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SEXTUPOLE CONFIGURATIONS FOR HIGH RESOLUTION BEAM M6

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I. Introduction

High momentum resolution is a primary criterion by which the meson laboratory beam M6 is designed. It is a three-stage beam with a momentum defining slit at the end of the first stage. The dispersion is maximum at this point to give good resolution. The beam may be made essentially monochromatic by stopping down a slit located here. Recombination is done in the second and third stages with moderately high dispersion at the end of the second stage. For a larger momentum band pass, momentum determination may be done by placing counters at this point. Further description of the beam line and its potential uses may be found elsewhere.[1,2]

The minimum momentum interval carried by the beam will be 0.03% of the central momentum. This figure also then represents the maximum momentum resolution obtainable. However the beam line can transmit a total momentum interval of 2% of the central momentum. To maximize the analyzing power of any experiment utilizing the beam, it is desirable to have this resolution capability for the entire momentum interval carried by the beam. One therefore must eliminate aberrations which cause variation of the spot size at the momentum focus with either momentum or initial angle.

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In Section II below we describe the principal aberrations inherent in the design of the beam. Sections III and IV present schemes for eliminating some of these aberrations to second order. Finally in Section V we examine each of the solutions including the effect of higher order terms.

II. The Beam and Principal Aberrations

A. Basic Beam Geometry

Each of the three stages of the beam contains two quadrupole doublets. The first focuses from point to parallel, while the second refocuses the beam to a point. For both doublets the horizontally defocusing quad is placed nearer the focus. This both maximizes the resolution and helps match the beam profile with the bending magnet apertures. Between the doublets, in the parallel region, are placed the bending magnets whose purpose is either to disperse or recombine the beam in momentum. At high energies with zero gradient bending magnets, we may, for purposes of this discussion, safely ignore the focusing properties of the bending magnets. At each focus is placed a field lens quadrupole which further aids in obtaining complete momentum recombination.

For a doublet focusing point to parallel, as shown in Figure 1, two principal planes are relevant.[3] The figure is drawn with the horizontally defocusing quadrupole nearer the focus, as is the case in beam line M6. If ℓ is the distance from the focus to the first quadrupoles, s is the distance between the centers of the quadrupoles, and f_1 and f_2 are their respective focal lengths, then in a thin lens approximation

we have:

$$f_1 = \ell \sqrt{s/(\ell + s)} \tag{1}$$

$$f_2 = \sqrt{s(\ell + s)}$$

The distances from the focus to the horizontal and vertical principal planes respectively are:

$$h_x = \ell + s + f_2 \tag{2}$$

$$h_y = \ell + s - f_2$$

The magnitude of the sine-like ray in each plane in the parallel section is equal to the distance from the focus to the corresponding principal plane.

B. Principal Aberrations

At high energies the important aberrations occurring in a beam line arise from three sources:[4] chromatic aberrations from the quadrupoles, the effect of particles traversing a bending magnet at an angle to the central ray, and the influence of sextupoles. Since in this beam the bending magnets are placed in the parallel sections we may safely ignore the second item. We will now concentrate our attention on the chromatic aberrations of the quadrupoles.

The principal impediment to achieving high resolution over the entire momentum band carried by the beam is the variation with momentum of the focusing strength of the quads. For a point-to-point image this variation is measured by the second-order matrix elements T_{126} and T_{346}. For this case Brown[4] has shown that the matrix element T_{126} is given by:

$$T_{126} = M_x \int_0 s_x'^2 \, dz \tag{3}$$

where M_x is the horizontal magnification and s'_x the slope of the horizontal sine-like ray. The integral is taken over the entire distance between foci. The term T_{346} may be evaluated similarly.

We now depict in Figure 2 a section of the beam, with principal planes shown for each doublet. For a thin lens approximation it may be shown that

$$T_{126} = 2(h_2 + h_3) \qquad (4)$$

$$T_{346} = 2(h_1 + h_4)$$

An exact numerical calculation shows that for NAL beams this result should be accurate to within a few percent. For the optical mode used in beam line M6 the chromatic aberration will clearly be significantly greater in the horizontal than in the vertical plane.

For a two-stage beam the chromatic aberration of each stage will be affected by the magnification of the other, but the result for each stage is unchanged.

III. Two Sextupole Solution

We now address ourselves to the problem of eliminating chromatic aberration at the end of the second section.[5] First we consider a solution which reduces the term T_{126} to zero but ignores the effect on T_{346}. As shown in the previous section chromatic aberration is larger in the horizontal plane. It is also in the horizontal plane that chromatic aberration affects the momentum resolution.

In Figure 3 we designate the positions of four sextupoles placed in the second stage of the beam, labeling them with the letters a, b, c, and d. The sextupoles straddle the doublets in pairs, sextupoles a and d being as close to the quadrupoles as possible. The dispersion ray d_x is also shown, with its crossover in the vicinity of sextupole c. In this section we consider the use of only sextupoles b and c. A solution using all four sextupoles will be discussed in Section IV.

A sextupole placed in a beam line to correct for chromatic aberrations will introduce geometric aberrations. The principal ones affecting beam spot size in this beam are T_{122} and T_{144}. Therefore we must include at least two sextupoles so their contributions to geometric terms will cancel while eliminating chromatic terms.

The changes in the relevant matrix elements due to a single sextupole are:[4]

$$\Delta T_{122} = M_x s_x{}^3 S \tag{5}$$

$$\Delta T_{144} = -M_x s_x s_y{}^2 S$$

$$\Delta T_{126} = 2M_x s_x{}^2 d_x S$$

where M_x is the horizontal magnification, s_x and s_y are the sine-like rays in each plane and d_x is the dispersion ray. The quantity S is a measure of the strength of the sextupole and is equal to $qB\ell/a^2p_0$, where B is the pole tip field, a the half aperture, and ℓ the length of the sextupole, and q and p_0 represent the charge and central momentum of the particles.

Since the sextupoles are both placed in the parallel section the two sine-like rays s_x and s_y have the same magnitude

for each of them. Hence by setting their strengths to be equal and opposite we may cancel the contributions to T_{122} and T_{144}. Letting $S = S_b = -S_c$ we can eliminate the T_{126} term by setting:

$$2M_x s_{xb}^2 S(d_{xb} - d_{xc}) = -T_{126} \tag{6}$$

Actual determination of the sextupole strengths was done using the program TRANSPORT.[6,7] Using sextupoles which are 2.5 feet long and have a half aperture of 5 cm, a pole tip field of 2.774 kilogauss is required.

IV. Four Sextupole Solution

To eliminate chromatic aberration to second order in both planes, four sextupoles are required. In addition to the chromatic term T_{346}, the geometric term T_{324} now becomes important. The coupling of a sextupole to these additional terms is given by:

$$\Delta T_{324} = -2M_y s_x s_y^2 S \tag{7}$$

$$\Delta T_{346} = -2M_y s_y^2 d_x S$$

where now s_y is the vertical sine-like ray and M_y is the vertical magnification. We see that the difference in coupling to the terms T_{144} and T_{324} lies only in the magnification term, which is a property of the entire beam line and is therefore the same for all sextupoles. Therefore if the sextupoles are set so that T_{144} is equal to zero, then T_{324} will also equal zero. We now have four terms to eliminate with four sextupoles. It remains to determine if the four couplings are sufficiently independent to guarantee that the solution will result in reasonable pole tip fields.

We may now write the equation to be solved in the form:

$$MS + T = 0 \tag{8}$$

where S is a vector giving the four sextupole strengths, T a vector made up of the uncorrected second order terms T_{122}, T_{144}, T_{126}, T_{346} respectively, and M is a matrix of the coupling terms. The uncorrected T matrix terms are those which occur when no sextupoles are included. The element M_{11} of this matrix, for example will have the form $M_x s_{xa}^3$, where s_{xa} is the magnitude of the horizontal sine-like ray at point a. By defining a new vector $\overline{T}$ as a renormalized T whose elements are given as:

$$\overline{T} = \begin{pmatrix} T_{122}/M_x \\ -T_{144}/M_x \\ T_{126}/2M_x \\ -T_{346}/2M_y \end{pmatrix} \tag{9}$$

we may introduce a simpler Matrix $\overline{M}$ and rewrite equation (8) as:

$$\overline{M}S + \overline{T} = 0 \tag{8a}$$

where now exhibit $\overline{M}$ explicitly as:

$$\overline{M} = \begin{pmatrix} s_{xa}^3 & s_{xb}^3 & s_{xc}^3 & s_{xd}^3 \\ s_{xa}s_{ya}^2 & s_{xb}s_{yb}^2 & s_{xc}s_{yc}^2 & s_{xd}s_{yd}^2 \\ s_{xa}^2 d_{xa} & s_{xb}^2 d_{xb} & s_{xc}^2 d_{xc} & s_{xd}^2 d_{xd} \\ s_{ya}^2 d_{xa} & s_{yb}^2 d_{xb} & s_{yc}^2 d_{xc} & s_{yd}^2 d_{xd} \end{pmatrix} \tag{10}$$

and label the submatrices as follows:

$$\overline{M} = \begin{pmatrix} M_{11} & M_{12}U \\ M_{21} & M_{22}U \end{pmatrix} \tag{10a}$$

where the matrix U, given by:

$$U = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \tag{11}$$

functions simply to interchange the columns of the matrix that multiplies it. With this definition, if the second stage of the beam were symmetric, so that the two doublets were mirror images of each other, we would have $M_{11} = M_{12}$.

Now if the matrix $\overline{M}$ is non-singular a solution will exist. Roughly, we may say that if the determinant of $\overline{M}$ is large, the resulting sextupole strengths will be small. Consider first the situation which would occur if the momentum recombination were done entirely in the second stage. Then we would have $d_{xc} = d_{xd} = 0$ and therefore $M_{22} = 0$. This would give us $\det(\overline{M}) = -\det(M_{12}) \cdot \det(M_{21})$, so by examining the structure of the submatrices we can gain understanding of the entire problem.

From the locations of the principal planes we see that:

$$\begin{aligned} s_{xa} &< s_{xb} \\ s_{ya} &> s_{yb} \\ s_{xd} &< s_{xc} \\ s_{yd} &> s_{yc} \end{aligned} \tag{12}$$

Examination of the coupling terms shows that sextupoles b and c will couple most strongly to T_{122} and T_{126} while sextupoles a and d couple more strongly to T_{144} and T_{346}. In essence what we are doing is first to correct T_{126} and T_{346} with sextupoles b and a respectively. Then we correct the resultant T_{122} and T_{144} terms with sextupoles c and d respectively. Examining the determinants of the submatrices and referring to equations (12) we find:

$$-\det(M_{12}) = s_{xc}s_{xd}(s_{xc}^2\, s_{yd}^2 - s_{yc}^2\, s_{xd}^2) > 0 \qquad (13)$$

$$\det\,(M_{21}) = d_{xa}d_{xb}(s_{xa}^2\, s_{yb}^2 - s_{ya}^2\, s_{xb}^2) > 0$$

If we now define the two component vectors $\overline{T}_1$ and $\overline{T}_2$ as giving the upper and lower (geometric and chromatic) parts of $\overline{T}$ and S_1 and S_2 as:

$$S_1 = \begin{pmatrix} S_a \\ S_b \end{pmatrix} \qquad S_2 = \begin{pmatrix} S_d \\ S_c \end{pmatrix} \qquad (14)$$

As explained in Section II, the components of $\overline{T}_1$ will be zero so we arrive at the solution:

$$S_1 = -M_{21}^{-1}\overline{T}_2 \qquad (15)$$

$$S_2 = -M_{12}^{-1}M_{11}S_1$$

Now, of course, momentum recombination is not all accomplished in the second stage and the conditions $d_{xc} = 0$ and $d_{xd} = 0$ cannot simultaneously be true. However if we adjust the field lens to place the momentum crossover in the region of sextupole c, then the situation should not differ too greatly from the previous case and solution should still be possible. We must now solve the simultaneous equations:

$$M_{11}S_1 + M_{12}S_2 = 0 \qquad (16)$$

$$M_{21}S_1 + M_{22}S_2 = -\overline{T}_2$$

We define a new two-component vector X as:

$$X = M_{11}S_1 \; . \qquad (17)$$

The arguments used above to show M_{12} to be non-singular apply also to M_{11} and from the first of equations (16) we get:

$$S_1 = M_{11}^{-1}X \tag{18}$$

$$S_2 = -M_{12}^{-1}X$$

Substituting into the second of equations (16) gives:

$$(M_{21}M_{11}^{-1} - M_{22}M_{12}^{-1})X = -\overline{T}_2 \tag{19}$$

Each of the submatrices M_{11}, M_{12}, M_{21}, and M_{22} is factorizable and, for example, we have:

$$M_{11} = \begin{pmatrix} s_{xa}^2 & s_{xb}^2 \\ s_{ya}^2 & s_{yb}^2 \end{pmatrix} \begin{pmatrix} s_{xa} & 0 \\ 0 & s_{xb} \end{pmatrix} \tag{20}$$

$$M_{21} = \begin{pmatrix} s_{xa}^2 & s_{xb}^2 \\ s_{ya}^2 & s_{yb}^2 \end{pmatrix} \begin{pmatrix} d_{xa} & 0 \\ 0 & d_{xb} \end{pmatrix}$$

The first matrix on the right side is the same in each equation so that in equation (19) we have:

$$M_{21}M_{11}^{-1} - M_{22}M_{12}^{-1} = \begin{pmatrix} \frac{d_{xa}}{s_{xa}} - \frac{d_{xd}}{s_{xd}} & 0 \\ 0 & \frac{d_{xb}}{s_{xb}} - \frac{d_{xc}}{s_{xc}} \end{pmatrix}$$

Since $s_{xb} = s_{xc}$, the lower right term is $(d_{xb} - d_{xc})/s_{xb}$, indicating that here, just as for the two sextupole case, only the difference in the magnitude of the dispersion ray at the two points is important. Also by setting the momentum crossover point at sextupole c, we see that d_{xd} will be negative. Thus

we are insured that both terms are non-zero, and a solution is indeed possible. Numerical values were once again obtained with the program TRANSPORT. For sextupoles with dimensions as before, we get pole tip fields as shown:

Sextupole	Pole Tip Field
S_a	-3.053 kg
S_b	7.203 kg
S_c	-6.829 kg
S_d	2.750 kg

V. Higher Order Effects

Both the two- and the four-sextupole solutions work perfectly to second order. The obvious question, of course, is the influence of higher order effects. Such effects were examined with the use of the program TURTLE,[8] and the resulting histograms are shown in Figures 4-17. Both horizontal and vertical planes are shown at both second and third foci. The solutions described minimize the second order terms at the second focus. The effect on the beam spot at the third focus is of interest since that is the position at the final target. All runs were made using the recombined mode of the beam as adapted to the needs of experiment no. 96.

In Figure 4 are shown respectively the vertical and horizontal beam profiles at the second focus, using the central design momentum and no sextupoles. The horizontal and vertical spots respectively at the third focus for the same beam configuration are shown in Figure 5. These profiles represent essentially

the first order beam spot. The aim of introducing correcting elements is to make the off-momentum profiles appear essentially the same.

In Figures 6 and 7 are shown the same set of profiles for a momentum one-half percent above the design central momentum. Figures 8 and 9 are the same for a momentum 1% above the design central momentum. All cases are with no sextupoles. As we get away from the central momentum all profiles begin to broaden due to chromatic aberration. As explained in Section II, the broadening in the vertical plane is substantially less than in the horizontal plane.

In Figures 10-15 we see repeated the same set of profiles, but with the two sextupole solution. We are correcting for chromatic aberration on the horizontal plane at the second focus. As can be seen, the horizontal profile at the second focus is now essentially the same for all momenta. A tail, due to higher order effects, appears, even in the on-momentum profile, but is negligible. In the horizontal plane at the third focus the chromatic aberration is greatly reduced. Some deterioration of the beam profile in the vertical plane at both foci is observed. However, if we examine the coupling terms of the sextupoles to the vertical aberrations, we discover that, with the beam geometry used, they are much smaller than those for the horizontal aberrations. Therefore the loss in the vertical plane is not nearly as great as the gain in the horizontal.

The profiles for the four sextupole solution are shown in Figures 16 and 17 for only the central momentum. The higher order terms due to coupling of sextupoles produce a substantial deterioration of the horizontal beam spot, at both second and third foci. This deterioration is, for a large fraction of the momentum band, at least as great as the effect being corrected. It cannot therefore be used as a practical solution. The conclusion is that, for this beam, one must be satisfied correcting in only the horizontal plane and accepting a small deterioration in the vertical.

References

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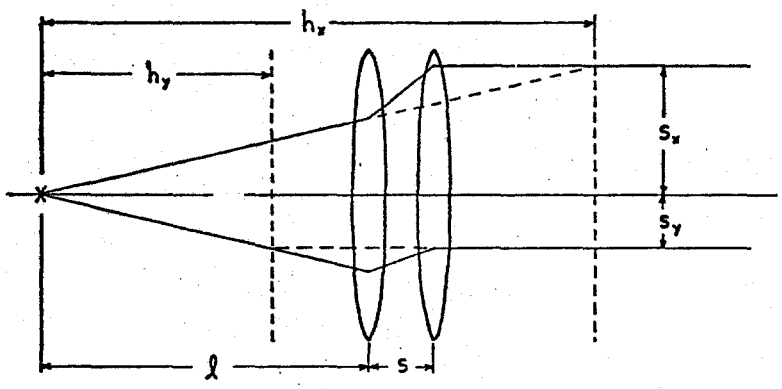

Figure 1. Doublet focusing point to parallel. The horizontally defocusing quadrupole is nearer the focus. Principal planes and sine-like rays are shown in the horizontal (x) and vertical (y) planes.

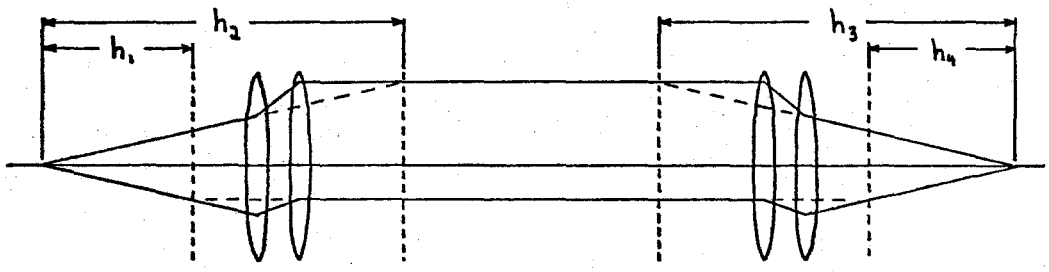

Figure 2. A section of beam line M6 omitting bending magnets. Principal planes are shown for each doublet. Sine-like rays in both planes are also included.

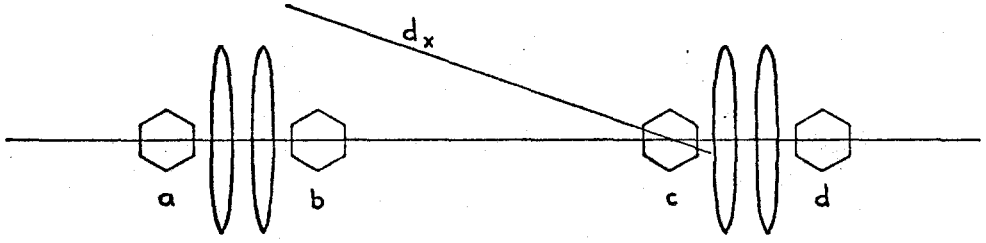

Figure 3. Second stage of beam line M6. Positions of four sextupoles a, b, c, and d are shown. The dispersion ray d_x is drawn in.

Recombined - no sexts
$\Delta p/p = 0$

(1)

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THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 328 RAYS

INTERVAL		
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	41
-0.100 TO	-0.090	105
-0.090 TO	-0.080	185
-0.080 TO	-0.070	235
-0.070 TO	-0.060	262
-0.060 TO	-0.050	234
-0.050 TO	-0.040	262
-0.040 TO	-0.030	265
-0.030 TO	-0.020	318
-0.020 TO	-0.010	291
-0.010 TO	-0.000	317
-0.000 TO	0.010	282
0.010 TO	0.020	[illegible]
0.020 TO	0.030	[illegible]
0.030 TO	0.040	[illegible]
0.040 TO	0.050	254
0.050 TO	0.060	235
0.060 TO	0.070	245
0.070 TO	0.080	212
0.080 TO	0.090	158
0.090 TO	0.100	136
0.100 TO	0.110	35
0.110 TO	0.120	0
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

(2)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 442 RAYS

INTERVAL		
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	0
-0.100 TO	-0.090	0
-0.090 TO	-0.080	0
-0.080 TO	-0.070	117
-0.070 TO	-0.060	223
-0.060 TO	-0.050	294
-0.050 TO	-0.040	323
-0.040 TO	-0.030	361
-0.030 TO	-0.020	392
-0.020 TO	-0.010	442
-0.010 TO	-0.000	387
-0.000 TO	0.010	365
0.010 TO	0.020	435
0.020 TO	0.030	384
0.030 TO	0.040	351
0.040 TO	0.050	322
0.050 TO	0.060	297
0.060 TO	0.070	223
0.070 TO	0.080	119
0.080 TO	0.090	0
0.090 TO	0.100	0
0.100 TO	0.110	0
0.110 TO	0.120	0
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 4. Beam profiles at the second focus in the vertical and horizontal planes respectively. No sextupoles are included and the momentum is the central design value.

(3)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 436 RAYS

INTERVAL		
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	0
-0.100 TO	-0.090	0
-0.090 TO	-0.080	0
-0.080 TO	-0.070	123
-0.070 TO	-0.060	227
-0.060 TO	-0.050	322
-0.050 TO	-0.040	323
-0.040 TO	-0.030	348
-0.030 TO	-0.020	381
-0.020 TO	-0.010	436
-0.010 TO	0.000	369
0.000 TO	0.010	384
0.010 TO	0.020	436
0.020 TO	0.030	395
0.030 TO	0.040	362
0.040 TO	0.050	310
0.050 TO	0.060	292
0.060 TO	0.070	204
0.070 TO	0.080	121
0.080 TO	0.090	0
0.090 TO	0.100	0
0.100 TO	0.110	0
0.110 TO	0.120	0
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 3 OF X IN CM 1470.000 FT FROM THE TARGET

(4)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 501 RAYS

INTERVAL		
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	0
-0.100 TO	-0.090	0
-0.090 TO	-0.080	0
-0.080 TO	-0.070	0
-0.070 TO	-0.060	71
-0.060 TO	-0.050	243
-0.050 TO	-0.040	354
-0.040 TO	-0.030	392
-0.030 TO	-0.020	452
-0.020 TO	-0.010	501
-0.010 TO	0.000	469
0.000 TO	0.010	489
0.010 TO	0.020	494
0.020 TO	0.030	429
0.030 TO	0.040	397
0.040 TO	0.050	396
0.050 TO	0.060	234
0.060 TO	0.070	79
0.070 TO	0.080	0
0.080 TO	0.090	0
0.090 TO	0.100	0
0.100 TO	0.110	0
0.110 TO	0.120	0
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	

NO 4 OF Y IN CM 1470.000 FT FROM THE TARGET

Figure 5. Beam profiles at the third focus in the horizontal and vertical planes respectively. No sextupoles are included and the momentum is the central design value.

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

INTERVAL			SCALE FACTOR: 100 X'S EQUAL 294 RAYS
LESS THAN	-0.200	0	
-0.200 TO	-0.190	0	
-0.190 TO	-0.180	3	X
-0.180 TO	-0.170	4	X
-0.170 TO	-0.160	14	XXXX
-0.160 TO	-0.150	19	XXXXXX
-0.150 TO	-0.140	31	XXXXXXXXXX
-0.140 TO	-0.130	60	XXXXXXXXXXXXXXXXXXXX
-0.130 TO	-0.120	69	XXXXXXXXXXXXXXXXXXXXXXX
-0.120 TO	-0.110	98	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.110 TO	-0.100	114	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.100 TO	-0.090	140	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.090 TO	-0.080	148	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.080 TO	-0.070	164	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.070 TO	-0.060	162	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.060 TO	-0.050	176	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.050 TO	-0.040	227	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.040 TO	-0.030	259	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.030 TO	-0.020	264	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.020 TO	-0.010	261	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.010 TO	-0.000	294	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.000 TO	0.010	265	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.010 TO	0.020	249	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.020 TO	0.030	256	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.030 TO	0.040	250	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.040 TO	0.050	242	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.050 TO	0.060	218	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.060 TO	0.070	182	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.070 TO	0.080	147	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.080 TO	0.090	146	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.090 TO	0.100	135	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.100 TO	0.110	126	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.110 TO	0.120	80	XXXXXXXXXXXXXXXXXXXXXXXXXXX
0.120 TO	0.130	56	XXXXXXXXXXXXXXXXXXX
0.130 TO	0.140	50	XXXXXXXXXXXXXXXXX
0.140 TO	0.150	42	XXXXXXXXXXXXXX
0.150 TO	0.160	22	XXXXXXX
0.160 TO	0.170	18	XXXXXX
0.170 TO	0.180	8	XX
0.180 TO	0.190	1	
0.190 TO	0.200	0	
GREATER THAN	0.200	0	

NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

(6)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

INTERVAL			SCALE FACTOR: 100 X'S EQUAL 233 RAYS
LESS THAN	-2.400	7	XXX
-2.400 TO	-2.390	10	XXXX
-2.390 TO	-2.380	15	XXXXXX
-2.380 TO	-2.370	28	XXXXXXXXXXXX
-2.370 TO	-2.360	37	XXXXXXXXXXXXXXX
-2.360 TO	-2.350	43	XXXXXXXXXXXXXXXXXX
-2.350 TO	-2.340	55	XXXXXXXXXXXXXXXXXXXXXXX
-2.340 TO	-2.330	80	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.330 TO	-2.320	99	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.320 TO	-2.310	120	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.310 TO	-2.300	98	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.300 TO	-2.290	134	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.290 TO	-2.280	175	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.280 TO	-2.270	152	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.270 TO	-2.260	189	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.260 TO	-2.250	185	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.250 TO	-2.240	175	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.240 TO	-2.230	171	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.230 TO	-2.220	169	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.220 TO	-2.210	228	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.210 TO	-2.200	233	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.200 TO	-2.190	227	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.190 TO	-2.180	201	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.180 TO	-2.170	209	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.170 TO	-2.160	208	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.160 TO	-2.150	220	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.150 TO	-2.140	189	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.140 TO	-2.130	179	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.130 TO	-2.120	163	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.120 TO	-2.110	166	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.110 TO	-2.100	143	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.100 TO	-2.090	139	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.090 TO	-2.080	111	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.080 TO	-2.070	101	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.070 TO	-2.060	77	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.060 TO	-2.050	71	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.050 TO	-2.040	65	XXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.040 TO	-2.030	49	XXXXXXXXXXXXXXXXXXXXX
-2.030 TO	-2.020	33	XXXXXXXXXXXXXX
-2.020 TO	-2.010	19	XXXXXXXX
-2.010 TO	-2.000	15	XXXXXX
GREATER THAN	-2.000	11	XXXX

NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 6. Beam profiles at the second focus in the vertical and horizontal planes respectively. No sextupoles are included and the momentum is one-half percent above the central design value.

(7)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 197 RAYS

INTERVAL			COUNT
LESS THAN		-0.200	80
-0.200	TO	-0.190	39
-0.190	TO	-0.180	53
-0.180	TO	-0.170	67
-0.170	TO	-0.160	70
-0.160	TO	-0.150	63
-0.150	TO	-0.140	97
-0.140	TO	-0.130	97
-0.130	TO	-0.120	111
-0.120	TO	-0.110	138
-0.110	TO	-0.100	121
-0.100	TO	-0.090	136
-0.090	TO	-0.080	137
-0.080	TO	-0.070	154
-0.070	TO	-0.060	171
-0.060	TO	-0.050	159
-0.050	TO	-0.040	164
-0.040	TO	-0.030	166
-0.030	TO	-0.020	178
-0.020	TO	-0.010	175
-0.010	TO	-0.000	188
-0.000	TO	0.010	197
0.010	TO	0.020	189
0.020	TO	0.030	151
0.030	TO	0.040	148
0.040	TO	0.050	134
0.050	TO	0.060	132
0.060	TO	0.070	166
0.070	TO	0.080	148
0.080	TO	0.090	144
0.090	TO	0.100	142
0.100	TO	0.110	128
0.110	TO	0.120	111
0.120	TO	0.130	106
0.130	TO	0.140	102
0.140	TO	0.150	100
0.150	TO	0.160	85
0.160	TO	0.170	61
0.170	TO	0.180	39
0.180	TO	0.190	47
0.190	TO	0.200	33
GREATER THAN		0.200	62

NO 3 OF X IN CM 1470.000 FT FROM THE TARGET

(9)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 394 RAYS

INTERVAL			COUNT
LESS THAN		-0.200	0
-0.200	TO	-0.190	0
-0.190	TO	-0.180	0
-0.180	TO	-0.170	0
-0.170	TO	-0.160	0
-0.160	TO	-0.150	0
-0.150	TO	-0.140	0
-0.140	TO	-0.130	0
-0.130	TO	-0.120	3
-0.120	TO	-0.110	21
-0.110	TO	-0.100	34
-0.100	TO	-0.090	73
-0.090	TO	-0.080	87
-0.080	TO	-0.070	165
-0.070	TO	-0.060	170
-0.060	TO	-0.050	243
-0.050	TO	-0.040	251
-0.040	TO	-0.030	319
-0.030	TO	-0.020	391
-0.020	TO	-0.010	360
-0.010	TO	-0.000	385
-0.000	TO	0.010	394
0.010	TO	0.020	365
0.020	TO	0.030	369
0.030	TO	0.040	288
0.040	TO	0.050	250
0.050	TO	0.060	223
0.060	TO	0.070	193
0.070	TO	0.080	169
0.080	TO	0.090	106
0.090	TO	0.100	72
0.100	TO	0.110	30
0.110	TO	0.120	16
0.120	TO	0.130	3
0.130	TO	0.140	0
0.140	TO	0.150	0
0.150	TO	0.160	0
0.160	TO	0.170	0
0.170	TO	0.180	0
0.180	TO	0.190	0
0.190	TO	0.200	0
GREATER THAN		0.200	0

NO 4 OF Y IN CM 1470.000 FT FROM THE TARGET

Figure 7. Beam profiles at the third focus in the horizontal and vertical planes respectively. No sextupoles are included and the momentum is one-half percent above the central design value.

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

INTERVAL — SCALE FACTOR: 100 X'S EQUAL 188 RAYS

INTERVAL			
LESS THAN		-0.200	82
-0.200	TO	-0.190	47
-0.190	TO	-0.180	50
-0.180	TO	-0.170	63
-0.170	TO	-0.160	77
-0.160	TO	-0.150	98
-0.150	TO	-0.140	86
-0.140	TO	-0.130	81
-0.130	TO	-0.120	115
-0.120	TO	-0.110	116
-0.110	TO	-0.100	122
-0.100	TO	-0.090	114
-0.090	TO	-0.080	153
-0.080	TO	-0.070	152
-0.070	TO	-0.060	134
-0.060	TO	-0.050	170
-0.050	TO	-0.040	152
-0.040	TO	-0.030	159
-0.030	TO	-0.020	158
-0.020	TO	-0.010	167
-0.010	TO	-0.000	164
-0.000	TO	0.010	188
0.010	TO	0.020	144
0.020	TO	0.030	172
0.030	TO	0.040	187
0.040	TO	0.050	168
0.050	TO	0.060	151
0.060	TO	0.070	159
0.070	TO	0.080	153
0.080	TO	0.090	147
0.090	TO	0.100	148
0.100	TO	0.110	131
0.110	TO	0.120	114
0.120	TO	0.130	101
0.130	TO	0.140	88
0.140	TO	0.150	97
0.150	TO	0.160	74
0.160	TO	0.170	80
0.170	TO	0.180	66
0.180	TO	0.190	34
0.190	TO	0.200	43
GREATER THAN		0.200	103

NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

INTERVAL — SCALE FACTOR: 100 X'S EQUAL 766 RAYS

INTERVAL			
LESS THAN		-4.620	351
-4.620	TO	-4.590	77
-4.590	TO	-4.580	73
-4.580	TO	-4.570	68
-4.570	TO	-4.560	77
-4.560	TO	-4.550	85
-4.550	TO	-4.540	77
-4.540	TO	-4.530	93
-4.530	TO	-4.520	99
-4.520	TO	-4.510	99
-4.510	TO	-4.500	87
-4.500	TO	-4.490	89
-4.490	TO	-4.480	90
-4.480	TO	-4.470	95
-4.470	TO	-4.460	102
-4.460	TO	-4.450	87
-4.450	TO	-4.440	111
-4.440	TO	-4.430	108
-4.430	TO	-4.420	92
-4.420	TO	-4.410	101
-4.410	TO	-4.400	97
-4.400	TO	-4.390	114
-4.390	TO	-4.380	118
-4.380	TO	-4.370	116
-4.370	TO	-4.360	102
-4.360	TO	-4.350	114
-4.350	TO	-4.340	124
-4.340	TO	-4.330	132
-4.330	TO	-4.320	107
-4.320	TO	-4.310	109
-4.310	TO	-4.300	103
-4.300	TO	-4.290	114
-4.290	TO	-4.280	100
-4.280	TO	-4.270	90
-4.270	TO	-4.260	99
-4.260	TO	-4.250	96
-4.250	TO	-4.240	84
-4.240	TO	-4.230	77
-4.230	TO	-4.220	101
-4.220	TO	-4.210	96
-4.210	TO	-4.200	80
GREATER THAN		-4.200	766

NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 8. Beam profiles at the second focus in the vertical and horizontal planes respectively. No sextupoles are included and the momentum is one percent above the central design value.

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 1032 RAYS

INTERVAL		Count
LESS THAN	-0.200	1032
-0.200 TO	-0.190	73
-0.190 TO	-0.180	64
-0.180 TO	-0.170	67
-0.170 TO	-0.160	86
-0.160 TO	-0.150	73
-0.150 TO	-0.140	78
-0.140 TO	-0.130	78
-0.130 TO	-0.120	8[illegible]
-0.120 TO	-0.110	85
-0.110 TO	-0.100	84
-0.100 TO	-0.090	93
-0.090 TO	-0.080	98
-0.080 TO	-0.070	102
-0.070 TO	-0.060	96
-0.060 TO	-0.050	75
-0.050 TO	-0.040	101
-0.040 TO	-0.030	81
-0.030 TO	-0.020	88
-0.020 TO	-0.010	99
-0.010 TO	-0.000	90
-0.000 TO	0.010	8[illegible]
0.010 TO	0.020	83
0.020 TO	0.030	76
0.030 TO	0.040	5[illegible]
0.040 TO	0.050	73
0.050 TO	0.060	63
0.060 TO	0.070	96
0.070 TO	0.080	91
0.080 TO	0.090	81
0.090 TO	0.100	82
0.100 TO	0.110	82
0.110 TO	0.120	65
0.120 TO	0.130	8[illegible]
0.130 TO	0.140	59
0.140 TO	0.150	78
0.150 TO	0.160	59
0.160 TO	0.170	93
0.170 TO	0.180	75
0.180 TO	0.190	68
0.190 TO	0.200	74
GREATER THAN	0.200	726

NO 3 OF X IN CM 1470.000 FT FROM THE TARGET

(12)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 237 RAYS

INTERVAL		Count
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	2
-0.180 TO	-0.170	10
-0.170 TO	-0.160	22
-0.160 TO	-0.150	34
-0.150 TO	-0.140	51
-0.140 TO	-0.130	63
-0.130 TO	-0.120	96
-0.120 TO	-0.110	118
-0.110 TO	-0.100	124
-0.100 TO	-0.090	134
-0.090 TO	-0.080	162
-0.080 TO	-0.070	21[illegible]
-0.070 TO	-0.060	193
-0.060 TO	-0.050	225
-0.050 TO	-0.040	22[illegible]
-0.040 TO	-0.030	224
-0.030 TO	-0.020	231
-0.020 TO	-0.010	237
-0.010 TO	-0.000	224
-0.000 TO	0.010	221
0.010 TO	0.020	211
0.020 TO	0.030	214
0.030 TO	0.040	214
0.040 TO	0.050	216
0.050 TO	0.060	194
0.060 TO	0.070	172
0.070 TO	0.080	182
0.080 TO	0.090	164
0.090 TO	0.100	143
0.100 TO	0.110	13[illegible]
0.110 TO	0.120	121
0.120 TO	0.130	108
0.130 TO	0.140	61
0.140 TO	0.150	57
0.150 TO	0.160	22
0.160 TO	0.170	22
0.170 TO	0.180	6
0.180 TO	0.190	2
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 4 OF Y IN CM 1470.020 FT FROM THE TARGET

Figure 9. Beam profiles at the third focus in the horizontal and vertical planes respectively. No sextupoles are included and the momentum is one percent above the central design value.

2 sexts - Δp/p = 0 (13)

TM-374

2254.000

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 318 RAYS

INTERVAL		
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	5
-0.110 TO	-0.100	54
-0.100 TO	-0.090	123
-0.090 TO	-0.080	170
-0.080 TO	-0.070	234
-0.070 TO	-0.060	261
-0.060 TO	-0.050	238
-0.050 TO	-0.040	245
-0.040 TO	-0.030	294
-0.030 TO	-0.020	295
-0.020 TO	-0.010	299
-0.010 TO	-0.000	305
-0.000 TO	0.010	275
0.010 TO	0.020	318
0.020 TO	0.030	312
0.030 TO	0.040	302
0.040 TO	0.050	247
0.050 TO	0.060	243
0.060 TO	0.070	225
0.070 TO	0.080	211
0.080 TO	0.090	177
0.090 TO	0.100	112
0.100 TO	0.110	61
0.110 TO	0.120	2
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

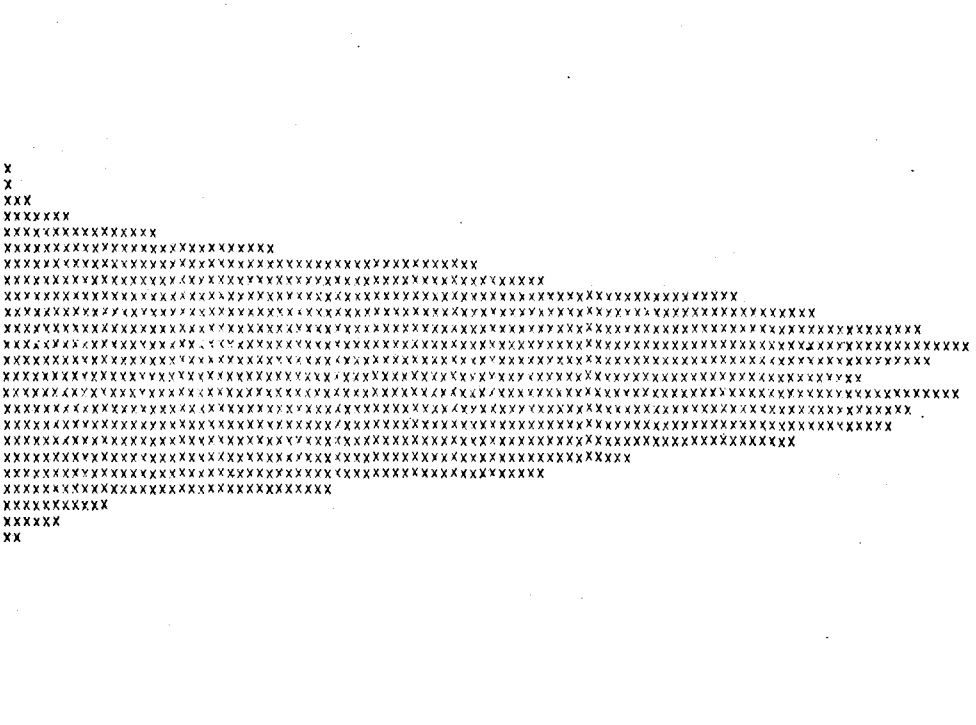
NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

(14)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 400 RAYS

INTERVAL		
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	4
-0.120 TO	-0.110	7
-0.110 TO	-0.100	12
-0.100 TO	-0.090	28
-0.090 TO	-0.080	64
-0.080 TO	-0.070	112
-0.070 TO	-0.060	199
-0.060 TO	-0.050	225
-0.050 TO	-0.040	304
-0.040 TO	-0.030	337
-0.030 TO	-0.020	383
-0.020 TO	-0.010	400
-0.010 TO	-0.000	386
-0.000 TO	0.010	357
0.010 TO	0.020	396
0.020 TO	0.030	378
0.030 TO	0.040	369
0.040 TO	0.050	328
0.050 TO	0.060	262
0.060 TO	0.070	227
0.070 TO	0.080	139
0.080 TO	0.090	46
0.090 TO	0.100	24
0.100 TO	0.110	10
0.110 TO	0.120	3
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0



NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 10. Beam profiles at the second focus in the vertical and horizontal planes respectively. Two sextupoles are used and the momentum is the central design value.

(15)
TM-374
2254.000

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

INTERVAL		SCALE FACTOR: 100 X'S EQUAL 398 RAYS
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	3
-0.100 TO	-0.090	10
-0.090 TO	-0.080	24
-0.080 TO	-0.070	46
-0.070 TO	-0.060	144
-0.060 TO	-0.050	225
-0.050 TO	-0.040	262
-0.040 TO	-0.030	328
-0.030 TO	-0.020	369
-0.020 TO	-0.010	377
-0.010 TO	-0.000	397
-0.000 TO	0.010	349
0.010 TO	0.020	391
0.020 TO	0.030	393
0.030 TO	0.040	382
0.040 TO	0.050	335
0.050 TO	0.060	323
0.060 TO	0.070	224
0.070 TO	0.080	202
0.080 TO	0.090	114
0.090 TO	0.100	63
0.100 TO	0.110	33
0.110 TO	0.120	13
0.120 TO	0.130	6
0.130 TO	0.140	5
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 3 OF X IN CM 1472.000 FT FROM THE TARGET

(16)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

INTERVAL		SCALE FACTOR: 100 X'S EQUAL 498 RAYS
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	0
-0.100 TO	-0.090	0
-0.090 TO	-0.080	0
-0.080 TO	-0.070	0
-0.070 TO	-0.060	98
-0.060 TO	-0.050	245
-0.050 TO	-0.040	346
-0.040 TO	-0.030	384
-0.030 TO	-0.020	447
-0.020 TO	-0.010	498
-0.010 TO	-0.000	467
-0.000 TO	0.010	478
0.010 TO	0.020	491
0.020 TO	0.030	424
0.030 TO	0.040	402
0.040 TO	0.050	381
0.050 TO	0.060	252
0.060 TO	0.070	85
0.070 TO	0.080	2
0.080 TO	0.090	0
0.090 TO	0.100	0
0.100 TO	0.110	0
0.110 TO	0.120	0
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 4 OF Y IN CM 1472.000 FT FROM THE TARGET

Figure 11. Beam profiles at the third focus in the horizontal and vertical planes respectively. Two sextupoles are used and the momentum is the central design value.

2 sexts . $\Delta p/p$ = .5% (17)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 238 RAYS

INTERVAL			
LESS THAN	-0.240	3	
-0.220 TO	-0.190	9	XXX
-0.190 TO	-0.180	14	XXXXX
-0.180 TO	-0.170	20	XXXXXXXX
-0.170 TO	-0.160	29	XXXXXXXXXXXX
-0.160 TO	-0.150	53	XXXXXXXXXXXXXXXXXXXXX
-0.150 TO	-0.140	53	XXXXXXXXXXXXXXXXXXXXX
-0.140 TO	-0.130	94	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.130 TO	-0.120	92	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.120 TO	-0.110	112	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.110 TO	-0.100	115	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.100 TO	-0.090	123	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.090 TO	-0.080	142	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.080 TO	-0.070	158	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.070 TO	-0.060	179	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.060 TO	-0.050	183	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.050 TO	-0.040	198	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.040 TO	-0.030	228	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.030 TO	-0.020	230	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.020 TO	-0.010	213	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.010 TO	-0.000	238	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.000 TO	0.010	219	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.010 TO	0.020	235	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.020 TO	0.030	231	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.030 TO	0.040	221	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.040 TO	0.050	227	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.050 TO	0.060	211	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.060 TO	0.070	183	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.070 TO	0.080	139	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.080 TO	0.090	144	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.090 TO	0.100	166	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.100 TO	0.110	93	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.110 TO	0.120	97	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.120 TO	0.130	93	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.130 TO	0.140	85	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.140 TO	0.150	46	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.150 TO	0.160	47	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.160 TO	0.170	38	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.170 TO	0.180	19	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.180 TO	0.190	13	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.190 TO	0.200	14	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
GREATER THAN	0.200	5	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

(18)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

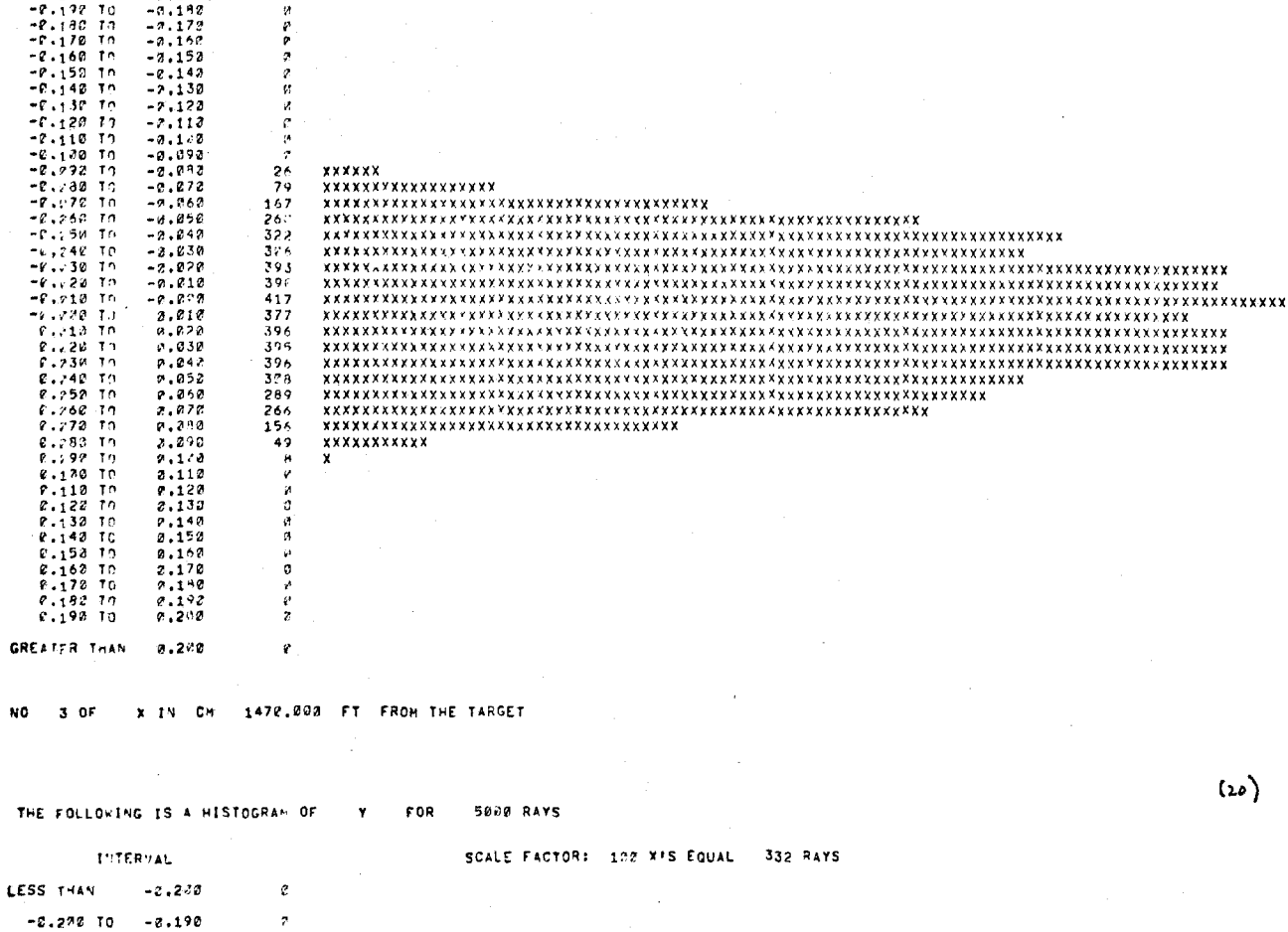
SCALE FACTOR: 100 X'S EQUAL 395 RAYS

INTERVAL			
LESS THAN	-2.400	0	
-2.400 TO	-2.390	0	
-2.390 TO	-2.380	0	
-2.380 TO	-2.370	0	
-2.370 TO	-2.360	0	
-2.360 TO	-2.350	0	
-2.350 TO	-2.340	0	
-2.340 TO	-2.330	1	
-2.330 TO	-2.320	7	X
-2.320 TO	-2.310	7	X
-2.310 TO	-2.300	17	XXXX
-2.300 TO	-2.290	33	XXXXXXXX
-2.290 TO	-2.280	92	XXXXXXXXXXXXXXXXXXXXXX
-2.280 TO	-2.270	151	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.270 TO	-2.260	210	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.260 TO	-2.250	254	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.250 TO	-2.240	331	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.240 TO	-2.230	356	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.232 TO	-2.227	394	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.220 TO	-2.210	394	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.210 TO	-2.200	371	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.200 TO	-2.190	392	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.190 TO	-2.180	362	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.180 TO	-2.170	395	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.170 TO	-2.160	344	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.160 TO	-2.150	292	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.150 TO	-2.140	262	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.140 TO	-2.130	195	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.130 TO	-2.120	94	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.122 TO	-2.110	35	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.110 TO	-2.100	14	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.100 TO	-2.090	7	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-2.090 TO	-2.080	2	
-2.080 TO	-2.070	0	
-2.070 TO	-2.060	2	
-2.060 TO	-2.050	0	
-2.050 TO	-2.040	0	
-2.040 TO	-2.030	0	
-2.030 TO	-2.020	0	
-2.020 TO	-2.010	0	
-2.010 TO	-2.000	0	
GREATER THAN	-2.000	0	

NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 12. Beam profiles at the second focus in the vertical and horizontal planes respectively. Two sextupoles are used and the momentum is one-half percent above the central design value.

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS



(20)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

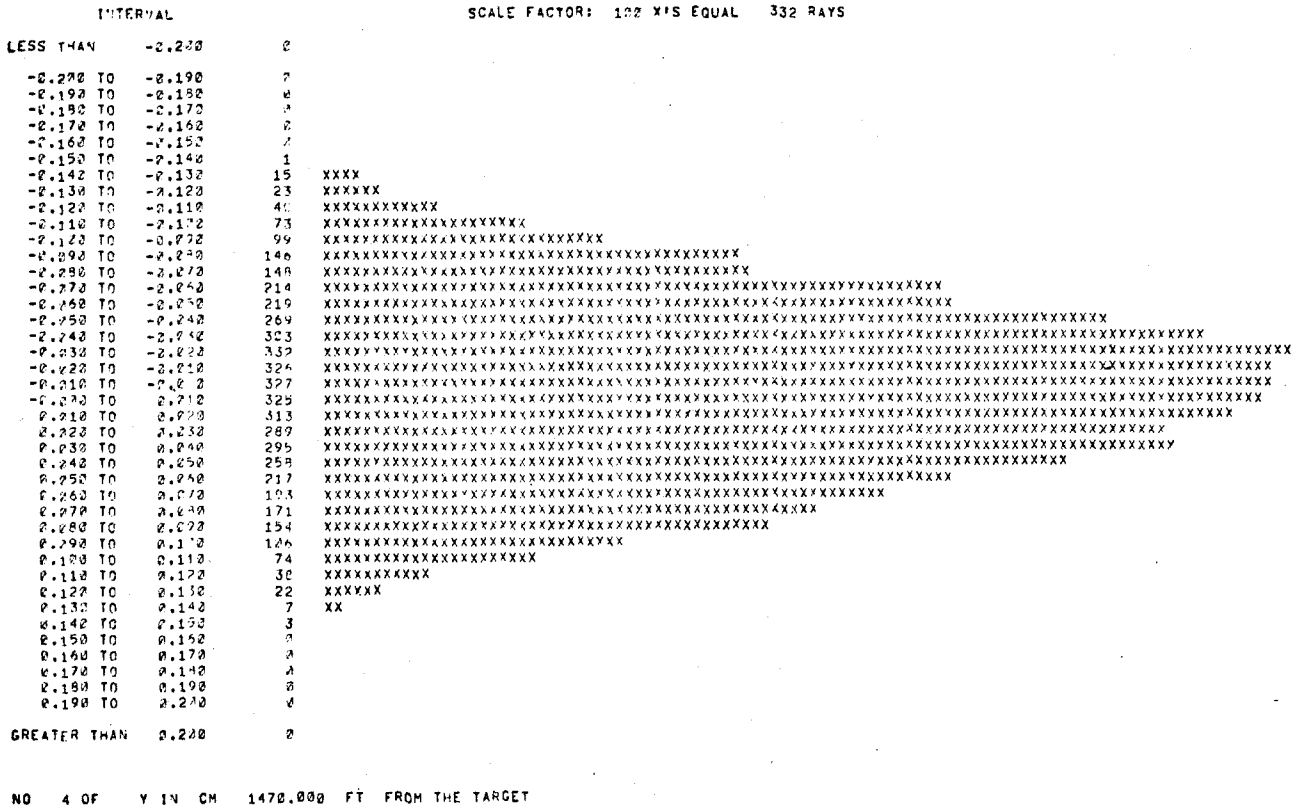


Figure 13. Beam profiles at the third focus in the horizontal and vertical planes respectively. Two sextupoles are used and the momentum is one-half percent above the central design value.

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 316 RAYS

INTERVAL		
LESS THAN	-0.200	316
-0.200 TO	-0.190	65
-0.190 TO	-0.180	84
-0.180 TO	-0.170	86
-0.170 TO	-0.160	77
-0.160 TO	-0.150	96
-0.150 TO	-0.140	88
-0.140 TO	-0.130	113
-0.130 TO	-0.120	102
-0.120 TO	-0.110	104
-0.110 TO	-0.100	105
-0.100 TO	-0.090	106
-0.090 TO	-0.080	112
-0.080 TO	-0.070	131
-0.070 TO	-0.060	121
-0.060 TO	-0.050	137
-0.050 TO	-0.040	129
-0.040 TO	-0.030	125
-0.030 TO	-0.020	116
-0.020 TO	-0.010	125
-0.010 TO	-0.000	117
-0.000 TO	0.010	132
0.010 TO	0.020	146
0.020 TO	0.030	133
0.030 TO	0.040	133
0.040 TO	0.050	135
0.050 TO	0.060	113
0.060 TO	0.070	123
0.070 TO	0.080	117
0.080 TO	0.090	137
0.090 TO	0.100	125
0.100 TO	0.110	95
0.110 TO	0.120	122
0.120 TO	0.130	122
0.130 TO	0.140	109
0.140 TO	0.150	102
0.150 TO	0.160	93
0.160 TO	0.170	82
0.170 TO	0.180	71
0.180 TO	0.190	84
0.190 TO	0.200	63
GREATER THAN	0.200	314

NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

(22)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 401 RAYS

INTERVAL		
LESS THAN	-4.600	0
-4.600 TO	-4.590	0
-4.590 TO	-4.580	0
-4.580 TO	-4.570	0
-4.570 TO	-4.560	0
-4.560 TO	-4.550	0
-4.550 TO	-4.540	0
-4.540 TO	-4.530	1
-4.530 TO	-4.520	9
-4.520 TO	-4.510	11
-4.510 TO	-4.500	19
-4.500 TO	-4.490	52
-4.490 TO	-4.480	92
-4.480 TO	-4.470	164
-4.470 TO	-4.460	244
-4.460 TO	-4.450	283
-4.450 TO	-4.440	333
-4.440 TO	-4.430	358
-4.430 TO	-4.420	401
-4.420 TO	-4.410	378
-4.410 TO	-4.400	377
-4.400 TO	-4.390	368
-4.390 TO	-4.380	375
-4.380 TO	-4.370	392
-4.370 TO	-4.360	327
-4.360 TO	-4.350	289
-4.350 TO	-4.340	262
-4.340 TO	-4.330	165
-4.330 TO	-4.320	74
-4.320 TO	-4.310	21
-4.310 TO	-4.300	8
-4.300 TO	-4.290	1
-4.290 TO	-4.280	0
-4.280 TO	-4.270	0
-4.270 TO	-4.260	0
-4.260 TO	-4.250	0
-4.250 TO	-4.240	0
-4.240 TO	-4.230	0
-4.230 TO	-4.220	0
-4.220 TO	-4.210	0
-4.210 TO	-4.200	0
GREATER THAN	-4.200	0

NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 14. Beam profiles at the second focus in the vertical and horizontal planes respectively. Two sextupoles are used and the momentum is one percent above the central design value.

(23)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

INTERVAL		SCALE FACTOR: 100 X'S EQUAL 386 RAYS
LESS THAN	-0.230	0
-0.220 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	3
-0.100 TO	-0.090	27
-0.090 TO	-0.080	67
-0.080 TO	-0.070	122
-0.070 TO	-0.060	127
-0.060 TO	-0.050	154
-0.050 TO	-0.040	197
-0.040 TO	-0.030	265
-0.030 TO	-0.020	323
-0.020 TO	-0.010	364
-0.010 TO	-0.000	369
-0.000 TO	0.010	386
0.010 TO	0.020	367
0.020 TO	0.030	380
0.030 TO	0.040	365
0.040 TO	0.050	343
0.050 TO	0.060	304
0.060 TO	0.070	266
0.070 TO	0.080	213
0.080 TO	0.090	151
0.090 TO	0.100	112
0.100 TO	0.110	76
0.110 TO	0.120	34
0.120 TO	0.130	5
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 3 OF X IN CM 1470.000 FT FROM THE TARGET

(24)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

INTERVAL		SCALE FACTOR: 100 X'S EQUAL 192 RAYS
LESS THAN	-0.200	12
-0.200 TO	-0.190	24
-0.190 TO	-0.180	31
-0.180 TO	-0.170	43
-0.170 TO	-0.160	64
-0.160 TO	-0.150	87
-0.150 TO	-0.140	93
-0.140 TO	-0.130	95
-0.130 TO	-0.120	118
-0.120 TO	-0.110	141
-0.110 TO	-0.100	141
-0.100 TO	-0.090	148
-0.090 TO	-0.080	156
-0.080 TO	-0.070	145
-0.070 TO	-0.060	191
-0.060 TO	-0.050	176
-0.050 TO	-0.040	151
-0.040 TO	-0.030	172
-0.030 TO	-0.020	187
-0.020 TO	-0.010	192
-0.010 TO	-0.000	165
-0.000 TO	0.010	168
0.010 TO	0.020	171
0.020 TO	0.030	175
0.030 TO	0.040	186
0.040 TO	0.050	177
0.050 TO	0.060	172
0.060 TO	0.070	139
0.070 TO	0.080	155
0.080 TO	0.090	165
0.090 TO	0.100	129
0.100 TO	0.110	128
0.110 TO	0.120	126
0.120 TO	0.130	124
0.130 TO	0.140	121
0.140 TO	0.150	99
0.150 TO	0.160	72
0.160 TO	0.170	66
0.170 TO	0.180	48
0.180 TO	0.190	22
0.190 TO	0.200	22
GREATER THAN	0.200	8

NO 4 OF Y IN CM 1470.000 FT FROM THE TARGET

Figure 15. Beam profiles at the third focus in the horizontal and vertical planes respectively. Two sextupoles are used and the momentum is one percent above the central design value.

4 sexts - $\Delta p/p = 0$ (15)

TM-374

2254.000

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 304 RAYS

INTERVAL			
LESS THAN	-0.270	2	
-0.200 TO	-0.190	0	
-0.190 TO	-0.180	0	
-0.180 TO	-0.170	0	
-0.170 TO	-0.160	0	
-0.160 TO	-0.150	0	
-0.150 TO	-0.140	6	X
-0.140 TO	-0.130	12	XXX
-0.130 TO	-0.120	31	XXXXXXXXXX
-0.120 TO	-0.110	41	XXXXXXXXXXXX
-0.110 TO	-0.100	87	XXXXXXXXXXXXXXXXXXXXXXXX
-0.100 TO	-0.090	118	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.090 TO	-0.080	182	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.080 TO	-0.070	222	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.070 TO	-0.060	237	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.060 TO	-0.050	230	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.050 TO	-0.040	244	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.040 TO	-0.030	257	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.030 TO	-0.020	291	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.020 TO	-0.010	292	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.010 TO	-0.000	269	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.000 TO	0.010	304	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.010 TO	0.020	274	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.020 TO	0.030	283	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.030 TO	0.040	272	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.040 TO	0.050	271	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.050 TO	0.060	223	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.060 TO	0.070	233	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.070 TO	0.080	186	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.080 TO	0.090	158	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.090 TO	0.100	123	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.100 TO	0.110	86	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.110 TO	0.120	51	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.120 TO	0.130	16	XXXXX
0.130 TO	0.140	12	XXX
0.140 TO	0.150	5	X
0.150 TO	0.160	1	
0.160 TO	0.170	0	
0.170 TO	0.180	0	
0.180 TO	0.190	0	
0.190 TO	0.200	0	
GREATER THAN	0.200	0	

NO 1 OF Y IN CM 1027.139 FT FROM THE TARGET

(16)

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 296 RAYS

INTERVAL			
LESS THAN	-0.200	135	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.200 TO	-0.190	32	XXXXXXXXXX
-0.190 TO	-0.180	31	XXXXXXXXXX
-0.180 TO	-0.170	30	XXXXXXXXXX
-0.170 TO	-0.160	39	XXXXXXXXXXXX
-0.160 TO	-0.150	38	XXXXXXXXXXXX
-0.150 TO	-0.140	41	XXXXXXXXXXXXX
-0.140 TO	-0.130	42	XXXXXXXXXXXXXX
-0.130 TO	-0.120	57	XXXXXXXXXXXXXXXXXX
-0.120 TO	-0.110	59	XXXXXXXXXXXXXXXXXX
-0.110 TO	-0.100	66	XXXXXXXXXXXXXXXXXXXX
-0.100 TO	-0.090	69	XXXXXXXXXXXXXXXXXXXXX
-0.090 TO	-0.080	94	XXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.080 TO	-0.070	109	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.070 TO	-0.060	163	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.060 TO	-0.050	174	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.050 TO	-0.040	222	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.040 TO	-0.030	242	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.030 TO	-0.020	246	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.020 TO	-0.010	296	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.010 TO	-0.000	281	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-0.000 TO	0.010	244	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.010 TO	0.020	257	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.020 TO	0.030	262	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.030 TO	0.040	241	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.040 TO	0.050	239	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.050 TO	0.060	194	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.060 TO	0.070	176	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.070 TO	0.080	136	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.080 TO	0.090	110	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.090 TO	0.100	73	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.100 TO	0.110	74	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.110 TO	0.120	59	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.120 TO	0.130	69	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.130 TO	0.140	53	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0.140 TO	0.150	34	XXXXXXXXXXXXXXXXXX
0.150 TO	0.160	32	XXXXXXXXXXXXXXXXXX
0.160 TO	0.170	28	XXXXXXXXXXXXXXXXXX
0.170 TO	0.180	24	XXXXXXXXXXXXXXXXXX
0.180 TO	0.190	31	XXXXXXXXXXXXXXXXXX
0.190 TO	0.200	28	XXXXXXXXXXXXXXXXXX
GREATER THAN	0.200	173	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

NO 2 OF X IN CM 1041.139 FT FROM THE TARGET

Figure 16. Beam profiles at the second focus in the vertical and horizontal planes respectively. Four sextupoles are used and the momentum is the central design value.

THE FOLLOWING IS A HISTOGRAM OF X FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 294 RAYS

INTERVAL		Count
LESS THAN	-0.200	173
-0.200 TO	-0.190	30
-0.190 TO	-0.180	31
-0.180 TO	-0.170	26
-0.170 TO	-0.160	28
-0.160 TO	-0.150	29
-0.150 TO	-0.140	35
-0.140 TO	-0.130	57
-0.130 TO	-0.120	69
-0.120 TO	-0.110	57
-0.110 TO	-0.100	73
-0.100 TO	-0.090	73
-0.090 TO	-0.080	111
-0.080 TO	-0.070	139
-0.070 TO	-0.060	172
-0.060 TO	-0.050	196
-0.050 TO	-0.040	238
-0.040 TO	-0.030	238
-0.030 TO	-0.020	261
-0.020 TO	-0.010	258
-0.010 TO	-0.000	242
-0.000 TO	0.010	28[illegible]
0.010 TO	0.020	294
0.020 TO	0.030	246
0.030 TO	0.040	244
0.040 TO	0.050	217
0.050 TO	0.060	171
0.060 TO	0.070	167
0.070 TO	0.080	109
0.080 TO	0.090	97
0.090 TO	0.100	71
0.100 TO	0.110	63
0.110 TO	0.120	61
0.120 TO	0.130	57
0.130 TO	0.140	42
0.140 TO	0.150	33
0.150 TO	0.160	40
0.160 TO	0.170	42
0.170 TO	0.180	30
0.180 TO	0.190	30
0.190 TO	0.200	31
GREATER THAN	0.200	136

NO 3 OF X IN CM 1470.000 FT FROM THE TARGET

(28)

THE FOLLOWING IS A HISTOGRAM OF Y FOR 5000 RAYS

SCALE FACTOR: 100 X'S EQUAL 477 RAYS

INTERVAL		Count
LESS THAN	-0.200	0
-0.200 TO	-0.190	0
-0.190 TO	-0.180	0
-0.180 TO	-0.170	0
-0.170 TO	-0.160	0
-0.160 TO	-0.150	0
-0.150 TO	-0.140	0
-0.140 TO	-0.130	0
-0.130 TO	-0.120	0
-0.120 TO	-0.110	0
-0.110 TO	-0.100	0
-0.100 TO	-0.090	1
-0.090 TO	-0.080	15
-0.080 TO	-0.070	47
-0.070 TO	-0.060	142
-0.060 TO	-0.050	233
-0.050 TO	-0.040	314
-0.040 TO	-0.030	382
-0.030 TO	-0.020	442
-0.020 TO	-0.010	444
-0.010 TO	-0.000	477
-0.000 TO	0.010	463
0.010 TO	0.020	455
0.020 TO	0.030	394
0.030 TO	0.040	378
0.040 TO	0.050	354
0.050 TO	0.060	255
0.060 TO	0.070	131
0.070 TO	0.080	54
0.080 TO	0.090	15
0.090 TO	0.100	6
0.100 TO	0.110	0
0.110 TO	0.120	0
0.120 TO	0.130	0
0.130 TO	0.140	0
0.140 TO	0.150	0
0.150 TO	0.160	0
0.160 TO	0.170	0
0.170 TO	0.180	0
0.180 TO	0.190	0
0.190 TO	0.200	0
GREATER THAN	0.200	0

NO 4 OF Y IN CM 1470.000 FT FROM THE TARGET

Figure 17. Beam profiles at the third focus in the horizontal and vertical planes respectively. Four sextupoles are used and the momentum is the central design value.