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A VERSATILE SECONDARY BEAM FOR THE MESON AREA

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ABSTRACT

A new secondary beam design is outlined for the Meson M6 Beamline that combines versatility with economy. The beamline described will transport charged particles of either sign to 800 GeV/c and bring the beam to a focus in one of three potential experimental areas. The plan makes maximal use of existing civil construction.

INTRODUCTION

Adoption of the recent plan to target Tevatron primary proton beam north of the existing Meson Target Box demands new designs for the Meson Area secondary beams. The desire to have a simple magnetic switch that will bring the M6 beam to enter either of two side by side experimental areas near the present Multiparticle Spectrometer imposes additional constraints on a suitable M6 beam design. The present paper discusses one such design which has the capability to transport and focus the following classes of beams:

a) Large longitudinal and transverse momentum acceptance secondary beams of either electric charge sign with central momentum up to 800 GeV/c.

b) High momentum resolution beams of either electric charge sign with large transverse momentum acceptance and central momentum up to 800 GeV/c.

c) Diffracted primary proton beams up to 1000 GeV in momentum. either electric charge sign with large transverse momentum acceptance and central momentum up to 800 GeV/c.

The relative secondary and primary beam energies for positive sign beams involve complicated considerations of primary beam dumping that will not be covered here. In general, however, any negative charge beam above about 100 GeV should be possible up to the 800 GeV limit.

Positive sign beams between $X_F=0.8$ and $X_F=1.0$ will be dominated by protons and require consideration on a case by case basis to avoid radiation safety problems as noted above. Above $P_O=800$ GeV, the dipole bending power will need to be increased and less favorable phase space acceptance may be necessary due to quadrupole saturation effects. With these disclaimers noted, we proceed to consider the beam optics and layout.

PHILOSOPHY

Once a given basic beam route has been chosen, and the acceptance in transverse momentum determined by the first quadrupole lenses, the rest of the optics in a long beam has a dizzying range of possibilities. The desire to maintain the achromiticity of the beam where bends are involved limits the choices somewhat, but beyond that, many possibilities exist.

A cost effective beam designer will select a beam design that uses a minimum number of magnets to accomplish his purpose and one which can be made to serve a range of uses with a minimum number of mechanical movements of beamline elements. In the ideal case no elements are moved, and all tuning is accomplished by changing the magnitudes and signs of magnet currents and/or the adjustment of remote controlled beam collimators.

The present design is one of these. It is not unique, and probably not fully optimized, but it serves as a benchmark against which other schemes can be measured. Two basic tunes are exhibited, both possible at any energy up to 800 GeV and both achievable without moving any magnet mechanically. The first, "Beam A," was designed to transmit a large flux of particles to an achromatic spot at either branch of a symmetrically located M6E or M6W experimental hall. It is probably the type that will be most in demand given the current trends in hadron physics. The second tune, "Beam B" was given a momentum dispersed intermediate focus in order to select a very small momentum bite and transmit this beam to either experiment. This beam will be typically an order of magnitude lower in intensity and could have one or more types of beam tagging incorporated in the later stages of the beam. In both Beam A and Beam B, the particular optics shown in Figures 1 and 2 are to some extent generic and can be changed within limits to achieve other needed conditions, again without mechanical movements.

The beam layout shown in Figures 3 and 4 reflects my desire to minimize the civil construction needed and therefore it makes maximum use of existing tunnels. The vertical motion of the beam is connected with the minimization of the flux of halo muons in experimental setups and seeks to eliminate potential site boundary muon flux problems. This subject is not addressed explicitly here.

Finally, the boundary condition that the present beam hit the existing Multiparticle Spectrometer was not imposed, partly because it is costly in magnets and partly because a new experimental hall is planned which can be built while the old beam and spectrometer run. The new beam could be implemented and the MPS relocated during a shutdown period of a few months.

OPTICS

The thin lens optical trace of Beam A is given in Fig. 1. The fact that all bends are made at or very near focii allow the beam be achromatic even with the large bends necessary. Doublet optics was chosen to minimize the number of quadrupoles needed.

No sextupole corrections have been included as these are necessary only in a very limited number of applications and could be incorporated later if an experimental demand matrializes.

The final spot was arbitrarily made large horizontally and small vertically, but this can be varied to suit. The source spot size is the current expectation of the Switchyard/Extraction Group, based on SAVER beam optics at extraction.

All beam fitting was done using the program TRANSPORT[1] on the Fermilab CYBER computer. Copies of the TRANSPORT input parameters are available from the author to persons with a desire to discover other useful tunes. Determination of the final beam transport efficiency and phase plots were obtained by the ray tracing program TURTLE[2], also on the CYBER, and these input parameters are similarly available.

The beam parameters of Beams A and B are given in Table I and the list of optical elements in Table II. The flux vs. beam energy plot for secondary flux of both charge signs are shown as Fig. 5. Finally, the initial beam phase space distribution in x, y and $\Delta P/P$ for Beam A from TURTLE, as well as the final ones at the experimental targets are given in Figures 6-11. Figures 12 and 13 show the correllation plots for x and y vs. $\Delta P/P$ at the experiment. Note that second order effects have caused a small nonlinear achromaticity in the x coordinate. This could be minimized by further trial and error work with TRANSPORT and TURTLE. The x' and y' plots are not shown as they are trivially available by inspection from Fig. 1. Fig. 1 also shows the +1% central ray as a measure of the dispersion function through the transport.

TABLE I

PARAMETERS OF BEAMS A AND B

Item	Beam A	Beam B
Momentum Acceptance (FWHM)	3.5%	0.3%
Angular Acceptance, Horizontal	0.90 mr	0.38 mr
Angular Acceptance, Vertical	0.37 mr	0.88 mr
Solid Angle Acceptance	1.2 sr%	0.10 sr%
Momentum Tuning Range	800 GeV/c	800 GeV/c
No. Doubler Dipoles Needed	7	7
No. Quadrupoles Needed	22	22

TABLE II

OPTICAL LISTING FOR BEAMS A AND B

Element		Beam A (kg or kg/in) @800 GeV	Beam B (kg or kg/in) @800 GeV
B1	(2 ea @Meson H Magnet)	17.5	17.5
Q1	(3 ea @3Q120)	+4.53	-3.94
Q2	(3 ea @3Q120)	-4.38	+2.97
B2	(2 ea @ES/D 21' Dipole)	30.8	30.8
Q3	(3 ea @3Q120)	-4.67	0.0
Q4	(3 ea @3Q120)	+3.80	0.0
B3	(2 ea @ES/D 21' Dipole)	34.6	34.6
Q5	(3 ea @3Q120)	+4.71	+4.10
Q6	(3 ea Q3Q120)	-4.67	-4.49
B5	(3 ea ES/D 21' Dipole)	36.2	36.2
Q7	(2 ea @4Q120)	+4.72	-5.28
Q8	(2 ea @4Q120)	-5.08	+4.98

The thin lens beam trace of Beam B is given in Fig. 2 and the analogous results for the properties of Beam B are shown in Tables I and II as well as in Figures 3, 4 and 12-20. Note, however, that the x and ΔP/P correlation plot is also given at the slit to show the dispersed focus. For the present run, the beam slit was set at a full width of 0.20 inches which passes a beam of only 0.3% FWHM.

Again, the final parameters were set to produce a small spot at the experiment, but other choices are clearly possible.

YIELDS

The particle yields shown in Fig. 5 come from a new computation and fitting of experimental data by A. J. Malensek[3]. These yields are probably the most accurate currently available.

REFERENCES

1. "TRANSPORT, A Computer Program for Designing Charged Particle Beam Transport Systems," K. L. Brown et al., SLAC-91, Rev 2, UC-28, May 1977.

2. "TURTLE, A Computer Program for Simulating Charged Particle Beam Transport Systems," David C. Carey, NAL-64,2041.000, PM9, May 1978.

3. "Empirical Formula for Thick Target Particle Production," A. J. Malensek, FERMILAB FN-341,2941.000, October 1981.

FIGURE CAPTIONS

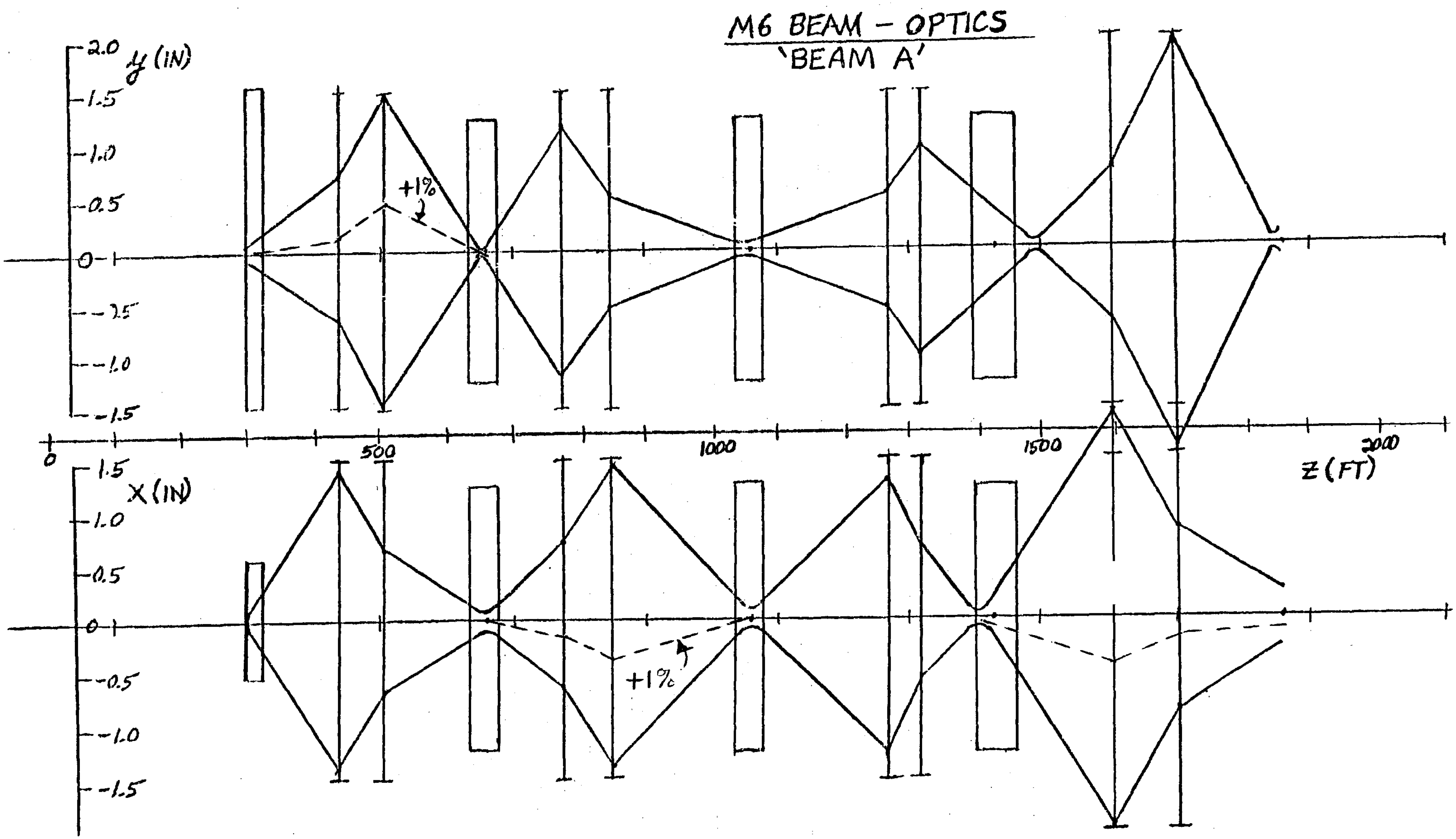

M6 BEAM - OPTICS
'BEAM A'
y (IN)
2.0
1.5
1.0
0.5
0
-.5
-1.0
-1.5
+1%
0
500
1000
1500
2000
Z (FT)
X (IN)
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
+1%

FIG 1

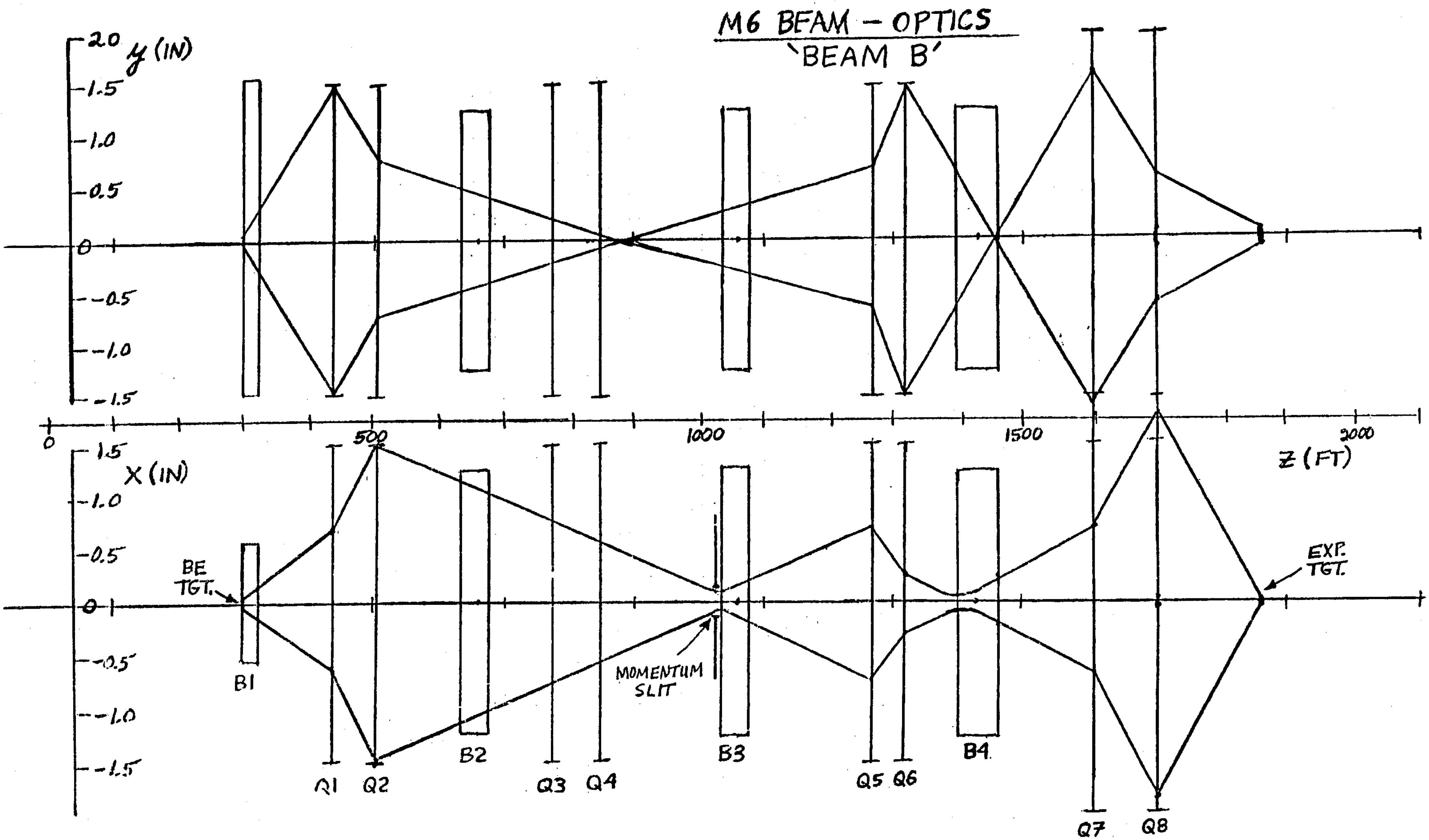

M6 BEAM - OPTICS
'BEAM B'
y (IN)
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
0
500
1000
1500
2000
Z (FT)
X (IN)
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
BE TGT.
B1
Q1
Q2
B2
Q3
Q4
MOMENTUM SLIT
B3
Q5
Q6
B4
Q7
Q8
EXP. TGT.

FIG 2

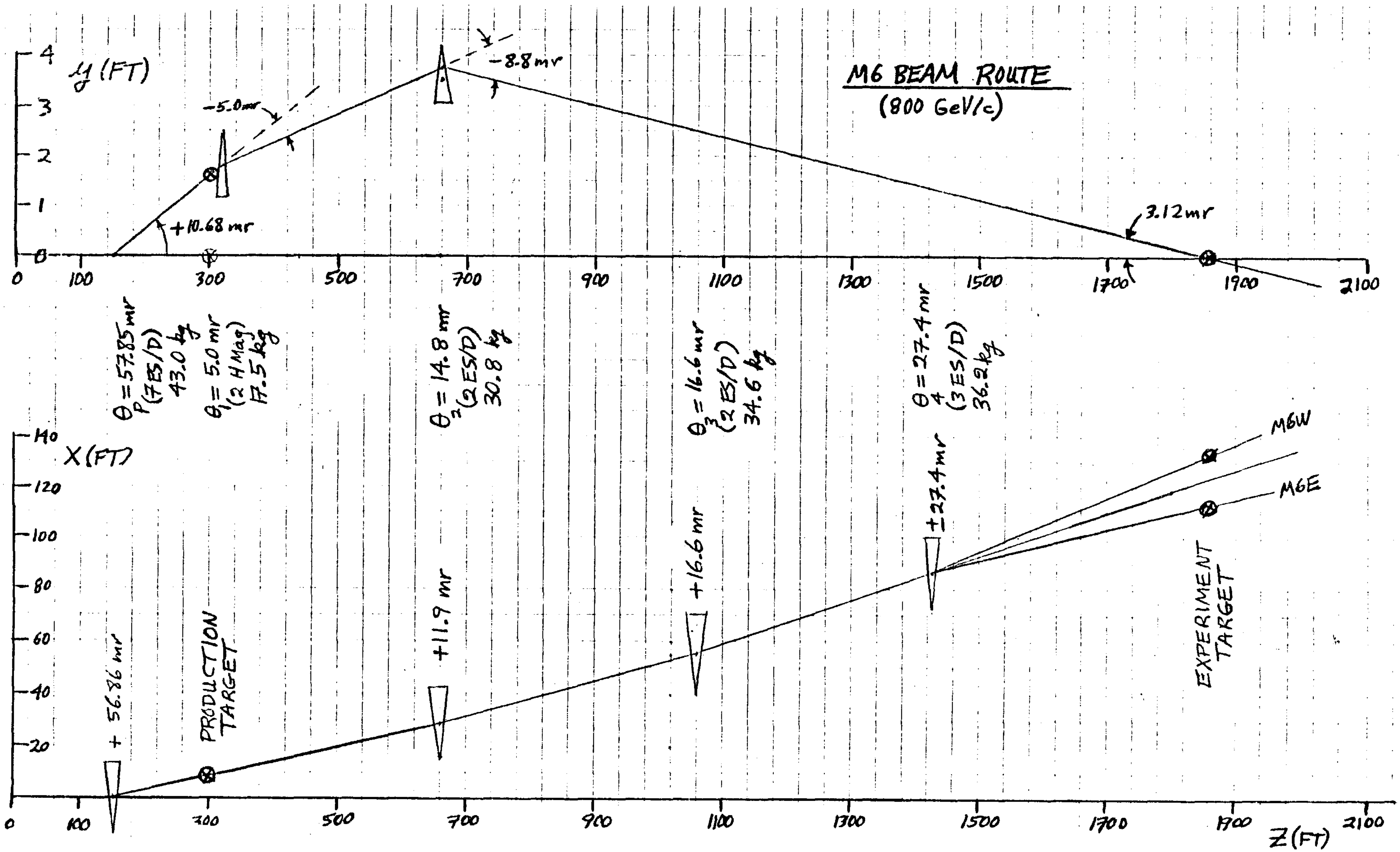

M6 BEAM ROUTE
(800 GeV/c)
y (FT)
X (FT)
Z (FT)
-5.0mr
-8.8mr
+10.68 mr
3.12mr
θP = 57.85 mr (7ES/D) 43.0 kg
θ1 = 5.0 mr (2 H Mag) 17.5 kg
θ2 = 14.8 mr (2ES/D) 30.8 kg
θ3 = 16.6 mr (2ES/D) 34.6 kg
θ4 = 27.4 mr (3ES/D) 36.2 kg
+ 56.86 mr
PRODUCTION TARGET
+11.9 mr
+16.6 mr
±27.4 mr
M6W
M6E
EXPERIMENT TARGET

FIG 3

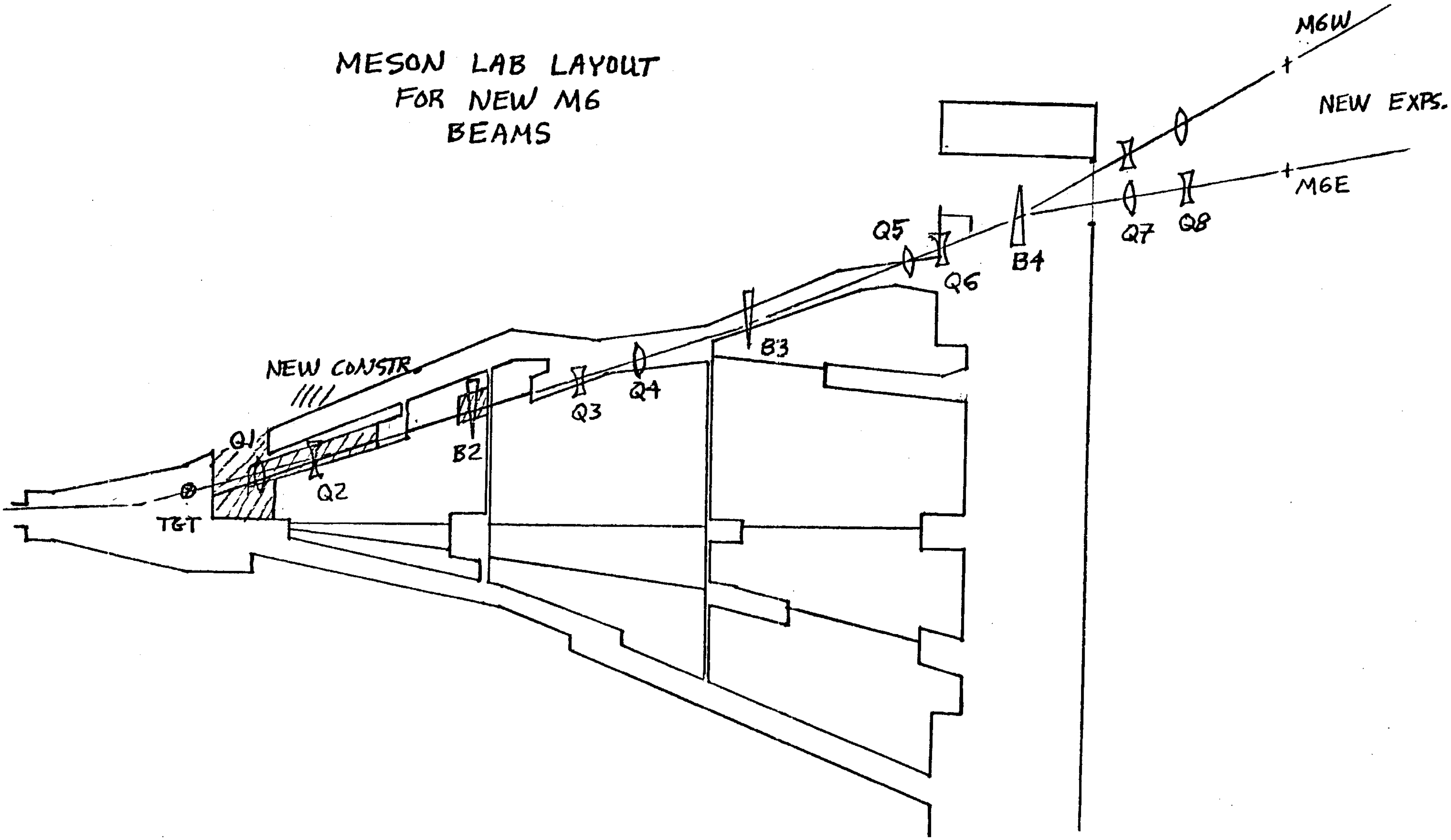
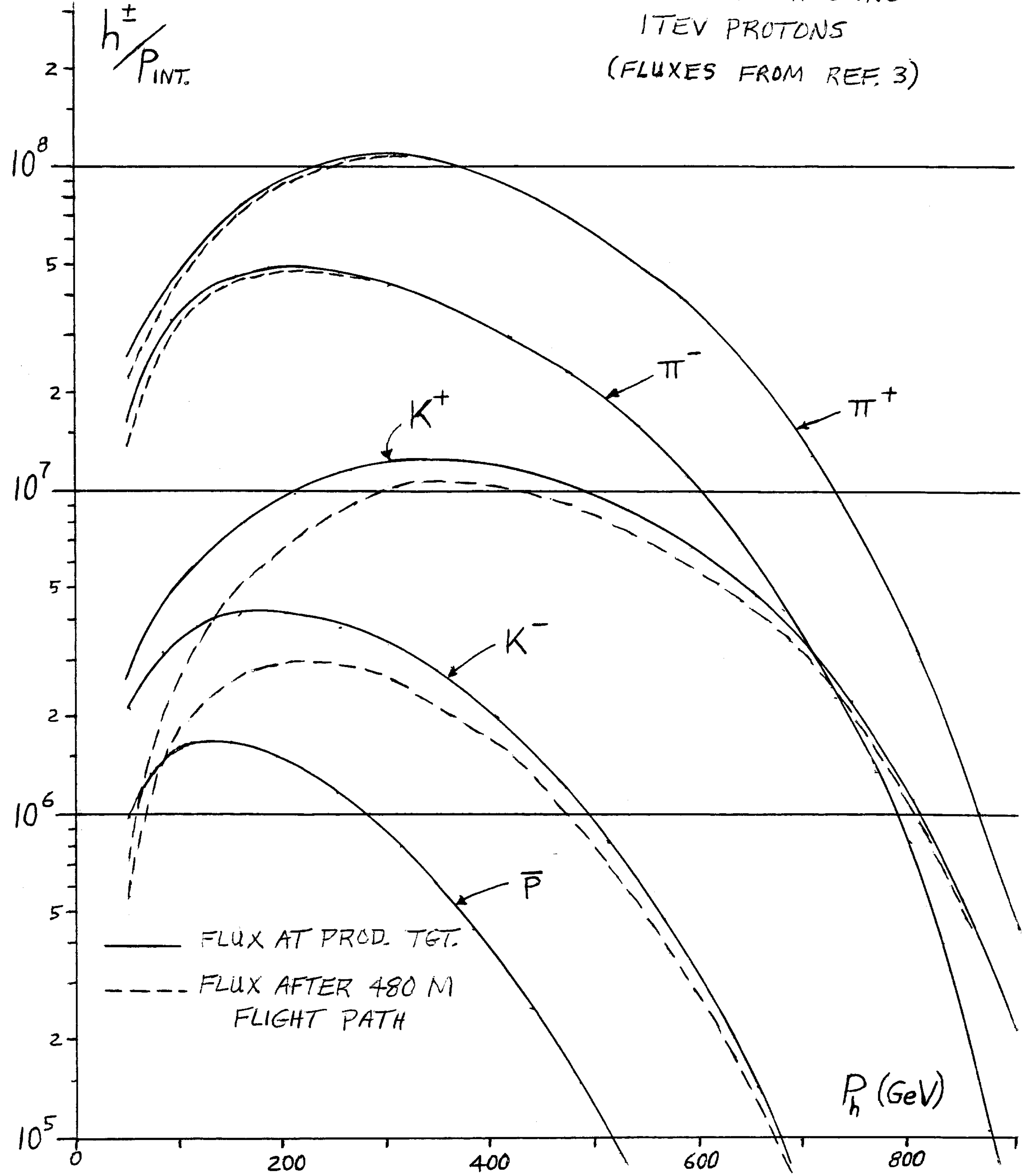

MESON LAB LAYOUT
FOR NEW M6
BEAMS
M6W
NEW EXPS.
M6E
Q5
Q6
B4
Q7
Q8
B3
Q4
Q3
NEW CONSTR.
Q1
Q2
B2
TGT

FIG 4

FIG 5

HADRON YIELDS FOR BEAM 'A'
FOR 10^{12} INTERACTING
1TEV PROTONS
(FLUXES FROM REF. 3)

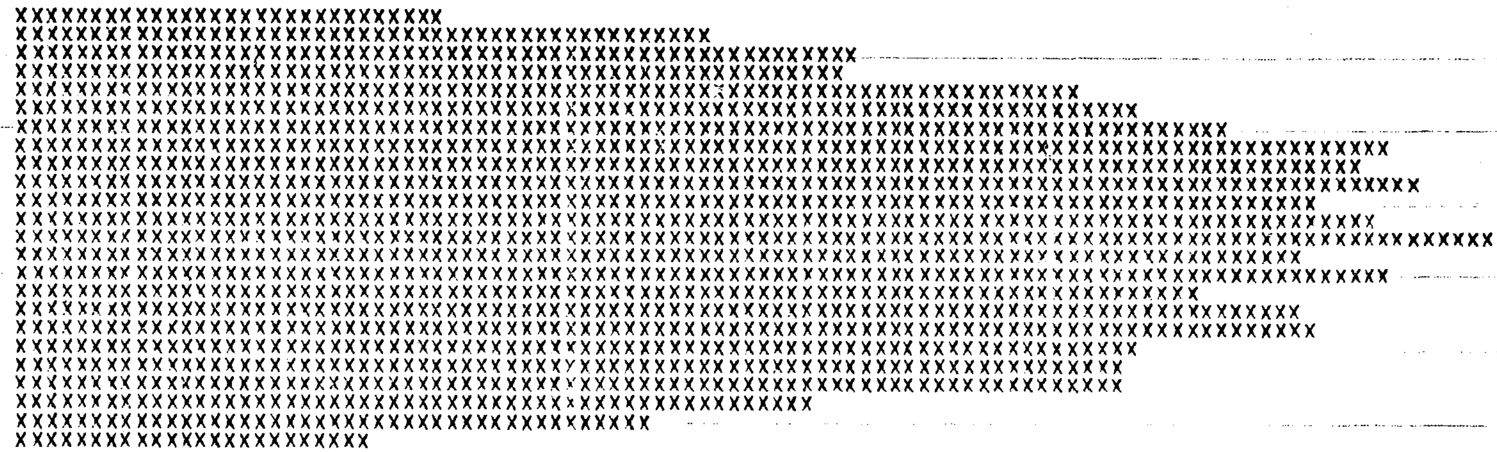


BEAM A
SOURCE
HORIZ. DIST.

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X**S EQUAL 282 RAYS

INTERVAL		
LESS THAN	-.100	0
-.100 TO	-.095	0
-.095 TO	-.090	0
-.090 TO	-.085	0
-.085 TO	-.080	0
-.080 TO	-.075	0
-.075 TO	-.070	0
-.070 TO	-.065	0
-.065 TO	-.060	0
-.060 TO	-.055	82
-.055 TO	-.050	133
-.050 TO	-.045	163
-.045 TO	-.040	160
-.040 TO	-.035	204
-.035 TO	-.030	217
-.030 TO	-.025	232
-.025 TO	-.020	263
-.020 TO	-.015	258
-.015 TO	-.010	270
-.010 TO	-.005	250
-.005 TO	.000	262
.000 TO	.005	282
.005 TO	.010	248
.010 TO	.015	264
.015 TO	.020	226
.020 TO	.025	247
.025 TO	.030	250
.030 TO	.035	216
.035 TO	.040	213
.040 TO	.045	212
.045 TO	.050	155
.050 TO	.055	124
.055 TO	.060	69
.060 TO	.065	0
.065 TO	.070	0
.070 TO	.075	0
.075 TO	.080	0
.080 TO	.085	0
.085 TO	.090	0
.090 TO	.095	0
.095 TO	.100	0
GREATER THAN	.100	0



CENTER = .000 RMS HALF WIDTH = .030

NO 1 OF X IN IN 0.000 FT FROM THE TARGET

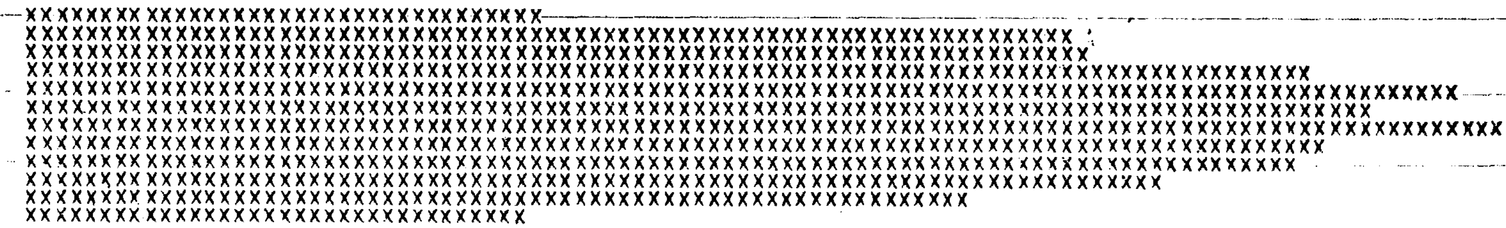
FIG 6

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X's EQUAL 551 RAYS

BEAM A
SOURCE VERT.
DISTR.

INTERVAL		
LESS THAN	-.100	0
-.100 TO	-.095	0
-.095 TO	-.090	0
-.090 TO	-.085	0
-.085 TO	-.080	0
-.080 TO	-.075	0
-.075 TO	-.070	0
-.070 TO	-.065	0
-.065 TO	-.060	0
-.060 TO	-.055	0
-.055 TO	-.050	0
-.050 TO	-.045	0
-.045 TO	-.040	0
-.040 TO	-.035	0
-.035 TO	-.030	0
-.030 TO	-.025	196
-.025 TO	-.020	394
-.020 TO	-.015	401
-.015 TO	-.010	480
-.010 TO	-.005	539
-.005 TO	.000	504
.000 TO	.005	551
.005 TO	.010	490
.010 TO	.015	476
.015 TO	.020	427
.020 TO	.025	354
.025 TO	.030	188
.030 TO	.035	0
.035 TO	.040	0
.040 TO	.045	0
.045 TO	.050	0
.050 TO	.055	0
.055 TO	.060	0
.060 TO	.065	0
.065 TO	.070	0
.070 TO	.075	0
.075 TO	.080	0
.080 TO	.085	0
.085 TO	.090	0
.090 TO	.095	0
.095 TO	.100	0
GREATER THAN	.100	0



CENTER = -.000 RMS HALF WIDTH = .015

2 OF Y IN IN 0.000 FT FROM THE TARGET

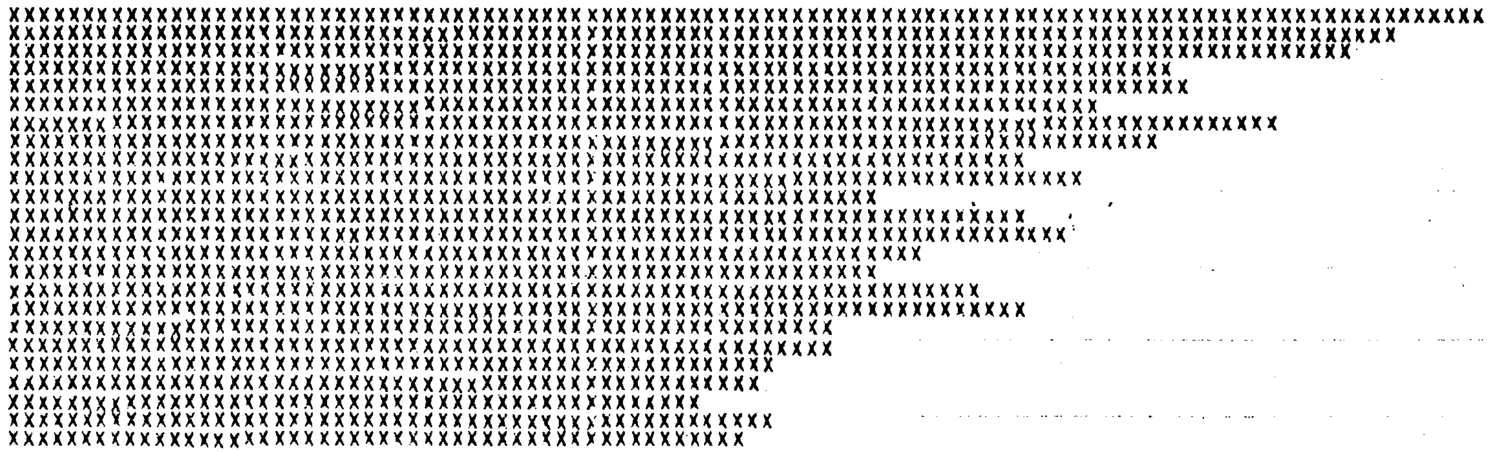
FIG 7

THE FOLLOWING IS A HISTOGRAM OF DP/P FOR 5000 RAYS

SCALE FACTOR: 100 X''S EQUAL 302 RAYS

BEAM A
SOURCE MOM.
DISTR.

INTERVAL	
ESS THAN -10.000	0
-10.000 TO -9.500	0
-9.500 TO -9.000	0
-9.000 TO -8.500	0
-8.500 TO -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	302
-5.500 TO -5.000	286
-5.000 TO -4.500	275
-4.500 TO -4.000	240
-4.000 TO -3.500	243
-3.500 TO -3.000	225
-3.000 TO -2.500	261
-2.500 TO -2.000	236
-2.000 TO -1.500	211
-1.500 TO -1.000	223
-1.000 TO -.500	181
-.500 TO -.000	210
-.000 TO .500	218
.500 TO 1.000	188
1.000 TO 1.500	179
1.500 TO 2.000	202
2.000 TO 2.500	209
2.500 TO 3.000	172
3.000 TO 3.500	170
3.500 TO 4.000	159
4.000 TO 4.500	156
4.500 TO 5.000	143
5.000 TO 5.500	160
5.500 TO 6.000	151
6.000 TO 6.500	0
6.500 TO 7.000	0
7.000 TO 7.500	0
7.500 TO 8.000	0
8.000 TO 8.500	0
8.500 TO 9.000	0
9.000 TO 9.500	0
9.500 TO 10.000	0
REATER THAN 10.000	0



CENTER = -.677 RMS HALF WIDTH = 3.439

0 3 OF DP/P IN PC 0.000 FT FROM THE TARGET

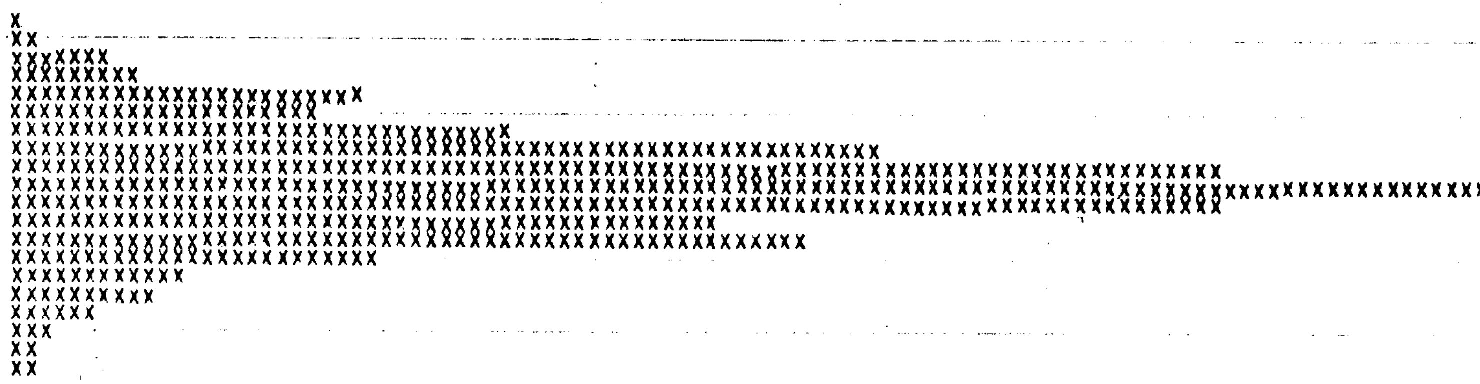
FIG 8

THE FOLLOWING IS A HISTOGRAM OF X FOR 973 RAYS

BEAM A
EXP. SPOT, HORIZ.

SCALE FACTOR: 100 X''S EQUAL 164 RAYS

INTERVAL			
ESS THAN		-2.000	0
-2.000	TO	-1.900	0
-1.900	TO	-1.800	0
-1.800	TO	-1.700	0
-1.700	TO	-1.600	0
-1.600	TO	-1.500	0
-1.500	TO	-1.400	0
-1.400	TO	-1.300	0
-1.300	TO	-1.200	0
-1.200	TO	-1.100	1
-1.100	TO	-1.000	3
-1.000	TO	-.900	4
-.900	TO	-.800	13
-.800	TO	-.700	16
-.700	TO	-.600	40
-.600	TO	-.500	35
-.500	TO	-.400	57
-.400	TO	-.300	97
-.300	TO	-.200	135
-.200	TO	-.100	164
-.100	TO	.000	135
.000	TO	.100	80
.100	TO	.200	90
.200	TO	.300	41
.300	TO	.400	21
.400	TO	.500	17
.500	TO	.600	10
.600	TO	.700	5
.700	TO	.800	4
.800	TO	.900	4
.900	TO	1.000	1
1.000	TO	1.100	0
1.100	TO	1.200	0
1.200	TO	1.300	0
1.300	TO	1.400	0
1.400	TO	1.500	0
1.500	TO	1.600	0
1.600	TO	1.700	0
1.700	TO	1.800	0
1.800	TO	1.900	0
1.900	TO	2.000	0
EATER THAN		2.000	0



CENTER = -.146 RMS HALF WIDTH = .304

31 OF X IN IN 1573.000 FT FROM THE TARGET

FIG 9

THE FOLLOWING IS A HISTOGRAM OF Y FOR 973 RAYS

INTERVAL			SCALE FACTOR: 100 X'S EQUAL 571 RAYS
LESS THAN	-2.000	0	
-2.000 TO	-1.900	0	
-1.900 TO	-1.800	0	
-1.800 TO	-1.700	0	
-1.700 TO	-1.600	0	
-1.600 TO	-1.500	0	
-1.500 TO	-1.400	0	
-1.400 TO	-1.300	0	
-1.300 TO	-1.200	0	
-1.200 TO	-1.100	0	
-1.100 TO	-1.000	0	
-1.000 TO	-.900	0	
-.900 TO	-.800	0	
-.800 TO	-.700	0	
-.700 TO	-.600	0	
-.600 TO	-.500	0	
-.500 TO	-.400	0	
-.400 TO	-.300	0	
-.300 TO	-.200	1	
-.200 TO	-.100	15	XX
-.100 TO	.000	377	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.000 TO	.100	571	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.100 TO	.200	9	X
.200 TO	.300	0	
.300 TO	.400	0	
.400 TO	.500	0	
.500 TO	.600	0	
.600 TO	.700	0	
.700 TO	.800	0	
.800 TO	.900	0	
.900 TO	1.000	0	
1.000 TO	1.100	0	
1.100 TO	1.200	0	
1.200 TO	1.300	0	
1.300 TO	1.400	0	
1.400 TO	1.500	0	
1.500 TO	1.600	0	
1.600 TO	1.700	0	
1.700 TO	1.800	0	
1.800 TO	1.900	0	
1.900 TO	2.000	0	
GREATER THAN	2.000	0	

CENTER = .005 RMS HALF WIDTH = .038

0 32 OF Y IN IN 1573.000 FT FROM THE TARGET

BEAM A
EXP. SPOT, VERT.

FIG 10

BEAM A
EXP., MOM. DISTR.

```
'HE FOLLOWING IS A HISTOGRAM OF DP/P    FOR     973 RAYS

      INTERVAL                              SCALE FACTOR:  100 X''S EQUAL     71 RAYS
SS THAN      -5.000         2   XX

-5.000 TO    -4.750         0
-4.750 TO    -4.500         0
-4.500 TO    -4.250         0
-4.250 TO    -4.000         0
-4.000 TO    -3.750         4   XXXXX
-3.750 TO    -3.500         2   XX
-3.500 TO    -3.250         5   XXXXXXX
-3.250 TO    -3.000         3   XXXX
-3.000 TO    -2.750        11   XXXXXXXXXXXXXXX
-2.750 TO    -2.500         5   XXXXXXX
-2.500 TO    -2.250        10   XXXXXXXXXXXXXX
-2.250 TO    -2.000        14   XXXXXXXXXXXXXXXXXXX
-2.000 TO    -1.750        22   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.750 TO    -1.500        14   XXXXXXXXXXXXXXXXXXX
-1.500 TO    -1.250        22   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.250 TO    -1.000        40   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.000 TO     -.750        29   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -.750 TO     -.500        41   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -.500 TO     -.250        51   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -.250 TO     -.000        47   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 -.000 TO      .250        71   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  .250 TO      .500        66   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  .500 TO      .750        56   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  .750 TO     1.000        61   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1.000 TO     1.250        50   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1.250 TO     1.500        49   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1.500 TO     1.750        67   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 1.750 TO     2.000        59   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 2.000 TO     2.250        41   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 2.250 TO     2.500        39   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 2.500 TO     2.750        22   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 2.750 TO     3.000        32   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 3.000 TO     3.250        12   XXXXXXXXXXXXXXXX
 3.250 TO     3.500        12   XXXXXXXXXXXXXXXX
 3.500 TO     3.750         4   XXXXX
 3.750 TO     4.000         7   XXXXXXXXX
 4.000 TO     4.250         3   XXXX
 4.250 TO     4.500         0
 4.500 TO     4.750         0
 4.750 TO     5.000         0

EATER THAN    5.000         0

         CENTER =      .568   RMS HALF WIDTH =     1.543

 33 OF DP/P IN PC     1573.000 FT    FROM THE TARGET
```

FIG 11

```
               TWO DIMENSIONAL PLOT OF DP/P VS     X

                   -2.000    -1.000    -.000     1.000     2.000 TOTALS
                    I**---**---**---**---**---**---**---**---**I--------
-5.000 TO  -4.500 I                                        I       0
-4.500 TO  -4.000 I                                        I       0
-4.000 TO  -3.500 I                  11 1  2  1            I       6
-3.500 TO  -3.000 I                  1 211  1 11           I       8
-3.000 TO  -2.500 I                 14 24  221             I      16
-2.500 TO  -2.000 I                2233133 122 2           I      24
-2.000 TO  -1.500 I               135443263 3 11           I      36
-1.500 TO  -1.000 I               3259A84665121            I      62
-1.000 TO   -.500 I                37D98C666               I      70
 -.500 TO   -.000 I                3AHCAPE61               I      98
 -.000 TO    .500 I                2IVTNV3                 I     137
  .500 TO   1.000 I               27NR$D72                 I     117
 1.000 TO   1.500 I               6ENUL5                   I      99
 1.500 TO   2.000 I            235H$TK85                   I     126
 2.000 TO   2.500 I             8IKJ942                    I      80
 2.500 TO   3.000 I          128JA842                      I      54
 3.000 TO   3.500 I         214681 11                      I      24
 3.500 TO   4.000 I        1115 21                         I      11
 4.000 TO   4.500 I          12                            I       3
 4.500 TO   5.000 I                                        I       0
                  I**---**---**---**---**---**---**---**---**I--------
                  I                                        I
                  I                                        I
                  I                 111                    I
                  I           11435936389421               I
          TOTALS  I 0000000013436057754500117954400000000000 I     971
     TOTAL NUMBER OF ENTRIES =        973 INCLUDING UNDERFLOW AND OVERFLOW AS FOLLOWS

                              UNDERFLOW          OVERFLOW
                 ACROSS           0                  0
                 DOWN             2                  0

 34 TWO DIMENSIONAL PLOT OF
          X IN IN       1573.000 FT     FROM THE TARGET
     DP/P IN PC         1573.000 FT     FROM THE TARGET
```

BEAM A

X VS ΔP/P AT EXP.

FIG 12

```
        TWO DIMENSIONAL PLOT OF DP/P VS     Y

                 -2.000    -1.000     -.000     1.000     2.000 TOTALS
                  I**---**---**---**---**---**---**---**---**I--------
-5.000 TO  -4.500 I                                          I       0
-4.500 TO  -4.000 I                                          I       0
-4.000 TO  -3.500 I                   1311                   I       6
-3.500 TO  -3.000 I                   4 13                   I       8
-3.000 TO  -2.500 I                   4732                   I      16
-2.500 TO  -2.000 I                   5A9                    I      24
-2.000 TO  -1.500 I                   1IH                    I      36
-1.500 TO  -1.000 I                    $N                    I      62
-1.000 TO   -.500 I                    $W                    I      70
 -.500 TO   -.000 I                    $$                    I      98
 -.000 TO    .500 I                    $$                    I     137
  .500 TO   1.000 I                    $$                    I     117
 1.000 TO   1.500 I                    $$                    I      99
 1.500 TO   2.000 I                   N$                     I     126
 2.000 TO   2.500 I                    $                     I      80
 2.500 TO   3.000 I                   9$                     I      54
 3.000 TO   3.500 I                   4K                     I      24
 3.500 TO   4.000 I                   362                    I      11
 4.000 TO   4.500 I                   21                     I       3
 4.500 TO   5.000 I                                          I       0
                  I**---**---**---**---**---**---**---**---**I--------
                  I                                          I
                  I                                          I
                  I                                          I
                  I                    35                    I
                  I                   177                    I
          TOTALS  I 0000000000000000005718000000000000000000000 I     971
        TOTAL NUMBER OF ENTRIES =        973 INCLUDING UNDERFLOW AND OVERFLOW AS FOLLOWS

                              UNDERFLOW       OVERFLOW
                  ACROSS              0              0
                  DOWN                2              0
```

```
NO  35 TWO DIMENSIONAL PLOT OF
           Y IN IN      1573.000 FT   FROM THE TARGET
        DP/P IN PC      1573.000 FT   FROM THE TARGET
```

BEAM A

Y VS ΔP/P AT EXP.

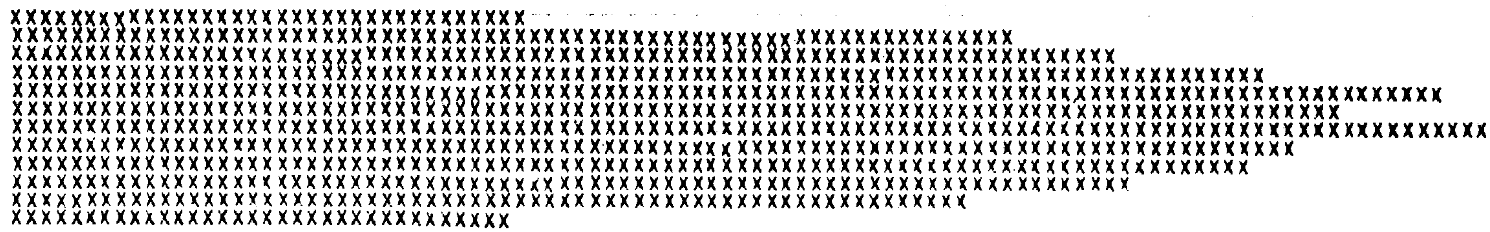
FIG 13

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X''S EQUAL 555 RAYS

BEAM B
SOURCE DIST., VERT.

INTERVAL		
LESS THAN	-.100	0
-.100 TO	-.095	0
-.095 TO	-.090	0
-.090 TO	-.085	0
-.085 TO	-.080	0
-.080 TO	-.075	0
-.075 TO	-.070	0
-.070 TO	-.065	0
-.065 TO	-.060	0
-.060 TO	-.055	0
-.055 TO	-.050	0
-.050 TO	-.045	0
-.045 TO	-.040	0
-.040 TO	-.035	0
-.035 TO	-.030	0
-.030 TO	-.025	196
-.025 TO	-.020	379
-.020 TO	-.015	420
-.015 TO	-.010	472
-.010 TO	-.005	540
-.005 TO	.000	500
.000 TO	.005	555
.005 TO	.010	485
.010 TO	.015	471
.015 TO	.020	426
.020 TO	.025	364
.025 TO	.030	192
.030 TO	.035	0
.035 TO	.040	0
.040 TO	.045	0
.045 TO	.050	0
.050 TO	.055	0
.055 TO	.060	0
.060 TO	.065	0
.065 TO	.070	0
.070 TO	.075	0
.075 TO	.080	0
.080 TO	.085	0
.085 TO	.090	0
.090 TO	.095	0
.095 TO	.100	0
GREATER THAN	.100	0



CENTER = -.000 RMS HALF WIDTH = .015

NO 2 OF Y IN IN 0.000 FT FROM THE TARGET

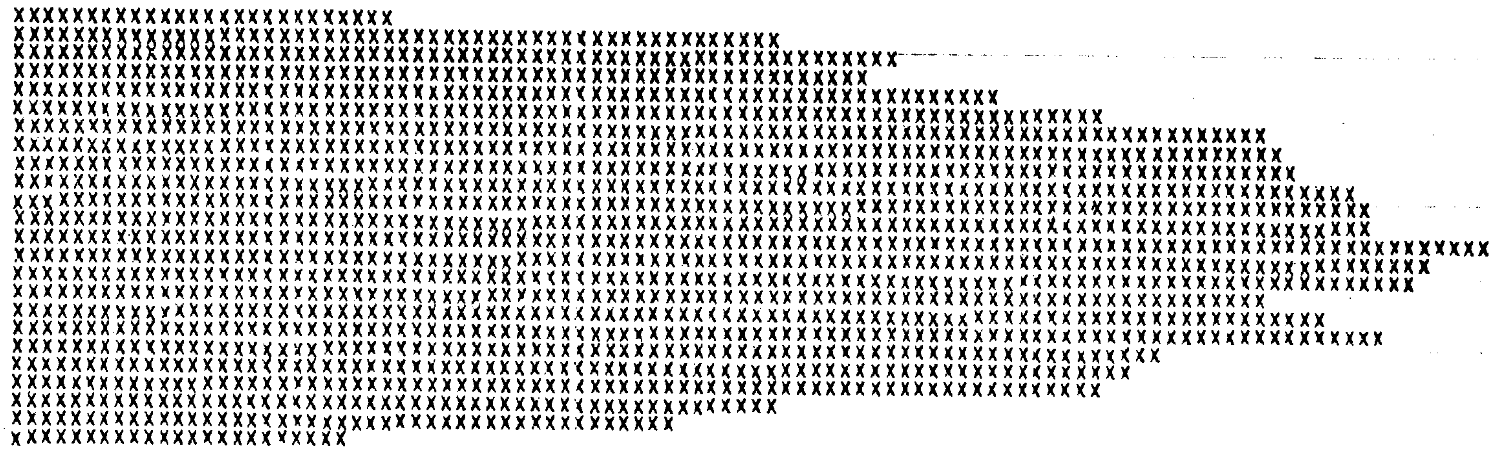
FIG 14

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 280 RAYS

BEAM B
SOURCE DISTR., HORIZ.

INTERVAL		
LESS THAN	-.100	0
-.100 TO	-.095	0
-.095 TO	-.090	0
-.090 TO	-.085	0
-.085 TO	-.080	0
-.080 TO	-.075	0
-.075 TO	-.070	0
-.070 TO	-.065	0
-.065 TO	-.060	0
-.060 TO	-.055	75
-.055 TO	-.050	146
-.050 TO	-.045	170
-.045 TO	-.040	164
-.040 TO	-.035	190
-.035 TO	-.030	209
-.030 TO	-.025	240
-.025 TO	-.020	241
-.020 TO	-.015	246
-.015 TO	-.010	255
-.010 TO	-.005	258
-.005 TO	.000	259
.000 TO	.005	280
.005 TO	.010	271
.010 TO	.015	266
.015 TO	.020	238
.020 TO	.025	250
.025 TO	.030	261
.030 TO	.035	221
.035 TO	.040	214
.040 TO	.045	208
.045 TO	.050	146
.050 TO	.055	126
.055 TO	.060	66
.060 TO	.065	0
.065 TO	.070	0
.070 TO	.075	0
.075 TO	.080	0
.080 TO	.085	0
.085 TO	.090	0
.090 TO	.095	0
.095 TO	.100	0
GREATER THAN	.100	0



CENTER = .000 RMS HALF WIDTH = .030

NO 1 OF X IN IN 0.000 FT FROM THE TARGET

FIG 15

BEAM B
SOURCE MOM. DISTR.

THE FOLLOWING IS A HISTOGRAM OF DP/P FOR 5000 RAYS

SCALE FACTOR: 100 X's EQUAL 163 RAYS

INTERVAL		
LESS THAN	-3.000	0
-3.000 TO	-2.850	163
-2.850 TO	-2.700	157
-2.700 TO	-2.550	151
-2.550 TO	-2.400	123
-2.400 TO	-2.250	163
-2.250 TO	-2.100	132
-2.100 TO	-1.950	112
-1.950 TO	-1.800	141
-1.800 TO	-1.650	125
-1.650 TO	-1.500	116
-1.500 TO	-1.350	126
-1.350 TO	-1.200	130
-1.200 TO	-1.050	150
-1.050 TO	-.900	135
-.900 TO	-.750	130
-.750 TO	-.600	122
-.600 TO	-.450	128
-.450 TO	-.300	132
-.300 TO	-.150	112
-.150 TO	.000	131
.000 TO	.150	126
.150 TO	.300	132
.300 TO	.450	129
.450 TO	.600	111
.600 TO	.750	120
.750 TO	.900	110
.900 TO	1.050	119
1.050 TO	1.200	132
1.200 TO	1.350	135
1.350 TO	1.500	120
1.500 TO	1.650	113
1.650 TO	1.800	106
1.800 TO	1.950	111
1.950 TO	2.100	93
2.100 TO	2.250	112
2.250 TO	2.400	127
2.400 TO	2.550	105
2.550 TO	2.700	111
2.700 TO	2.850	106
2.850 TO	3.000	103
GREATER THAN	3.000	0

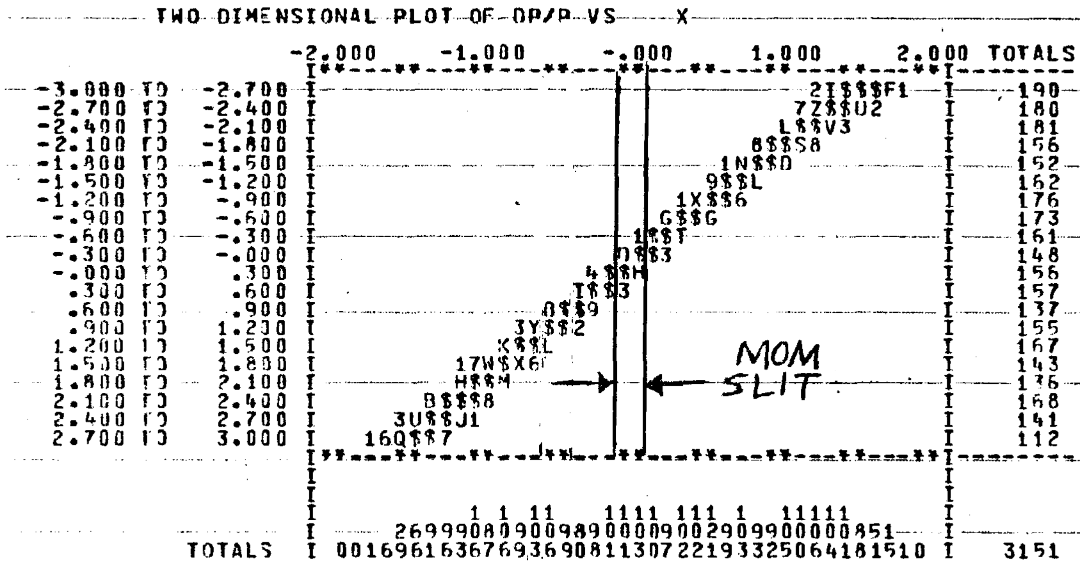
CENTER = -.158 RMS HALF WIDTH = 1.733

NO 3 OF DP/P IN PC 0.000 FT FROM THE TARGET

FIG 16

BEAM B

X VS ΔP/P AT MOM. SLIT



TOTAL NUMBER OF ENTRIES = 3151 INCLUDING UNDERFLOW AND OVERFLOW AS FOLLOWS

	UNDERFLOW	OVERFLOW
ACROSS	0	0
DOWN	0	0

NO 17 TWO DIMENSIONAL PLOT OF
X IN IN 729.500 FT FROM THE TARGET
DP/P IN PC 729.500 FT FROM THE TARGET

FIG 17

BEAM B
HORIZ. DISTR.
AT EXP.

```
THE FOLLOWING IS A HISTOGRAM OF     X     FOR     199 RAYS

        INTERVAL                              SCALE FACTOR:  100 X**S EQUAL    102 RAYS
LESS THAN        -1.000        0

  -1.000 TO      -.950         0
   -.950 TO      -.900         0
   -.900 TO      -.850         0
   -.850 TO      -.800         0
   -.800 TO      -.750         0
   -.750 TO      -.700         0
   -.700 TO      -.650         0
   -.650 TO      -.600         0
   -.600 TO      -.550         0
   -.550 TO      -.500         0
   -.500 TO      -.450         0
   -.450 TO      -.400         0
   -.400 TO      -.350         0
   -.350 TO      -.300         0
   -.300 TO      -.250         0
   -.250 TO      -.200         0
   -.200 TO      -.150         0
   -.150 TO      -.100         0
   -.100 TO      -.050         0
   -.050 TO       .000        97  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .000 TO       .050       102  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .050 TO       .100         0
    .100 TO       .150         0
    .150 TO       .200         0
    .200 TO       .250         0
    .250 TO       .300         0
    .300 TO       .350         0
    .350 TO       .400         0
    .400 TO       .450         0
    .450 TO       .500         0
    .500 TO       .550         0
    .550 TO       .600         0
    .600 TO       .650         0
    .650 TO       .700         0
    .700 TO       .750         0
    .750 TO       .800         0
    .800 TO       .850         0
    .850 TO       .900         0
    .900 TO       .950         0
    .950 TO      1.000         0

GREATER THAN     1.000         0

                  CENTER =      .001    RMS HALF WIDTH =      .020

NO  35 OF     X IN IN     1573.000 FT    FROM THE TARGET
```

FIG 18

```
THE FOLLOWING IS A HISTOGRAM OF     Y     FOR     199 RAYS

        INTERVAL                           SCALE FACTOR:  100 X**S EQUAL     57 RAYS
LESS THAN      -1.000          0

  -1.000 TO     -.950          0
   -.950 TO     -.900          0
   -.900 TO     -.850          0
   -.850 TO     -.800          0
   -.800 TO     -.750          0
   -.750 TO     -.700          0
   -.700 TO     -.650          0
   -.650 TO     -.600          0
   -.600 TO     -.550          0
   -.550 TO     -.500          0
   -.500 TO     -.450          0
   -.450 TO     -.400          0
   -.400 TO     -.350          0
   -.350 TO     -.300          0
   -.300 TO     -.250          0
   -.250 TO     -.200          0
   -.200 TO     -.150          1   X
   -.150 TO     -.100         11   XXXXXXXXXXXXXXXXXXX
   -.100 TO     -.050         31   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.050 TO      .000         56   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .000 TO      .050         57   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .050 TO      .100         37   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .100 TO      .150          5   XXXXXXXX
    .150 TO      .200          1   X
    .200 TO      .250          0
    .250 TO      .300          0
    .300 TO      .350          0
    .350 TO      .400          0
    .400 TO      .450          0
    .450 TO      .500          0
    .500 TO      .550          0
    .550 TO      .600          0
    .600 TO      .650          0
    .650 TO      .700          0
    .700 TO      .750          0
    .750 TO      .800          0
    .800 TO      .850          0
    .850 TO      .900          0
    .900 TO      .950          0
    .950 TO     1.000          0

GREATER THAN    1.000          0
                   CENTER =     -.002    RMS HALF WIDTH =      .060

D  36 OF     Y IN IN    1573.000 FT    FROM THE TARGET
```

BEAM B
VERT. DISTR. AT
EXP.

FIG 19

```
THE FOLLOWING IS A HISTOGRAM OF DP/P    FOR      199 RAYS

        INTERVAL                                 SCALE FACTOR:  100 X**S EQUAL     72 RAYS
LESS THAN        -3.000          0

  -3.000 TO    -2.850            0
  -2.850 TO    -2.700            0
  -2.700 TO    -2.550            0
  -2.550 TO    -2.400            0
  -2.400 TO    -2.250            0
  -2.250 TO    -2.100            0
  -2.100 TO    -1.950            0
  -1.950 TO    -1.800            0
  -1.800 TO    -1.650            0
  -1.650 TO    -1.500            0
  -1.500 TO    -1.350            0
  -1.350 TO    -1.200            0
  -1.200 TO    -1.050            0
  -1.050 TO     -.900            0
   -.900 TO     -.750            0
   -.750 TO     -.600            0
   -.600 TO     -.450            0
   -.450 TO     -.300            1   X
   -.300 TO     -.150           25   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
   -.150 TO      .000           72   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .000 TO      .150           70   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .150 TO      .300           28   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    .300 TO      .450            3   XXXX
    .450 TO      .600            0
    .600 TO      .750            0
    .750 TO      .900            0
    .900 TO     1.050            0
   1.050 TO     1.200            0
   1.200 TO     1.350            0
   1.350 TO     1.500            0
   1.500 TO     1.650            0
   1.650 TO     1.800            0
   1.800 TO     1.950            0
   1.950 TO     2.100            0
   2.100 TO     2.250            0
   2.250 TO     2.400            0
   2.400 TO     2.550            0
   2.550 TO     2.700            0
   2.700 TO     2.850            0
   2.850 TO     3.000            0

GREATER THAN    3.000            0
                       CENTER =       .005   RMS HALF WIDTH =       .140

NO  37 OF DP/P IN PC    1573.000 FT   FROM THE TARGET
```

BEAM B
MOM. DISTR. AT
EXP.

FIG 20

BEAM B

X VS ΔP/P AT EXP

```
                 TWO-DIMENSIONAL PLOT OF DP/P VS     X

                              -1.000     -.500      -.000      .500      1.000 TOTALS
                               I**---**---**---**---**---**---**---**---**I--------
  -3.000 TO   -2.700 I                                         I       0
  -2.700 TO   -2.400 I                                         I       0
  -2.400 TO   -2.100 I                                         I       0
  -2.100 TO   -1.800 I                                         I       0
  -1.800 TO   -1.500 I                                         I       0
  -1.500 TO   -1.200 I                                         I       0
  -1.200 TO    -.900 I                                         I       0
   -.900 TO    -.600 I                                         I       0
   -.600 TO    -.300 I                   1                     I       1
   -.300 TO    -.000 I                  D$                     I      97
   -.000 TO     .300 I                  $H                     I      98
    .300 TO     .600 I                  3                      I       3
    .600 TO     .900 I                                         I       0
    .900 TO    1.200 I                                         I       0
   1.200 TO    1.500 I                                         I       0
   1.500 TO    1.800 I                                         I       0
   1.800 TO    2.100 I                                         I       0
   2.100 TO    2.400 I                                         I       0
   2.400 TO    2.700 I                                         I       0
   2.700 TO    3.000 I                                         I       0
                     I**---**---**---**---**---**---**---**---**I--------
                     I                                         I
                     I                                         I
                     I                   1                     I
                     I                  90                     I
            TOTALS   I 0000000000000000072000000000000000000 I     199
         TOTAL NUMBER OF ENTRIES =        199 INCLUDING UNDERFLOW AND OVERFLOW AS FOLLOWS
                             UNDERFLOW          OVERFLOW
                  ACROSS             0                 0
                  DOWN               0                 0
 NO  38 TWO DIMENSIONAL PLOT OF
              X IN IN     1573.000 FT    FROM THE TARGET
         DP/P IN PC     1573.000 FT    FROM THE TARGET
```

FIG 21

BEAM B

Y VS ΔP/P AT EXP.

```
              TWO DIMENSIONAL PLOT OF DP/P VS     Y

                       -1.000    -.500     -.000      .500     1.000 TOTALS
                        I**---**---**---**---**---**---**---**---**I--------
   -3.000 TO  -2.700 I                                          I       0
   -2.700 TO  -2.400 I                                          I       0
   -2.400 TO  -2.100 I                                          I       0
   -2.100 TO  -1.800 I                                          I       0
   -1.800 TO  -1.500 I                                          I       0
   -1.500 TO  -1.200 I                                          I       0
   -1.200 TO   -.900 I                                          I       0
    -.900 TO   -.600 I                                          I       0
    -.600 TO   -.300 I                    1                     I       1
    -.300 TO   -.000 I                 18MULB1                  I      97
    -.000 TO    .300 I                   90YQ41                 I      98
     .300 TO    .600 I                    12                    I       3
     .600 TO    .900 I                                          I       0
     .900 TO   1.200 I                                          I       0
    1.200 TO   1.500 I                                          I       0
    1.500 TO   1.800 I                                          I       0
    1.800 TO   2.100 I                                          I       0
    2.100 TO   2.400 I                                          I       0
    2.400 TO   2.700 I                                          I       0
    2.700 TO   3.000 I                                          I       0
                        I**---**---**---**---**---**---**---**---**I--------
                        I                                          I
                        I                                          I
                        I                                          I
                        I                  13553                   I
              TOTALS    I 0000000000000000011167751000000000000000 I     199
           TOTAL NUMBER OF ENTRIES =        199 INCLUDING UNDERFLOW AND OVERFLOW AS FOLLOWS
                                UNDERFLOW      OVERFLOW
                    ACROSS           0              0
                    DOWN             0              0
NO  39 TWO DIMENSIONAL PLOT OF
            Y IN IN     1573.000 FT    FROM THE TARGET
         DP/P IN PC     1573.000 FT    FROM THE TARGET
```

FIG 22