I      21
 5.000 TO    5.500 I       1  11 211373                   I      20
 5.500 TO    6.000 I 1  11311 12  1861                    I      27
 6.000 TO    6.500 I    1     11 1211321                  I      14
 6.500 TO    7.000 I       1 1 1121 1221                 I      13
 7.000 TO    7.500 I     1 2 211 1  41 1                  I      14
 7.500 TO    8.000 I         1111  2 111                 I       9
                    I*----*----*----*----*----*----*----*--I--------
                    I                                     I
                    I                                     I
                    I                                     I
                    I             111221111               I
                    I   12245787903757830O875431          I
          TOTALS    I 165394411597628064520710472000O0    I    2269
```

TOTAL NUMBER OF ENTRIES = 2309 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	4	36

NO 25 TWO DIMENSIONAL PLOT OF
X IN IN 1318.546 FT FROM THE TARGET
Y IN IN 1318.546 FT FROM THE TARGET

Figure 15

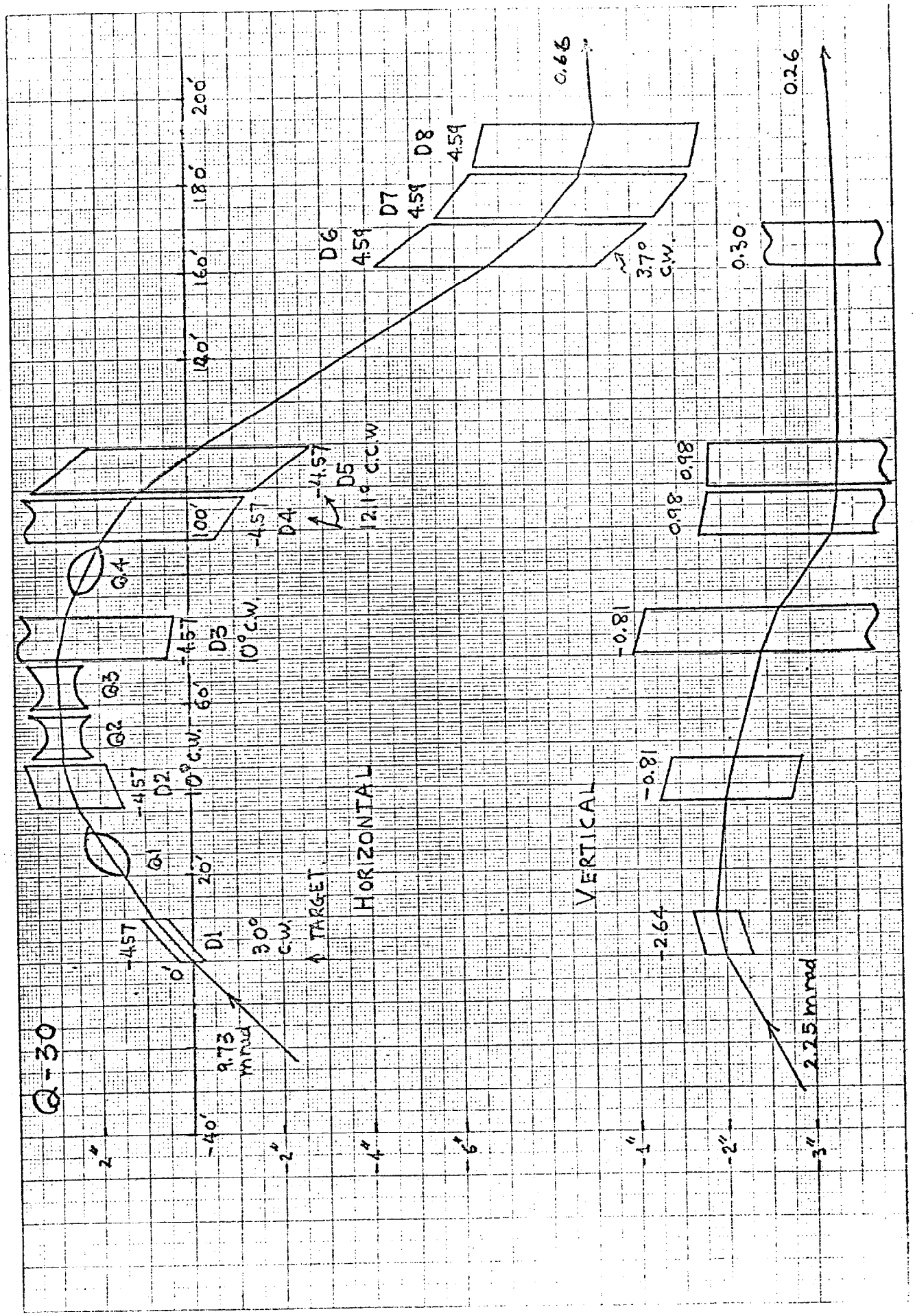

Q-30
Q1
Q2
Q3
Q4
D1
D2
D3
D4
D5
D6
D7
D8
-457
-4.57
4.59
0'
20'
60'
100'
140'
160'
180'
200'
-40'
10° c.w.
10° c.w.
30° c.w.
12.1° c.c.w.
3.7° c.w.
TARGET
9.73 mrad
HORIZONTAL
VERTICAL
-0.81
-2.64
0.98
0.30
0.26
0.66
2.25 mrad
2"
-2"
-4"
-6"
-1"
-2"
-3"

Figure 16

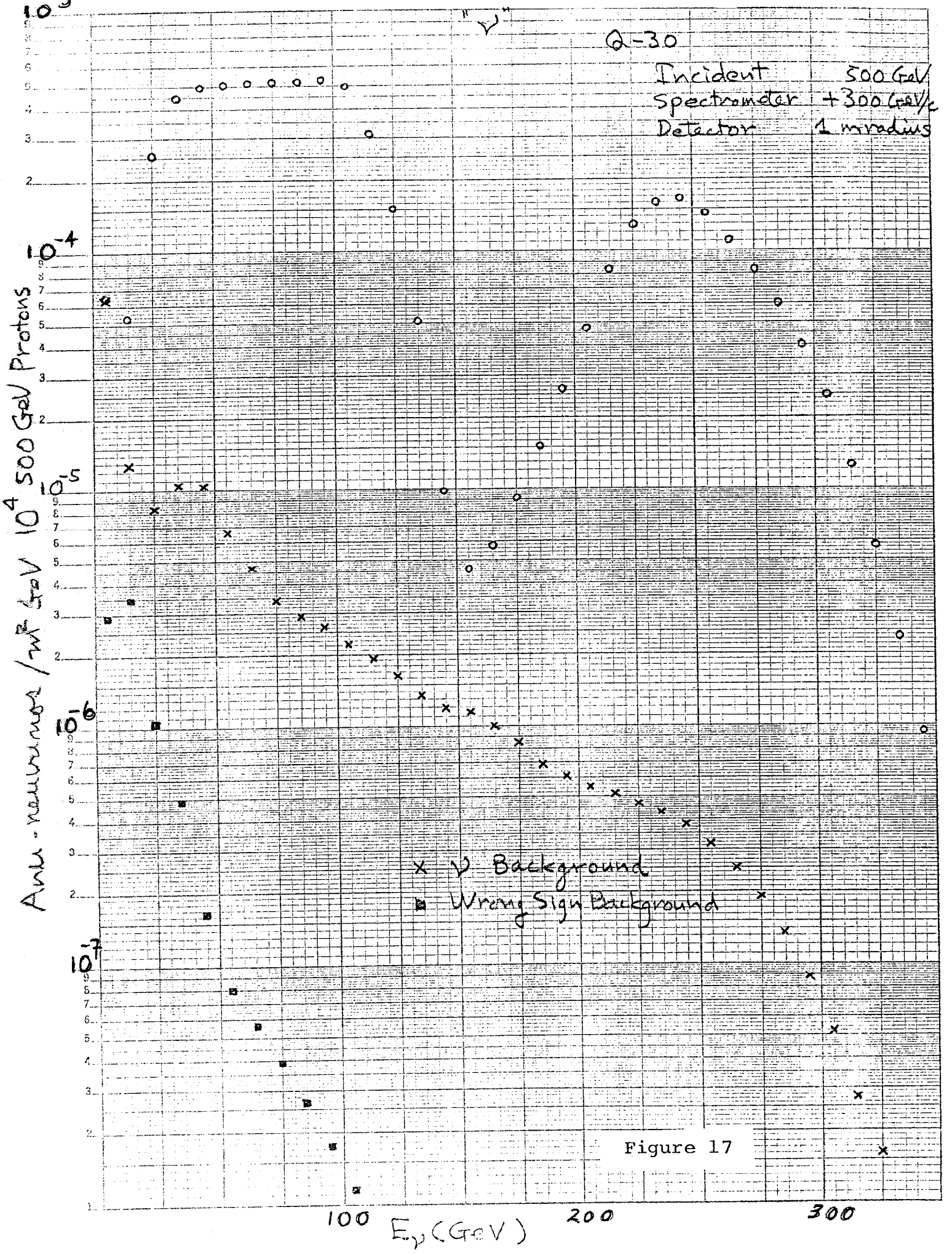

"ν"
Q-30
Incident 500 GeV/c
Spectrometer +300 GeV/c
Detector 1 mradius
Anti-neutrinos / m² 4eV 10⁴ 500 GeV Protons
× ν Background
■ Wrong Sign Background
100
200
300
Eν (GeV)

Figure 17

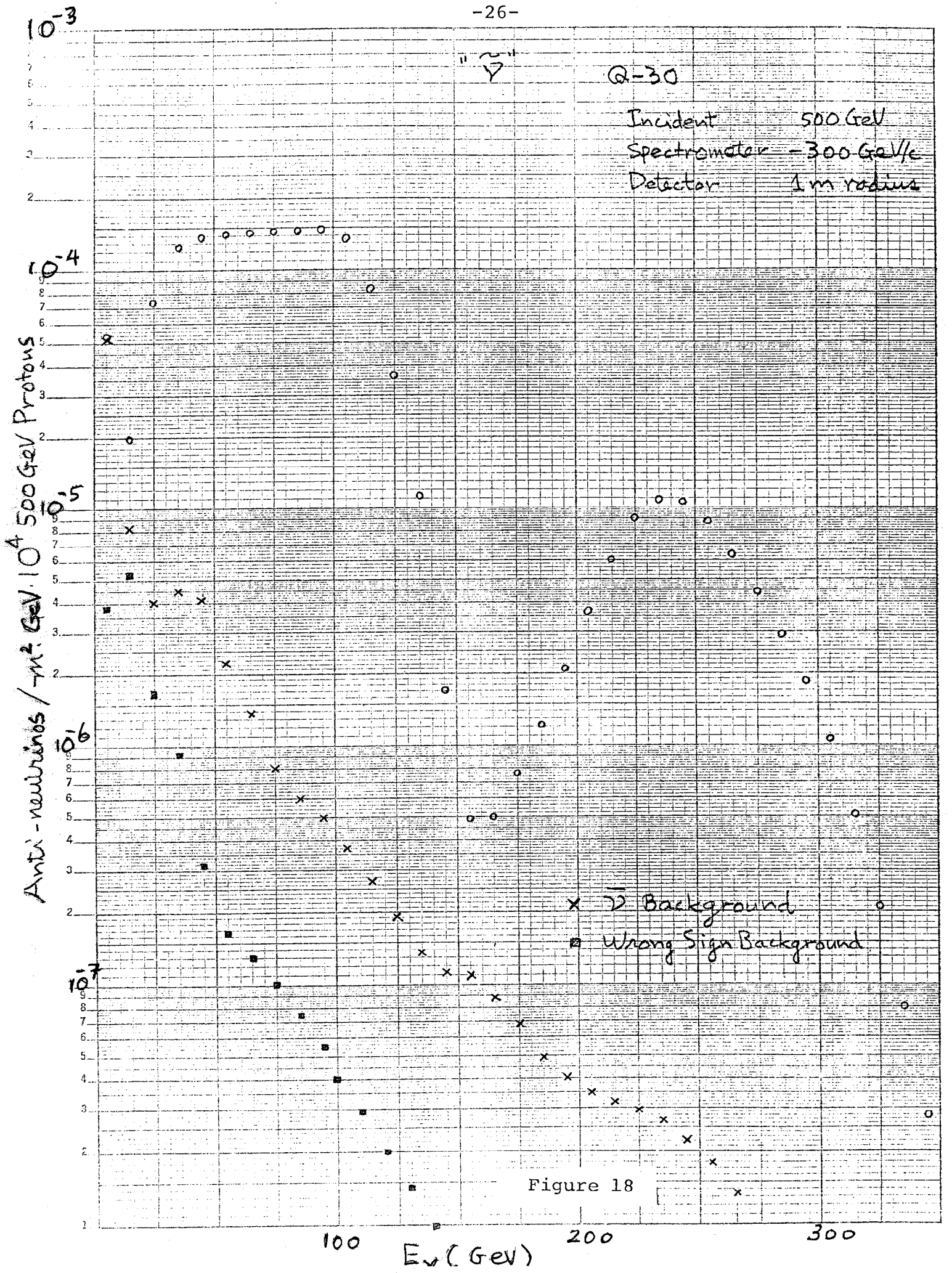

"$\tilde{\nu}$"
Q-30
Incident 500 GeV
Spectrometer −300 GeV/c
Detector 1 m radius
Anti-neutrinos / m² GeV · 10⁴ 500 GeV Protons
× $\bar{\nu}$ Background
Wrong Sign Background
100
200
300
E_ν (GeV)

Figure 18

THE FOLLOWING IS A HISTOGRAM OF DP/P FOR 2217 RAYS

INTERVAL			SCALE FACTOR: 100 X'S EQUAL 154 RAYS
LESS THAN	-40.000	0	
-40.000 TO	-38.000	0	
-38.000 TO	-36.000	0	
-36.000 TO	-34.000	0	
-34.000 TO	-32.000	0	
-32.000 TO	-30.000	0	
-30.000 TO	-28.000	0	
-28.000 TO	-26.000	0	
-26.000 TO	-24.000	0	
-24.000 TO	-22.000	0	
-22.000 TO	-20.000	0	
-20.000 TO	-18.000	20	XXXXXXXXXXX
-18.000 TO	-16.000	44	XXXXXXXXXXXXXXXXXXXXXXXXX
-16.000 TO	-14.000	70	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-14.000 TO	-12.000	80	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-12.000 TO	-10.000	91	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-10.000 TO	-8.000	127	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-8.000 TO	-6.000	144	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.000 TO	-4.000	151	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.000 TO	-2.000	134	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.000 TO	0.000	145	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.000 TO	2.000	154	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.000 TO	4.000	144	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
4.000 TO	6.000	147	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
6.000 TO	8.000	140	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
8.000 TO	10.000	107	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10.000 TO	12.000	100	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
12.000 TO	14.000	82	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
14.000 TO	16.000	68	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
16.000 TO	18.000	64	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
18.000 TO	20.000	51	XXXXXXXXXXXXXXXXXXXXXXXXX
20.000 TO	22.000	32	XXXXXXXXXXXXXXXX
22.000 TO	24.000	34	XXXXXXXXXXXXXXXXX
24.000 TO	26.000	20	XXXXXXXXXX
26.000 TO	28.000	22	XXXXXXXXXXX
28.000 TO	30.000	16	XXXXXXXX
30.000 TO	32.000	12	XXXXX
32.000 TO	34.000	5	XXX
34.000 TO	36.000	5	XXX
36.000 TO	38.000	4	XX
38.000 TO	40.000	6	XXX
GREATER THAN	40.000	0	

CENTER = 2.178 RMS HALF WIDTH = 11.272

NO 23 OF DP/P IN PC 193.500 FT FROM THE TARGET

Figure 19

TWO DIMENSIONAL PLOT OF XPR VS DP/P

```
                    -40.000   -20.000     0.000     20.000     40.000 TOTALS
                      I**---**---**---**---**---**---**---**---**I--------
-2.000 TO   -1.800 I                                        1111146 I      15
-1.800 TO   -1.600 I                                     144739544  I      41
-1.600 TO   -1.400 I                                  12359665A64   I      57
-1.400 TO   -1.200 I                               46BAF9C87747     I     100
-1.200 TO   -1.000 I                             15BHGCECGEC8B41    I     154
-1.000 TO    -.800 I                           77DD889GC98966       I     131
 -.800 TO    -.600 I                         8FEHDFAFFAA7F71        I     172
 -.600 TO    -.400 I                       47MH7ADE8BGCC95          I     167
 -.400 TO    -.200 I                       BJ9BEDJ9BABBA1           I     159
 -.200 TO     .000 I                     5FJECBE9ND8A52             I     160
  .000 TO     .200 I                   28FEHOGKHFHD63               I     179
  .200 TO     .400 I                   88CJFAIJDDFB6                I     167
  .400 TO     .600 I                 2LECFCEHLDHJ6                  I     183
  .600 TO     .800 I                 7AONBDDCEEEC1                  I     157
  .800 TO    1.000 I               3J66C8EGJC73                     I     128
 1.000 TO    1.200 I               77CDBCI76                        I      93
 1.200 TO    1.400 I               FAAC982                          I      66
 1.400 TO    1.600 I             49C9731                            I      45
 1.600 TO    1.800 I             B7D22                              I      35
 1.800 TO    2.000 I             53                                 I       8
                      I**---**---**---**---**---**---**---**---**I--------
                      I                                          I
                      I                                          I
                      I                  11111111111             I
                      I              2478924534544400 8665332211 I
          TOTALS      I 00000000000400174145447070284124026055 46 I    2217
```

TOTAL NUMBER OF ENTRIES = 2217 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	0	0

NO. 14 TWO DIMENSIONAL PLOT OF
DP/P IN PC 0.000 FT FROM THE TARGET
XPR IN MR 0.000 FT FROM THE TARGET, FLAG AT 193.500 FT

Figure 20

TWO DIMENSIONAL PLOT OF YPR VS DP/P

```
                    -40.000   -20.000      0.000    20.000    40.000 TOTALS
                      I**---**---**---**---**---**---**---**---**I--------
-2.000 TO   -1.800 I                  1 1422474753736461 211 1    I      72
-1.800 TO   -1.600 I                 315A33AA8595343311541 2211   I     103
-1.600 TO   -1.400 I                33738B9C7D97585225543112       I     135
-1.400 TO   -1.200 I                33247668A747AA663713211     1 I     118
-1.200 TO   -1.000 I               24254662A868B54744 31 11   1    I     105
-1.000 TO    -.800 I              22 766C965669C771562121343 1 2 I     133
 -.800 TO    -.600 I              1351398E77BB6A 74474 21221       I     130
 -.600 TO    -.400 I              1527356537A3B47462241213  1 2   I     107
 -.400 TO    -.200 I               1339678 4A3BA73844462322111     I     123
 -.200 TO     .000 I              3143267EC652A9763475 3212     1 I     125
  .000 TO     .200 I              31332B2BA9796938643533        12 I     129
  .200 TO     .400 I               333897ACB8766647 71442241 11    I     137
  .400 TO     .600 I              21334888B6777744555 32212        I     115
  .600 TO     .800 I               235288885A6778C4 42 1           I     110
  .800 TO    1.000 I              219165A8886BA57438722             I     123
 1.000 TO    1.200 I              1323243328393586                  I      78
 1.200 TO    1.400 I              14553A718BC894421                 I      95
 1.400 TO    1.600 I              142749846252C73                   I      76
 1.600 TO    1.800 I              23276668A6A5542                   I      82
 1.800 TO    2.000 I               25263853 753                     I      49
                   I**---**---**---**---**---**---**---**---**I--------
                   I                                          I
                   I                                          I
                   I                  1111111111              I
                   I              136782343444430986653322 11 I
         TOTALS    I 0000000000981121962393474917412402505546 I   2145
```

TOTAL NUMBER OF ENTRIES = 2217 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	17	55

NO 15 TWO DIMENSIONAL PLOT OF
DP/P IN PC 0.000 FT FROM THE TARGET
YPR IN MR 0.000 FT FROM THE TARGET, FLAG AT 193.500 FT

Figure 21

```
THE FOLLOWING IS A HISTOGRAM OF     X     FOR     2217 RAYS

        INTERVAL                               SCALE FACTOR:  100 X+S EQUAL    392 RAYS

LESS THAN        -8.000        0
  -8.000 TO    -7.500        0
  -7.500 TO    -7.000        0
  -7.000 TO    -6.500        0
  -6.500 TO    -6.000        0
  -6.000 TO    -5.500        0
  -5.500 TO    -5.000        0
  -5.000 TO    -4.500        0
  -4.500 TO    -4.000        0
  -4.000 TO    -3.500        0
  -3.500 TO    -3.000        0
  -3.000 TO    -2.500       20   XXXXX
  -2.500 TO    -2.000       61   XXXXXXXXXXXXXXX
  -2.000 TO    -1.500      108   XXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.500 TO    -1.000      341   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.000 TO     -.500      392   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.500 TO     -.000      213   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.000 TO      .500      154   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .500 TO     1.000      123   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   1.000 TO     1.500      133   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   1.500 TO     2.000      105   XXXXXXXXXXXXXXXXXXXXXXXXXX
   2.000 TO     2.500      109   XXXXXXXXXXXXXXXXXXXXXXXXXXX
   2.500 TO     3.000       77   XXXXXXXXXXXXXXXXXXX
   3.000 TO     3.500       95   XXXXXXXXXXXXXXXXXXXXXXXX
   3.500 TO     4.000       99   XXXXXXXXXXXXXXXXXXXXXXXXX
   4.000 TO     4.500       63   XXXXXXXXXXXXXXXX
   4.500 TO     5.000       65   XXXXXXXXXXXXXXXX
   5.000 TO     5.500       34   XXXXXXXX
   5.500 TO     6.000       25   XXXXXX
   6.000 TO     6.500        0
   6.500 TO     7.000        0
   7.000 TO     7.500        0
   7.500 TO     8.000        0

GREATER THAN      8.000        0

                CENTER =      .617   RMS HALF WIDTH =     2.030

NO  26 OF    X IN IN    1343.500 FT   FROM THE TARGET
```

Figure 22

THE FOLLOWING IS A HISTOGRAM OF Y FOR 2217 RAYS

INTERVAL		SCALE FACTOR: 100 X*S EQUAL 195 RAYS
LESS THAN -8.000	80	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-8.000 TO -7.500	26	XXXXXXXXXXXXX
-7.500 TO -7.000	27	XXXXXXXXXXXXX
-7.000 TO -6.500	22	XXXXXXXXXXX
-6.500 TO -6.000	32	XXXXXXXXXXXXXXXX
-6.000 TO -5.500	31	XXXXXXXXXXXXXXX
-5.500 TO -5.000	37	XXXXXXXXXXXXXXXXXX
-5.000 TO -4.500	28	XXXXXXXXXXXXXX
-4.500 TO -4.000	59	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.000 TO -3.500	58	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-3.500 TO -3.000	73	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-3.000 TO -2.500	56	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.500 TO -2.000	86	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.000 TO -1.500	89	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.500 TO -1.000	116	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.000 TO -.500	176	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-.500 TO -.000	138	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-.000 TO .500	195	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.500 TO 1.000	145	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1.000 TO 1.500	108	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1.500 TO 2.000	112	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.000 TO 2.500	78	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.500 TO 3.000	67	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
3.000 TO 3.500	61	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
3.500 TO 4.000	76	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
4.000 TO 4.500	44	XXXXXXXXXXXXXXXXXXXXXX
4.500 TO 5.000	41	XXXXXXXXXXXXXXXXXXXXX
5.000 TO 5.500	24	XXXXXXXXXXXX
5.500 TO 6.000	35	XXXXXXXXXXXXXXXXX
6.000 TO 6.500	18	XXXXXXXXX
6.500 TO 7.000	24	XXXXXXXXXXXX
7.000 TO 7.500	10	XXXXX
7.500 TO 8.000	8	XXXX
GREATER THAN 8.000	37	XXXXXXXXXXXXXXXXXX

CENTER = -.339 RMS HALF WIDTH = 3.916

NO 27 OF Y IN IN 1343.500 FT FROM THE TARGET

Figure 23

TWO DIMENSIONAL PLOT OF Y VS X

```
                    -8.000     -3.000      2.000      7.000    TOTALS
                     I**---**---**---**---**---**---**--I--------
8.000 TO   -7.500 I                1 32611 215 2 1 1       I      26
7.500 TO   -7.000 I               11153  1123111132        I      27
7.000 TO   -6.500 I                25422    3     31       I      22
6.500 TO   -6.000 I                 2452212322132 1        I      32
6.000 TO   -5.500 I                116361121 1112211       I      31
5.500 TO   -5.000 I                1 5624222111 613        I      37
5.000 TO   -4.500 I                  5421  121143211       I      28
4.500 TO   -4.000 I               1355A34252424413 1       I      59
4.000 TO   -3.500 I               2268C3 642213322         I      58
3.500 TO   -3.000 I               1119H4427236533122       I      73
3.000 TO   -2.500 I                 1895433324334 2        I      56
2.500 TO   -2.000 I                24EFBA38236311111       I      86
2.000 TO   -1.500 I                438HA9554143454         I      89
1.500 TO   -1.000 I               125IRB849844552 21       I     116
1.000 TO    -.500 I               137K$QIJ4E36442611       I     176
-.500 TO    -.000 I               1140KDLF767752212        I     138
-.000 TO     .500 I                27WYLMFJCA4451412       I     195
 .500 TO    1.000 I               1150QOFA774167412        I     145
1.000 TO    1.500 I                 6HMF2585A3163311       I     108
1.500 TO    2.000 I               1250L77674942812 2       I     112
2.000 TO    2.500 I                24CF654556335 21        I      78
2.500 TO    3.000 I                119C523A344631111       I      67
3.000 TO    3.500 I                359B2124242732112       I      61
3.500 TO    4.000 I               121HH42434612424 2       I      76
4.000 TO    4.500 I                135932232 15411 2       I      44
4.500 TO    5.000 I               1125531233 32424         I      41
5.000 TO    5.500 I                  6221 1 211332         I      24
5.500 TO    6.000 I               135312 1 24322 312       I      35
6.000 TO    6.500 I                1 3  31  214 2  1       I      18
6.500 TO    7.000 I               12 334 111  23 111       I      24
7.000 TO    7.500 I                11111 1    1111         I      10
7.500 TO    8.000 I                 21131                   I       8
                     I**---**---**---**---**---**---**--I--------
                     I                                   I
                     I                                   I
                     I                33211111           I
                     I              1491705230079956 32  I
          TOTALS     I 0000000000555933112365169033000 0 I    2100
```

TOTAL NUMBER OF ENTRIES = 2217 INCLUDING UNDERFLOW AND OVERFLOW

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	80	37

NO 28 TWO DIMENSIONAL PLOT OF
X IN IN 1343.500 FT FROM THE TARGET
Y IN IN 1343.500 FT FROM THE TARGET

Figure 24