TM-661
2972.000

350 GeV/c DICHROMATIC NEUTRINO TARGET TRAIN

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May 6, 1976

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° C.W., 24.38° C.W. and 20° 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° 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.)

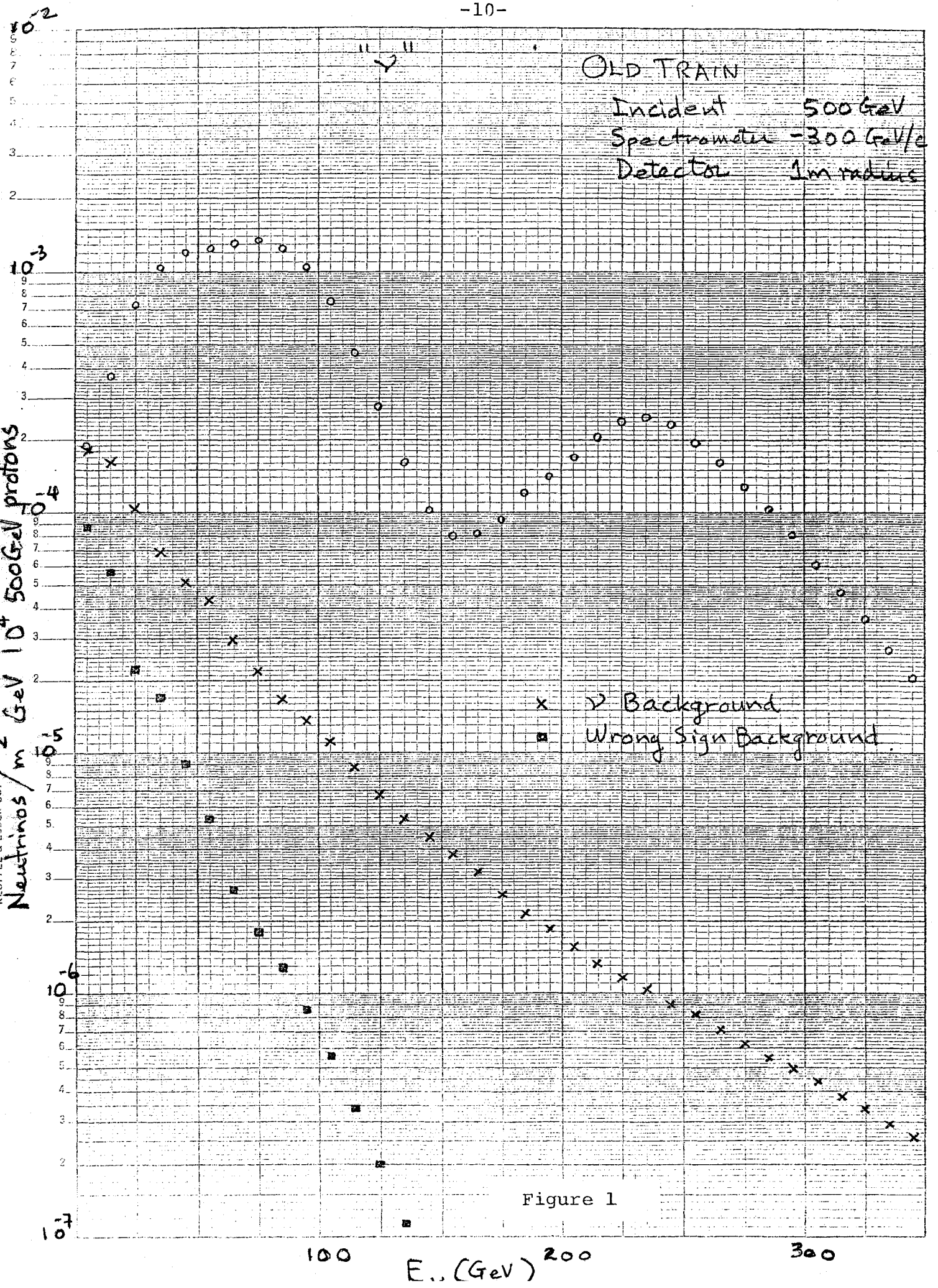
OLD TRAIN
Incident 500 GeV
Spectrometer -300 GeV/c
Detector 1m radius
ν Background
Wrong Sign Background
Neutrinos/m² GeV 10⁴ 500GeV protons
E_ν (GeV)
100
200
300
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
K&E SEMI-LOGARITHMIC 46 6210
5 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Figure 1

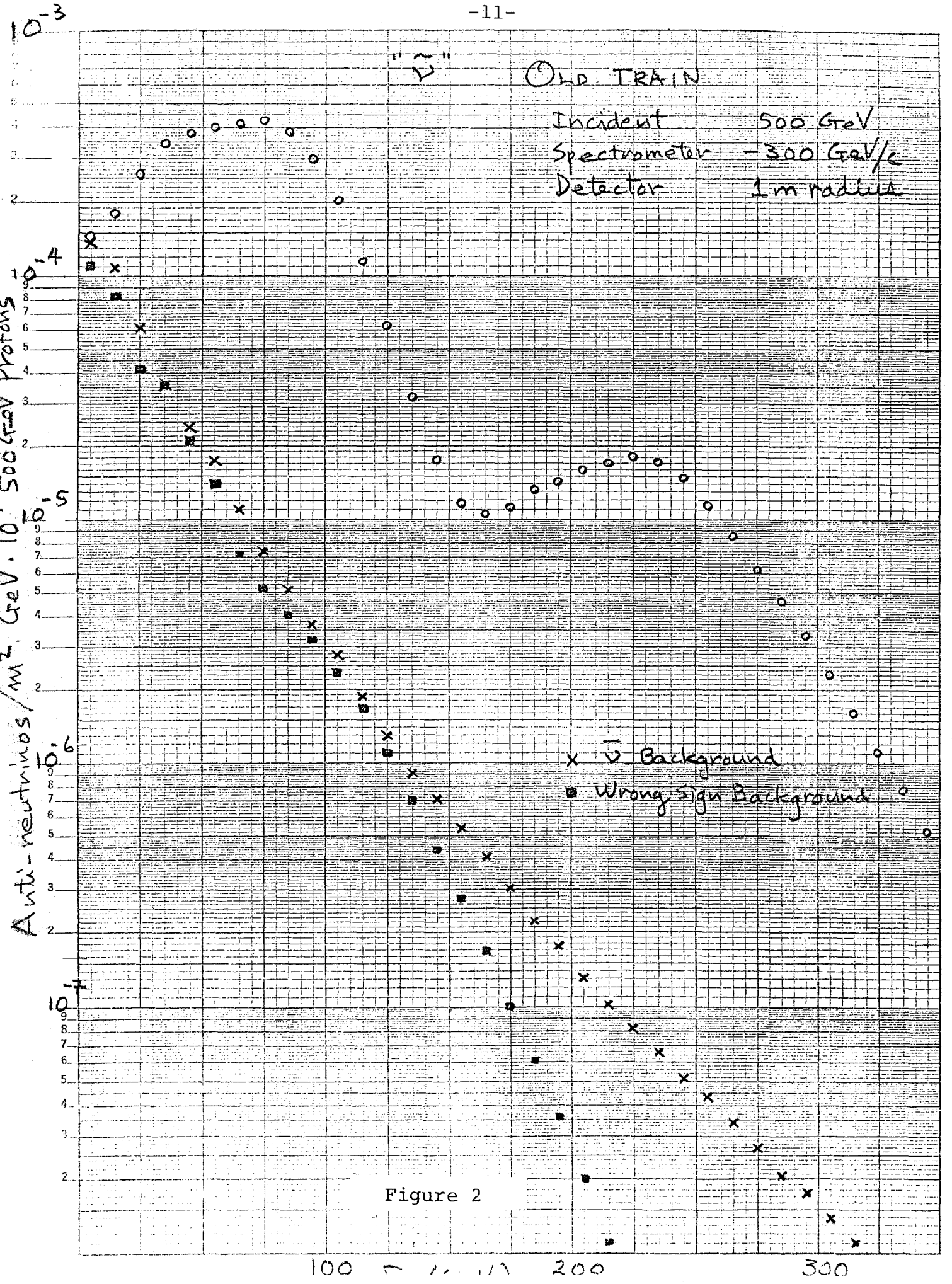
"ν̃"
OLD TRAIN
Incident 500 GeV
Spectrometer -300 GeV/c
Detector 1m radius
× ν̄ Background
■ Wrong sign Background
Anti-neutrinos/m². GeV. 10⁴ 500 GeV Protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
100
200
300

Figure 2

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

```
        INTERVAL                                  SCALE FACTOR:  100 X'S EQUAL   201 RAYS

LESS THAN    -50.000        0
-50.000 TO   -45.000        0
-45.000 TO   -40.000        5   XX
-40.000 TO   -35.000       12   XXXXX
-35.000 TO   -30.000       27   XXXXXXXXXXXXX
-30.000 TO   -25.000       54   XXXXXXXXXXXXXXXXXXXXXXXXX
-25.000 TO   -20.000      122   XXXXXXXXXXXXXXXXXXXX
```

```
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 1BDG4842              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   256BA77837B7325212 412514533 I     127
 1.400 TO   -1.200 I    56A7B3977884B36552131222221 I     133
 1.200 TO   -1.000 I    359F8D98855431623252646914 1 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      5896A58535632732531332341 I     112
  .200 TO     .400 I      76A799A5474362723 1346313 I     122
  .400 TO     .600 I      69D8AB53244764323 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         47A67416243231141381 1 I      79
 1.600 TO    1.800 I        29A874623442413 2123222 I      83
 1.800 TO    2.000 I         6876D674 2345622131112 I      90
 2.000 TO    2.200 I         1566544226323432114 35 I      72
 2.200 TO    2.400 I          4866973545321353211 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   1252685086529067765535457465 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

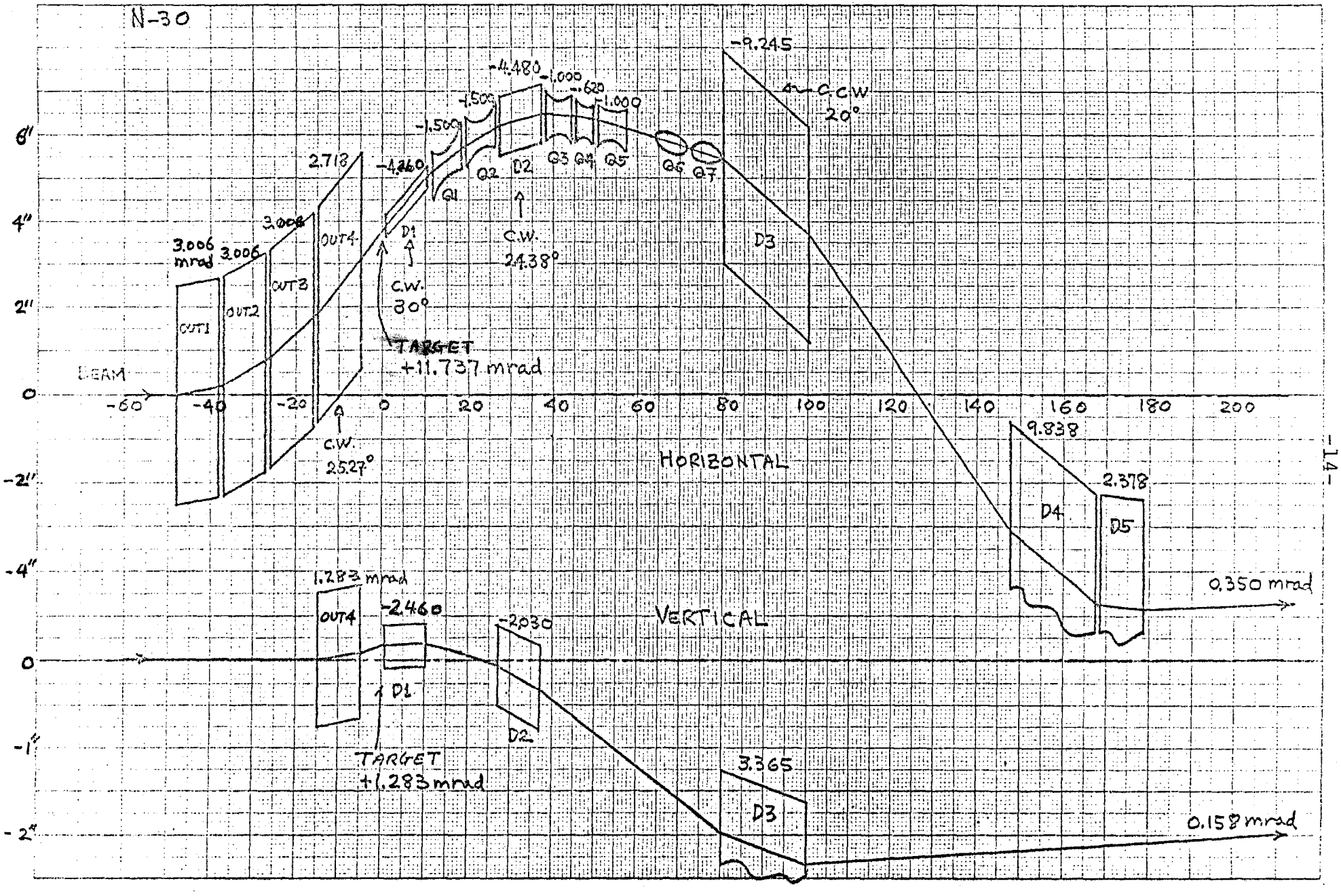
N-30
BEAM
OUT1
OUT2
OUT3
OUT4
3.006 mrad
3.006
3.008
2.718
-4.260
-1.509
-1.509
-4.480
-1.000
-.620
-1.000
-9.245
C.C.W. 20°
Q1
Q2
D2
Q3
Q4
Q5
Q6
Q7
D1
C.W. 30°
C.W. 24.38°
D3
TARGET +11.737 mrad
C.W. 25.27°
HORIZONTAL
9.838
2.378
D4
D5
0.350 mrad
1.283 mrad
OUT4
-2.460
-2.030
VERTICAL
D1
D2
TARGET +1.283 mrad
3.365
D3
0.158 mrad
6"
4"
2"
0
-2"
-4"
-1"
-2"
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200

Figure 5

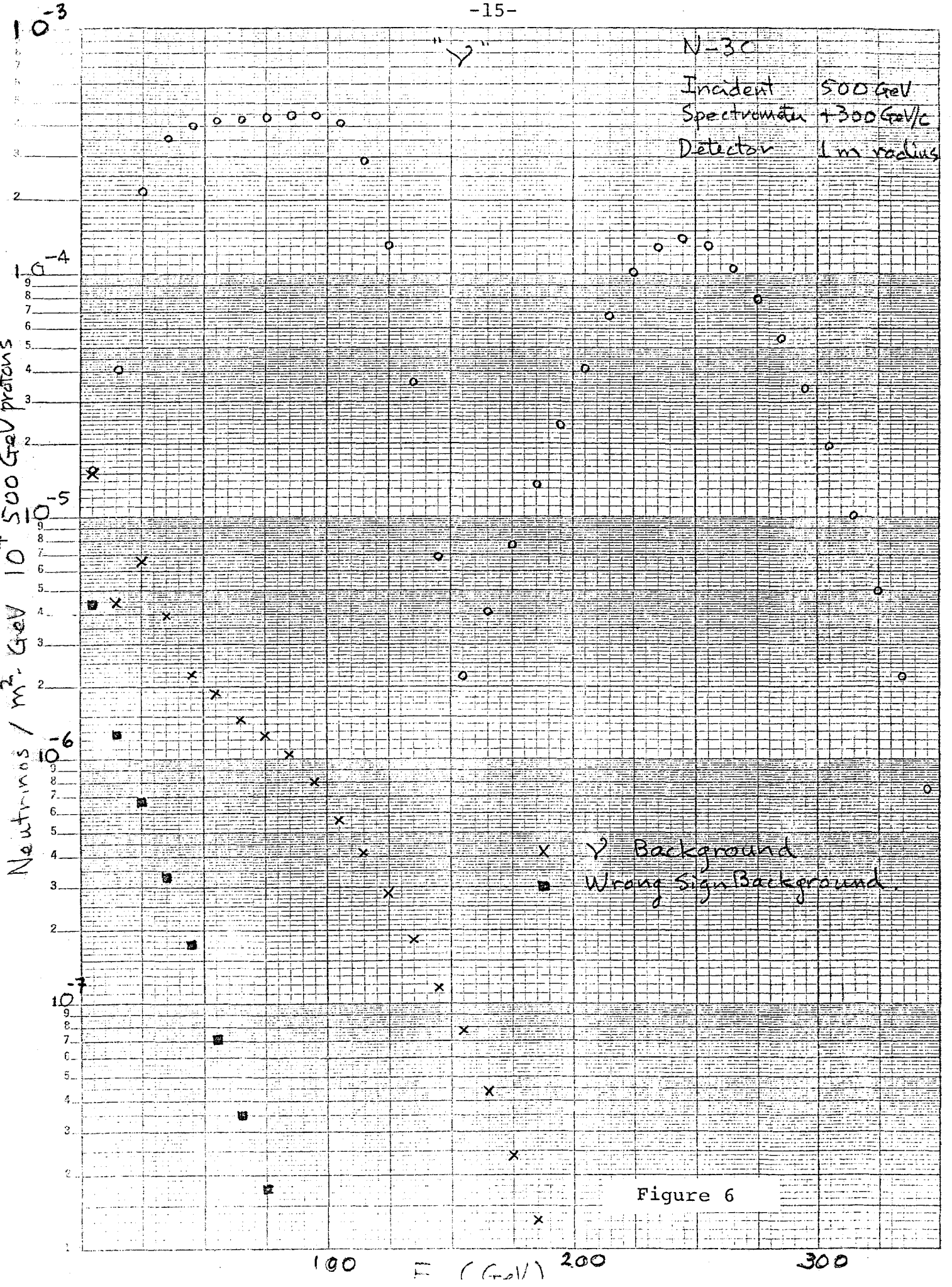
"ν"
N-3C
Incident 500 GeV
Spectrometer +300 GeV/c
Detector 1 m radius
Neutrinos / m². GeV 10⁴ 500 GeV protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
ν Background
Wrong Sign Background
100
200
300
E (GeV)

Figure 6

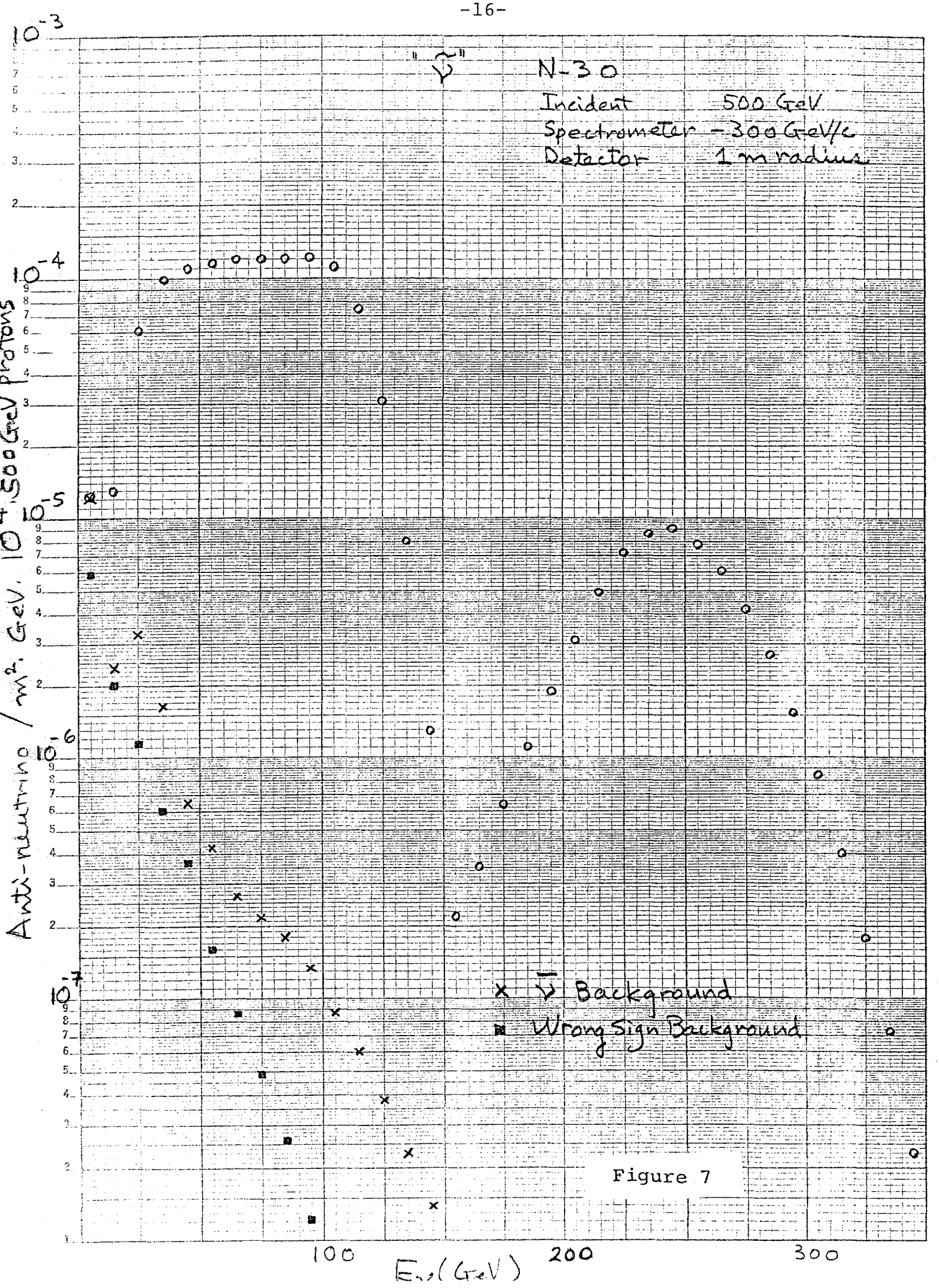
"$\tilde{\nu}$"
N-30
Incident 500 GeV
Spectrometer -300 GeV/c
Detector 1 m radius
Anti-neutrino / m². GeV. 10^4, 500 GeV protons
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
× $\bar{\nu}$ Background
■ Wrong Sign Background
100
200
300
E_ν (GeV)

Figure 7

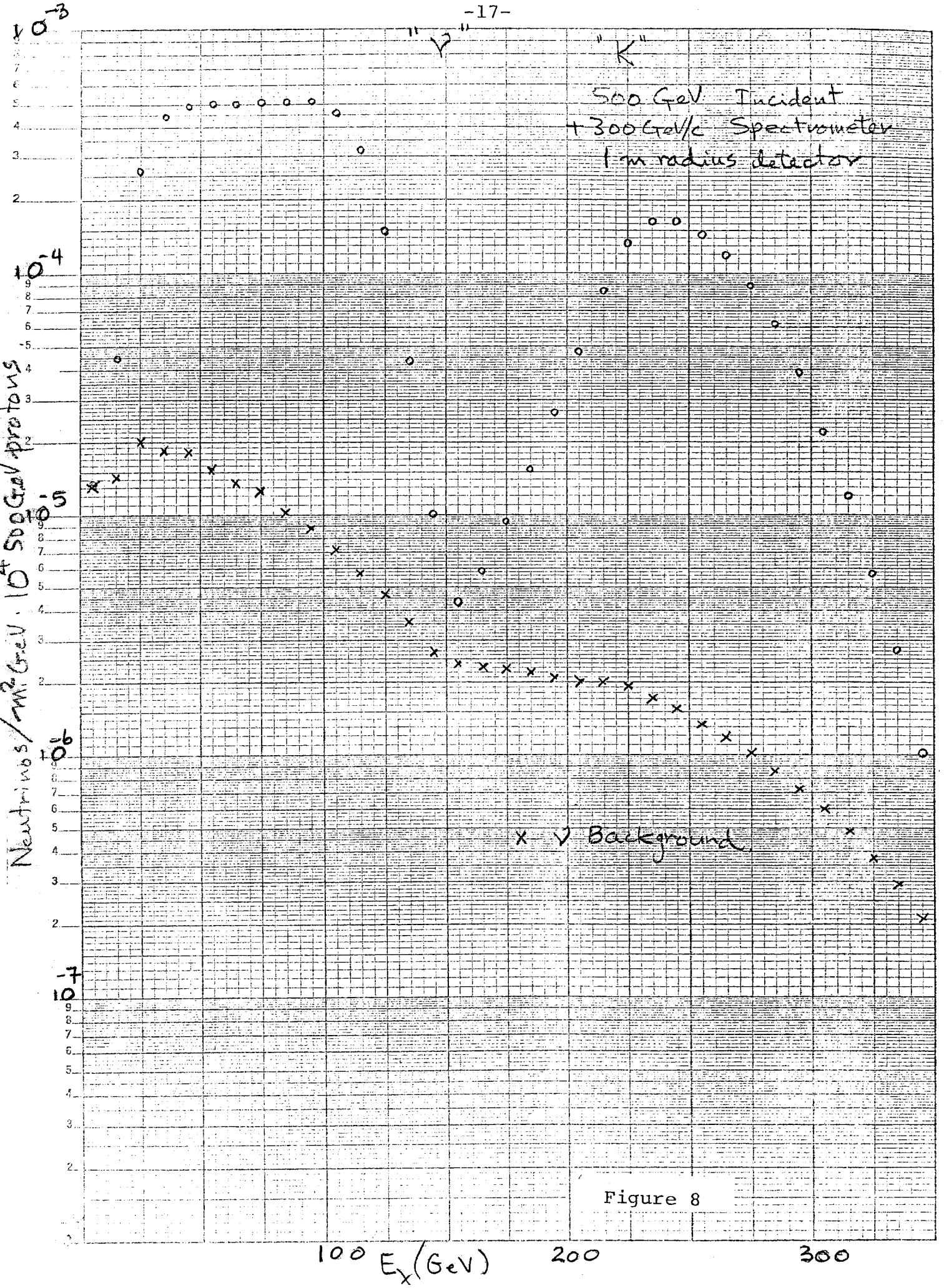
"ν"
"K"
500 GeV Incident
+300 GeV/c Spectrometer
1 m radius detector
ν Background
Neutrinos/m² GeV · 10⁴ 500 GeV/protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
100
200
300
Eν (GeV)

Figure 8

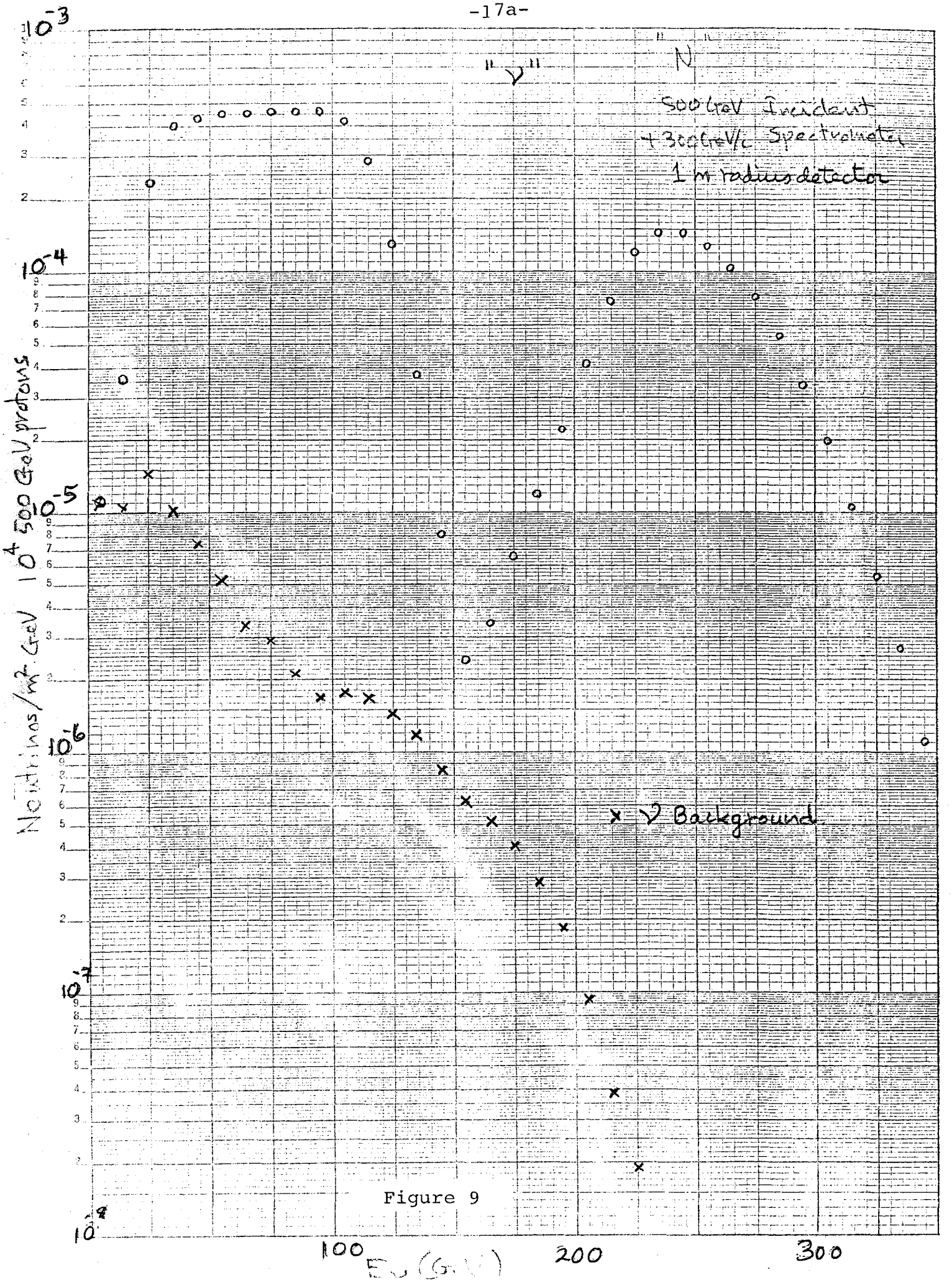
"ν"
"N"
500 GeV Incident
+ 300 GeV/c Spectrometer
1 m radius detector
× ν Background
Neutrinos/m² GeV 10⁴ 500 GeV protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
100
200
300
Eν (GeV)

Figure 9

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

SCALE FACTOR: 100 X'S EQUAL 140 RAYS

INTERVAL			
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	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-12.000 TO	-10.000	86	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-10.000 TO	-8.000	119	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-8.000 TO	-6.000	127	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.000 TO	-4.000	126	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.000 TO	-2.000	128	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.000 TO	0.000	140	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.000 TO	2.000	137	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2.000 TO	4.000	139	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
4.000 TO	6.000	129	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
6.000 TO	8.000	109	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
8.000 TO	10.000	92	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10.000 TO	12.000	108	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
12.000 TO	14.000	81	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
14.000 TO	16.000	70	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
16.000 TO	18.000	74	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
18.000 TO	20.000	66	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
20.000 TO	22.000	49	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
22.000 TO	24.000	41	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
24.000 TO	26.000	34	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
26.000 TO	28.000	28	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
28.000 TO	30.000	32	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
30.000 TO	32.000	24	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
32.000 TO	34.000	14	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
34.000 TO	36.000	22	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
36.000 TO	38.000	18	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
38.000 TO	40.000	13	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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             95BBAAD781                    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                111111111 1              I
                    I          134788122243320908665332221    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 44352552B666845646132231214    I    113
-1.000 TO    -.800 I          1 451868B76575886714631336671 52  I    151
 -.800 TO    -.600 I           129A3397997BA6B1954B712333323 4  I    168
 -.600 TO    -.400 I          216649469635A3B46555453542323222  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           232442543283A41746411            I     80
 1.200 TO    1.400 I            2365496179C764231               I     87
 1.400 TO    1.600 I           2232558736351B4221               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                111111111 1              I
                    I          245878121233320907676443232121 1 I
          TOTALS    I 0000000079565957797665780578347148144283 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

SCALE FACTOR: 100 X'S EQUAL 274 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   XXXXXXXXXXXXXXX
  -5.000 TO    -4.500       55   XXXXXXXXXXXXXXXXXXX
  -4.500 TO    -4.000       74   XXXXXXXXXXXXXXXXXXXXXXXXXX
  -4.000 TO    -3.500       85   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -3.500 TO    -3.000       77   XXXXXXXXXXXXXXXXXXXXXXXXXXX
  -3.000 TO    -2.500      100   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -2.500 TO    -2.000      112   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -2.000 TO    -1.500      138   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.500 TO    -1.000      175   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.000 TO     -.500      260   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.500 TO     -.000      274   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.000 TO      .500      190   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .500 TO     1.000      140   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   1.000 TO     1.500      105   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   1.500 TO     2.000      102   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   2.000 TO     2.500       80   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   2.500 TO     3.000       77   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   3.000 TO     3.500       51   XXXXXXXXXXXXXXXXXXXX
```

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   XXXXXXXXXXXXXXXXXXXXXX
  -4.000 TO    -3.500       57   XXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -3.500 TO    -3.000       80   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -3.000 TO    -2.500       90   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -2.500 TO    -2.000      101   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -2.000 TO    -1.500      143   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.500 TO    -1.000      174   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  -1.000 TO     -.500      175   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.500 TO     -.000      189   XXXXXXXXXXXXXXXXXXXX
```

```
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        21312354B858   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     1348455575DFFB94247835         I     143
-1.500 TO   -1.000 I  11113863425JDDHCFA78864331        I     174
-1.000 TO    -.500 I  2 13245549B9CBEGBDB887441         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            111221111             I
                   I   1224578790375783008754 31      T
          TOTALS   I 1653944115976280645207104720000 0 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

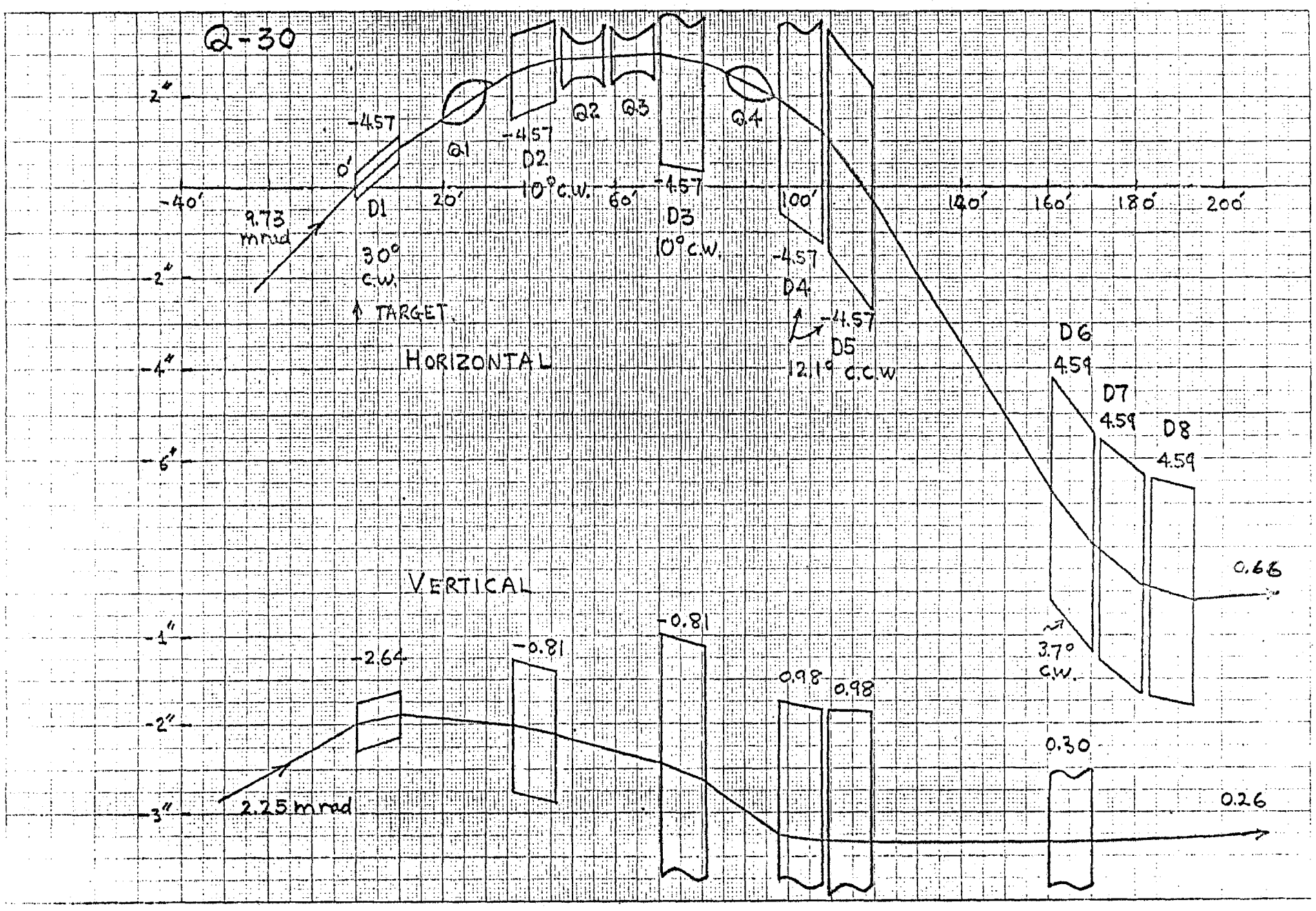
Q-30
2"
-2"
-4"
-6"
-40'
20'
60'
100'
140'
160'
180'
200'
-4.57
0'
D1
9.73 mrad
30° c.w.
TARGET
Q1
-4.57
D2
10° c.w.
Q2
Q3
-4.57
D3
10° c.w.
Q4
-4.57
D4
-4.57
D5
12.1° c.c.w
HORIZONTAL
D6
4.59
D7
4.59
D8
4.59
0.66
VERTICAL
-1"
-2"
-3"
-2.64
2.25 mrad
-0.81
-0.81
0.98
0.98
3.7° c.w.
0.30
0.26

Figure 16

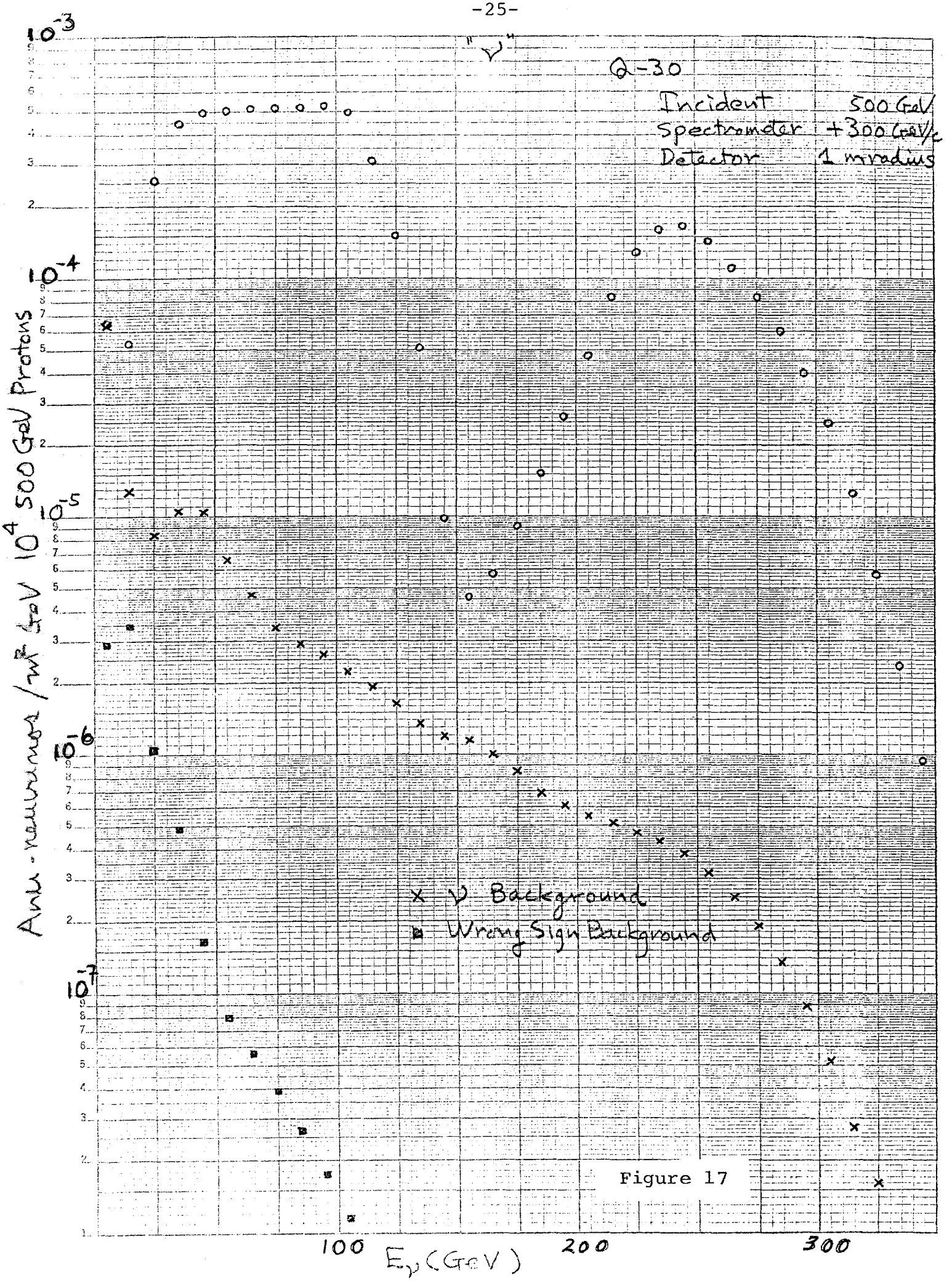
"ν"
Q-30
Incident 500 GeV
Spectrometer +300 GeV/c
Detector 1 mradius
Anti-neutrinos / m² GeV 10⁴ 500 GeV Protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
× ν Background
■ Wrong Sign Background
100
200
300
Eν (GeV)

Figure 17

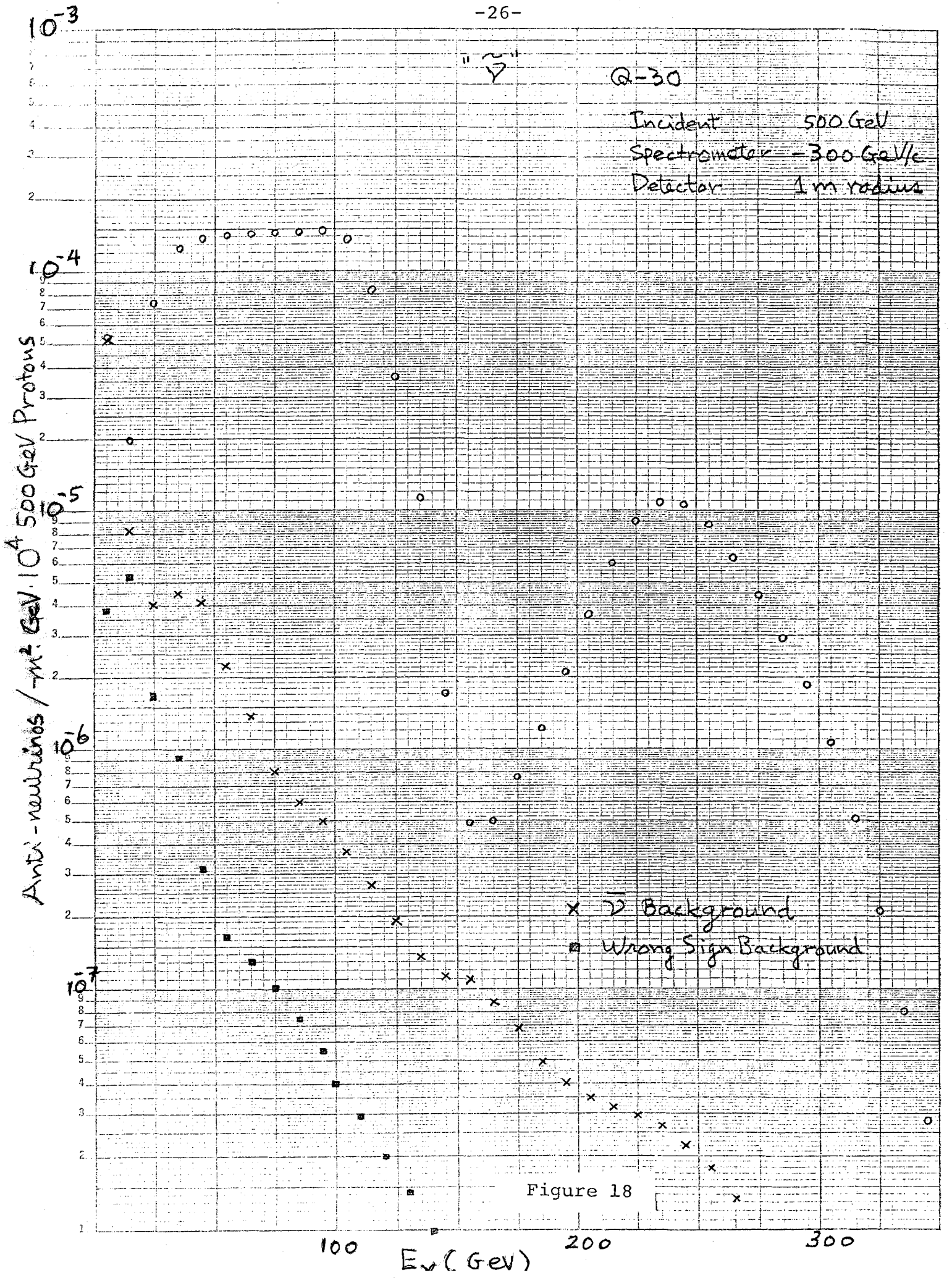
"$\tilde{\nu}$"
Q-30
Incident 500 GeV
Spectrometer -300 GeV/c
Detector 1 m radius
Anti-neutrinos / m² GeV · 10⁴ 500 GeV Protons
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
× $\bar{\nu}$ Background
▪ Wrong Sign Background
100
200
300
E_ν (GeV)

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   XXXXXXXXXXXX
-18.000 TO   -16.000       44   XXXXXXXXXXXXXXXXXXXXXXXXXX
-16.000 TO   -14.000       70   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-14.000 TO   -12.000       80   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-12.000 TO   -10.000       91   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-10.000 TO    -8.000      127   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -8.000 TO    -6.000      144   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -6.000 TO    -4.000      151   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -4.000 TO    -2.000      134   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -2.000 TO     0.000      145   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  0.000 TO     2.000      154   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  2.000 TO     4.000      144   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  4.000 TO     6.000      147   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  6.000 TO     8.000      140   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  8.000 TO    10.000      107   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 10.000 TO    12.000      100   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 12.000 TO    14.000       82   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 14.000 TO    16.000       68   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 16.000 TO    18.000       64   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 18.000 TO    20.000       51   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 20.000 TO    22.000       32   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 22.000 TO    24.000       34   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 24.000 TO    26.000       20   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 26.000 TO    28.000       22   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 28.000 TO    30.000       16   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 30.000 TO    32.000       10   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 32.000 TO    34.000        5   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 34.000 TO    36.000        5   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 36.000 TO    38.000        4   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 38.000 TO    40.000        6   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

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              2BFEHDGKHFHD63               I     179
  .200 TO     .400 I              88CJFAIJDDFB6                I     167
  .400 TO     .600 I             2LECFCEHLDHJ6                 I     183
  .600 TO     .800 I             7ADNBDDCEEEC1                 I     157
  .800 TO    1.000 I            3J66CBEGJC73                   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             13396784A3BA73844462322111    I    123
 -.200 TO     .000 I            3143267EC652A9763475 3212    1 I    125
  .000 TO     .200 I            31332B2BA9796988643533      12 I    129
  .200 TO     .400 I             333897ACB876664771442241 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            132324332839358586             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           1367823434444309866533221 1   I
          TOTALS    I 0000000000981121962393474917412402605546 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

SCALE FACTOR: 100 X+S EQUAL 392 RAYS

INTERVAL			
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	XXXXXXXXXXXXXX
-2.000 TO	-1.500	108	XXXXXXXXXXXXXXXXXXXXXXXXXX
-1.500 TO	-1.000	341	XXXXXXXXXXXXXXXXXXXX

THE FOLLOWING IS A HISTOGRAM OF Y FOR 2217 RAYS

SCALE FACTOR: 100 X+S EQUAL 195 RAYS

INTERVAL			
LESS THAN	-8.000	80	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-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	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.000 TO	-3.500	58	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
-3.500 TO	-3.000	73	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-3.000 TO	-2.500	56	XXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.500 TO	-2.000	86	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.000 TO	-1.500	89	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.500 TO	-1.000	116	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.000 TO	-.500	176	XXXXXXXXXXXXXXXXXXXX

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              18954333224334 2      I      56
2.500 TO   -2.000 I             24EFBA38236311111      I      86
2.000 TO   -1.500 I             43BHA9554143454        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            1250L776749428122       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            121HH424346124242       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           149170523007995632     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