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OPTIMIZATION OF THE VERTICAL DISPERSION SUPPRESSOR FOR THE SSC

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1. Introduction and Results

For the proton-proton SSC the placement of bend magnets on tope of each other (up-down scheme) seems to be favorable from an operational point of view. Unfortunately, such a scheme demands an additional vertical dispersion suppressor to kill a vertical dispersion function induced by the vertical bend magnets. The total length of vertical beam separators per ring with the length of each about 600m can be as large as 6 km, with the cost about $25M.

In this paper we describe the results of systematic search for the optimum structure of the vertical beam separator. The separators made of regular bend magnets and a separator with skew quadrupole are considered. We assumed the following criteria:

1. The separator has to provide the necessary vertical beam separation.

2. The beam deflection has to be monotonic along an insertion, without large oscillations, especially without change of the sign of deflection.

3. The vertical dispersion function and its derivative at the end of the separator have to be zero.

4. Under these constraints the cost of the separator has to be minimal.

We don't impose the constraint that the vertical dispersion function η^* is zero at the IP.

First of all, all the same it is rather small, about 1 cm, and doesn't change the luminosity substantially, because the beam size $\eta^* \cdot \Delta p/p$ with $\Delta p/p \sim 10^{-4}$, of order of 1μm is much less than rms beam size $\sigma^* = \sqrt{\varepsilon_N \beta^*/\gamma}$ which is of order of 7μm.

The second reason is that, as we found, this constraint increases the necessary strength of the bend magnets (almost order of magnitude) and the length of the separator.

We minimized the cost of the separator instead of its length, because the very short separator demands very strong (or long) bend magnets, so that the total cost of the short separator could be more than for the longer one. This statement is illustrated by figures 1a, 1b, and 1c where each point represents a possible structure of a separator and the cost of each separator is plotted versus its length.

As it is easy to see, the cost of the separator decreases if the total length increases, because the bend magnets are getting shorter and less expensive. It is true until the magnets are longer then some minimal limit, which we assume to be 1m. After that the cost increases with the total length again (fig. 1c).

Most of the points on fig. 1 correspond to separators with oscillating beam deflection. Only a few of them survive, if the condition number 2 is imposed (see fig. 2a, 2b). The oscillations of the vertical deflection z(s) along the insertion is shown on fig. 3 for different bend angles of the splitting magnet.

In the table 1 the parameters of the several separators, which have been found under conditions 1-4 are summarized (the shortest and the least expensive separators). The parameters given are the bend angles and coordinates of the center of bend magnets, the total length and the estimated cost of the separator.

As a model of the insertion we use the structure designed by A. Garren for 6 T lattice with phase advance 60° per cell. The coordinate of IP is 850.0 m.

Table 1. Parameters of Some Vertical Separators

Bend Angles coordinates, m 1	2	3	4	5	length, m cost, k$
0.16e-03 923.0	0.104406e-01 937.9802	-0.153045e-01 1022.4161	-0.776325e-02 1047.1104	0.124671e-01 1087.7058	231.94 6468.889
0.16e-03 923.0	0.928193e-02 938.3841	-0.188233e-01 1029.5255	0.107700e-01 1103.7920	-0.138859e-02 1236.0902	305.96 6337.79
0.16e-03 923.0	-0.188554e-03 1026.1371	0.606108e-03 1204.5085	0.101745e-02 1396.2186	-0.159501e-02 1539.0822	607.759 4427.18
0.16e-03 923.0	-0.177432e-03 1029.0869	0.673003e-03 1216.8319	0.989394e-03 1416.9675	-0.164497e-02 1541.6484	610.035 4452.286

In the last section we discuss a separator with skew quadrupoles in it. Such a design makes a separator shorter then separator made of bend magnets only.

2. For systematic study of the vertical beam separation we can explore the fact, that the vertical beam separator made of a

number of bend magnets doesn't change the vertical beta function and phase advance along the insertion, as far as the weak focusing and the effect of fringe field are negligible. So, we can start with an insertion without separator, find Twiss-functions for the insertion and use them to calculate vertical dispersion function for any placement of the vertical bend magnets in the insertion. To do that in a systematic way a program has been developed, which generate a set of separators with constraints given above and pick up the best solution. Of course, the question of how the solution depends on the initial structure of the insertion remains open. The antisymmetric insertion includes on both sides of the IP a trombone, a low beta triplet and some matching quads, placed symmetrically in respect with the interaction point. The trombones in the insertion provide a regular structure with enough room for different placement of the bend magnets. The parameters of the insertion are given in the Appendix 2.

Given insertion, the vertical dispersion function $\eta(s)$ with zero initial conditions $\eta(s_i) = \eta'(s_i) = 0$ takes a form:

$$\eta(s) = \sqrt{\beta(s)} \int_{s_i}^{s_f} ds' K(s') \sqrt{\beta(s')} \, \mathrm{Sin}\, (\phi(s) - \phi(s'))$$

Here $K(s) = 1/R$ is the local curvature, $\beta(s)$ and $\phi(s)$ are vertical beta function and phase advance

$$\phi(s) = \int^{s} ds'/\beta(s') \; ; \; \phi(s + c) = \phi(s) + 2\pi Q$$

So, $\eta(s)$ and $\eta'(s)$ are equal to zero at the end of the insertion $s = s_f$ if the following conditions are satisfied:

$$\int_{s_i}^{s_f} ds' \, K(s) \sqrt{\beta(s)} \, \mathrm{Sin}\, (\phi(s) - \phi^*) = 0$$

$$\int_{s_i}^{s_f} ds \, K(s) \sqrt{\beta(s)} \, \mathrm{Cos}\, (\phi(s) - \phi^*) = 0$$

where ϕ^* is arbitrary and can be taken as the phase advance at the IP. As far as we can neglect the weak focusing in the bend magnets, the integral over a bend with K=constant is

$$K \int_{s_0 - \ell/2}^{s_0 + \ell/2} ds \sqrt{\beta(s)} \exp(i\phi(s)) = \alpha \sqrt{\beta(s_o)} \exp(i\phi(s_o))$$

where at the right-hand side α is the bend angle $\alpha = K \times 1$, ℓ is the length of the magnet and s_o is the coordinate of the center of the magnet. With this result the constraints $\eta(s_f) = \eta'(s_f) = 0$ can be rewritten as follows:

(1) $$\sum \alpha k \sqrt{\beta_k} \, \mathrm{Sin}\, (\phi_k - \phi^*) = 0$$

$$\sum \alpha k \sqrt{\beta_k} \, \mathrm{Cos}\, (\phi_k - \phi^*) = 0$$

with $\beta_k = \beta(s_k)$, $\phi_k = \phi(s_k)$. The sum is going over all vertical bend magnets in the insertion.

The vertical deflection of the beam z(s) is given by the equation

$$z'' = K(s)$$

At the end of the k-th bend magnets for initial conditions $z(s) = z'(s) = 0$ it gives

$$z_K = \sum_{1}^{K} \alpha_i (s_K - s_i + l_K/2)$$

$$z'_K = \sum_{1}^{K} \alpha_i$$

So, for head-on collisions it has to be

$$(2) \quad \sum \alpha_i = 0, \qquad \sum \alpha_i s_i = h$$

where the summation is taken over all vertical bends on each side of the IP independently, and h is the half of the beam separation in the arcs.

Altogether, there are six conditions (1), (2) which can be considered as the system of equations for unknown bend angles α_K. For a symmetric insertion it is enough to have two bend magnets on both sides of the IP. It makes the symmetric separator shorter, but works only for head-on collisions.

For an asymmetric insertion it is necessary to have at least four independent bend magnets on both sides of IP. The symmetry in respect with two beams is guaranteed if the bend magnets are placed symmetrically with IP and have opposite signs of the curvatures. We assume this arrangement.

To minimize long-range beam-beam interaction two beams have to be split as fast as possible. For this reason the fifth shared magnet was placed right after the low-beta triplet. We assumed, that the splitting magnet has to provide the beam deflection at least of $20\sigma^* \simeq 140\mu m$. It give $\alpha_{min} = 1.6e-04$.

We found that increase of the bend angle of the splitting magnet causes oscillations of the beam deflection z(s) along the insertion. For $\alpha = 5.3-04$, z(s) goes back to the magnitude at the IP, and for $\alpha = 7e-04$ z(s) can even change sign (see f.3). For this reason we used $\alpha = \alpha_{min}$. In this case the first two or three bend magnets and quads in between have to be shared by two beams.

To avoid the problem we tried to use the second splitting magnet and to vary its strength to diminish the oscillations.

For the bend angle of the second split magnet the deflection in all six bend magnets is given in the T.2. The oscillations are as big as in the case of the separator with five magnets.

Table 2. The Beam Deflection in the 6-Magnet Separator
=1.0e-04

z1	z2	z3	z4	z5	z6	
0.0	3.14e-04	-0.0898	0.011	-0.056	0.082	0.35
-0.1e-03	3.14e-04	0.0096	0.006	-0.038	0.073	0.35
-0.3e-03	3.14e-04	0.0083	-0.004	-0.003	0.055	0.35
-0.4e-03	3.14e-04	0.077	-0.008	0.015	0.046	0.35
-0.5e-03	3.14e-04	0.0071	-0.013	0.033	0.037	0.35

With fixed bend angle of the first magnet the four other angles are determined by the system of equation (1), (2) for a given placement of the bend magnets. To compare the different configurations we estimated the cost of each configuration with the formula:

$$\$ = S_M \sum k_i l_i + S_T L + S_Q L/L_{AV}$$

where $L = s_5 - s_1 + 0.5 \times (l_5 + l_1)$ is the total length of the separator, $L_{AV} = 14.5$m is the average distance between quads in the separator, $k_i = 1$ for shared magnets and $k_i = 2$ otherwise. We assumed, that the cost per meter of the bend magnet is S_M = 5.21 K$/m, of the tunnel S_T = 4.32K$/m and of the quad S_Q = 33.2K$/m as they are given in the SSC report [1].

The cost versus the length of different separators are plotted on the figure 2. The plot shows, that the minimal length of the separator is limited because of the increase of the length and the cost of the bend magnets. One of the possible structure of the separator with beam separation ±35cm is given in the Appendix 2. The graphics of the beta functions and dispersion function in both planes are shown on the figure 4. Some additional remarks on the program algorithm are given in the Appendix 1.

3. The very different approach for the design of a vertical beam separator has been suggested by W. MacKay (TAC). His idea is to make a vertical separator as two vertical bend magnets and add a skew quad to rotate the dispersion function so that at the exit of the separator there is a horizontal dispersion function, but vertical function is equal to zero. The horizontal dispersion function can be matched with the arc by horizontal dispersion suppressor, which is in the insertion all the same. We have found a configuration, which works in this way and the

result is shown on figure 5 and 6. The structure of the suppressor is given in the Appendix 3. The separator is short. The drawback of this approach is that the mixing of the horizontal and vertical motion makes the systematic study of such separator very complicated. Each change of beta function at the IP would cause a problem of rematching of the whole insertion etc. For this reason we limited ourself with a given example of such a possibility.

Appendix 1 Some Remarks on the Program

The program used Twiss function for a given insertion, which can be calculated in a number of points along the insertion with standard code like MAD. The program extrapolate these data with spline-functions, so that the value of Twiss parameters are known in arbitrary points of the insertion. We neglect the change of the parameters due to the weak focusing and fringe fields at this point.

The program generates four independent random numbers according to the given distribution functions (see below) and uses them to place the bend magnets in the insertion. For a given placement, the coefficient of the equation (1), (2) are calculated using the spline-functions and the system of equations determines the structure of the separator.

After a big number of separators (1,000) is generated the program orders them according to some additional criterion such as the minimum cost or length of the separators and calculates the distributions of random numbers, which gave the best 200 separators (for each magnet independently). These distributions are used as the distribution functions for the next iterations.

The Figure 7 shows how a distribution function is modified through 20 successive iterations. Such an adjustable Monte-Carlo method rather efficient and converge rapidly. It takes about 1 hour of CPU time on VAX-730 to generate and analyze 100,000 separators of different structure.

Literature

[1] SSC Aperture Estimate for Cost Comparisons, Aperture Task Force, August, 1985 SSC-SR-1013.

Figures

Figure 1

Cost versus length of the separator. Each point corresponds to a separator with 5 vertical bend magnets

$\alpha_1 = 0.16e-03; \alpha_{min} = 1.0/R$

Fig. 1a $\alpha_{max} = 2.0e-02$

Fig. 1b $\alpha_{max} = 1.0e-02$

Fig. 1c $\alpha_{max} = 0.3e{=}-2$

Figure 2

The same as Figure 1, but the constraint on vertical oscillations of the orbit is imposed.

Figure 3

The vertical oscillation of the orbit for three different angles of the splitting magnet:

$\alpha_1 = 0.75e-03$

$\alpha_1 = 0.49e-03$

$\alpha_1 = 0.16e-03$

The positions of the quads are shown.

Figure 4

Twiss functions for the insertion with a separator.

Figure 5

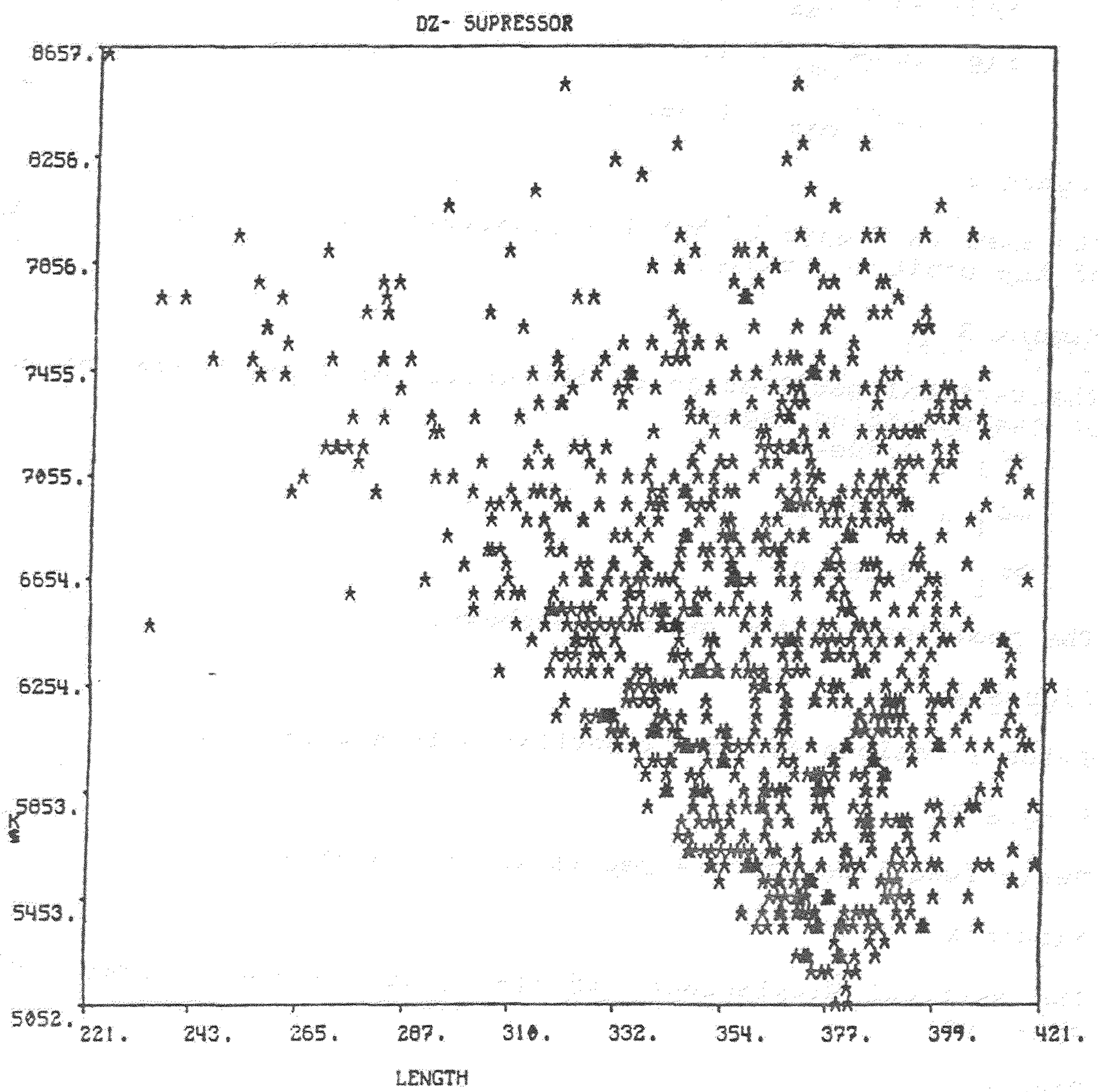
Twiss functions for the separator with a skew quad.

Figure 6

The vertical displacement of the orbit for the separator with a skew quad.

Figure 7

The change of a distribution function with iterations.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7055.
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6254.
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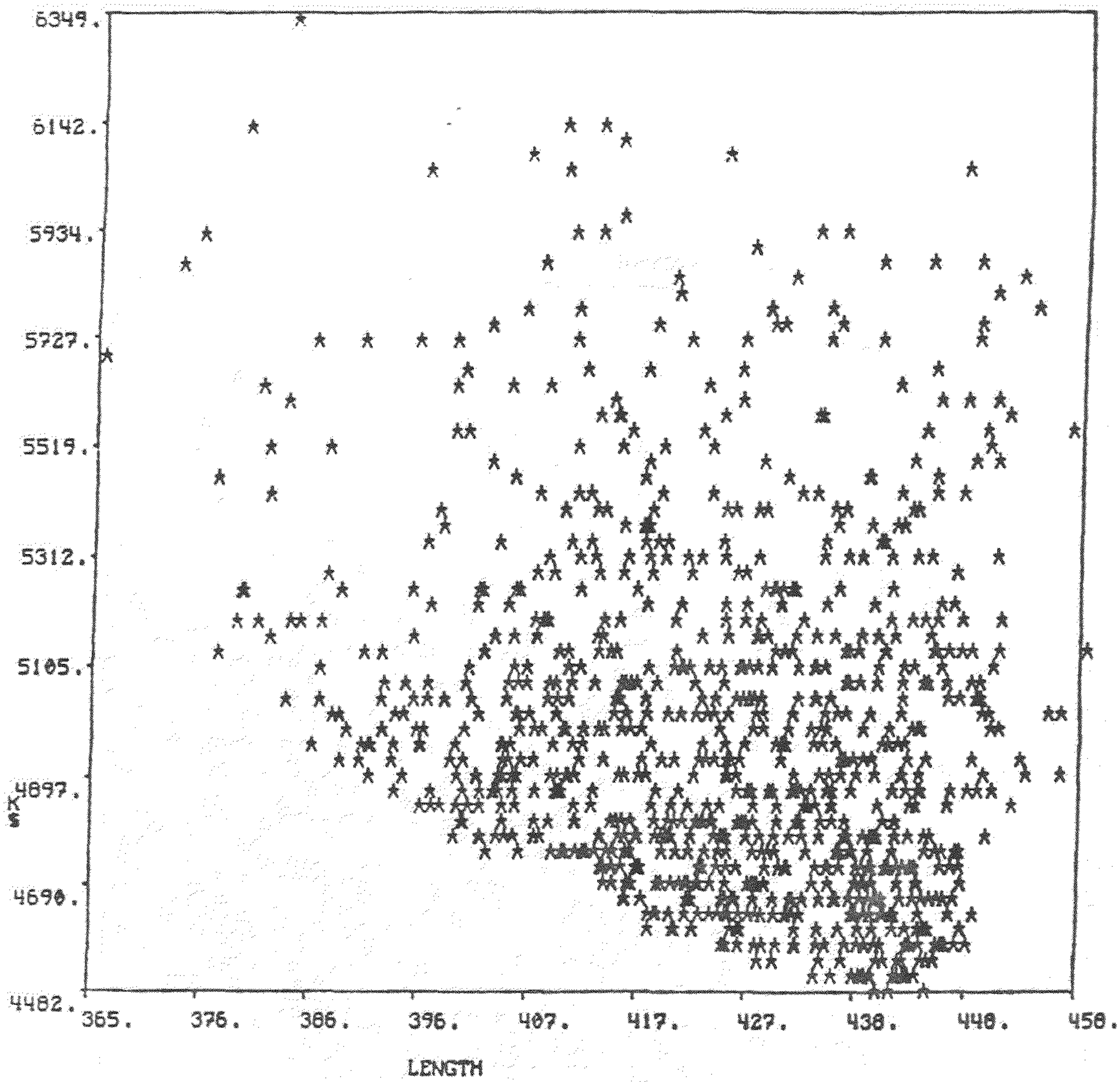
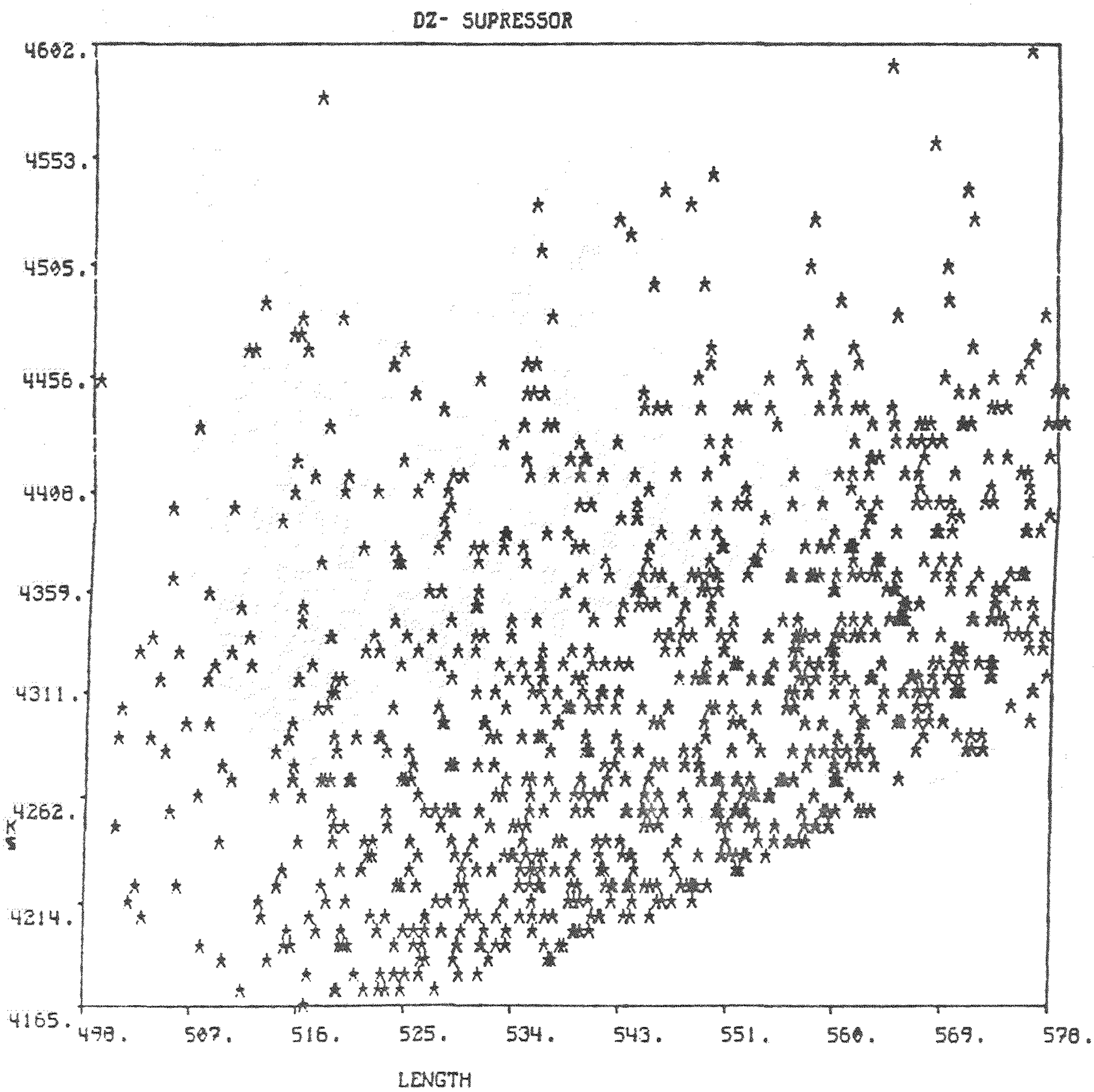
310.
332.
354.
377.
399.
421.
LENGTH

DZ- SUPRESSOR

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K$
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516.
525.
534.
543.
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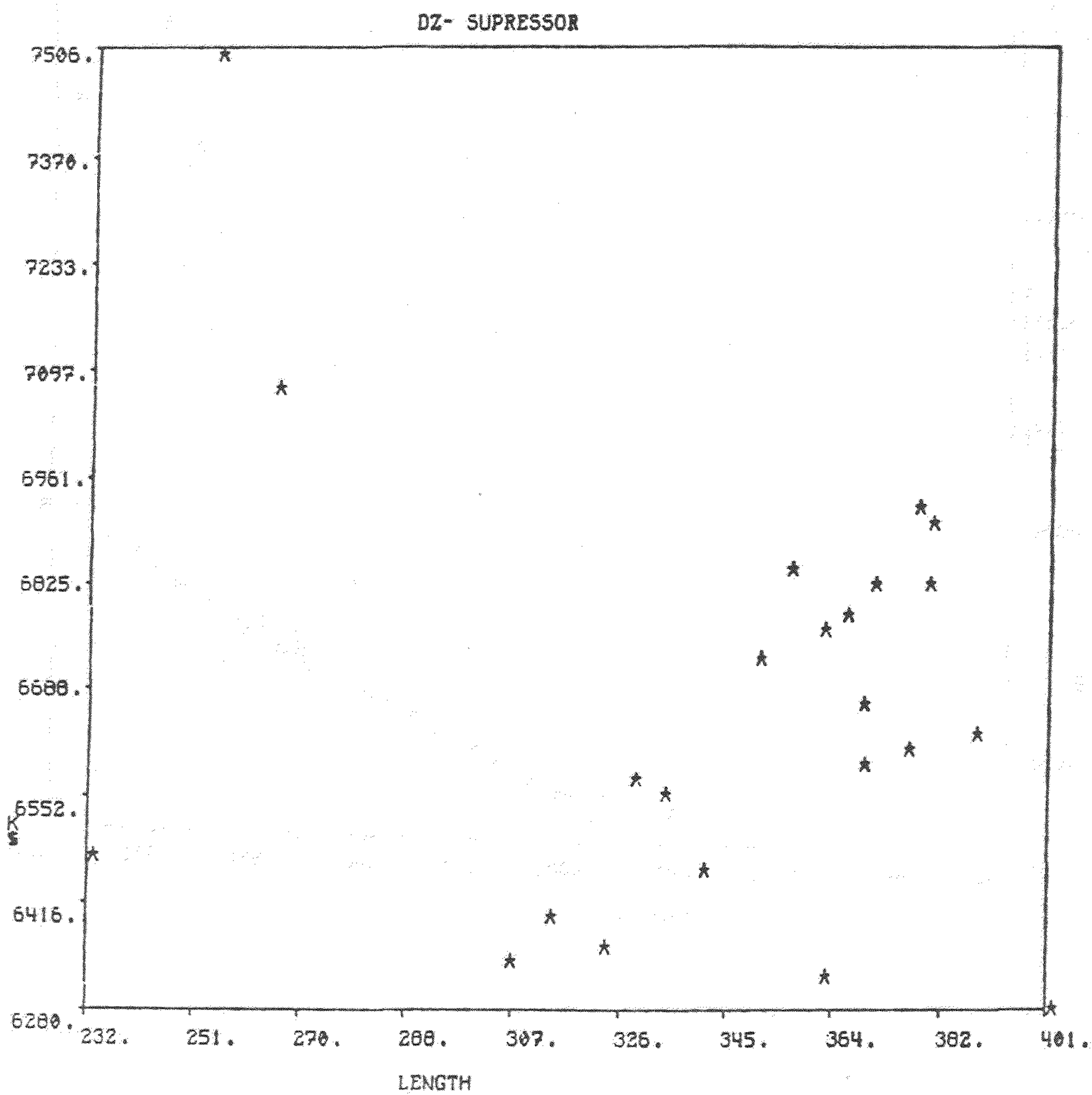
569.
578.
LENGTH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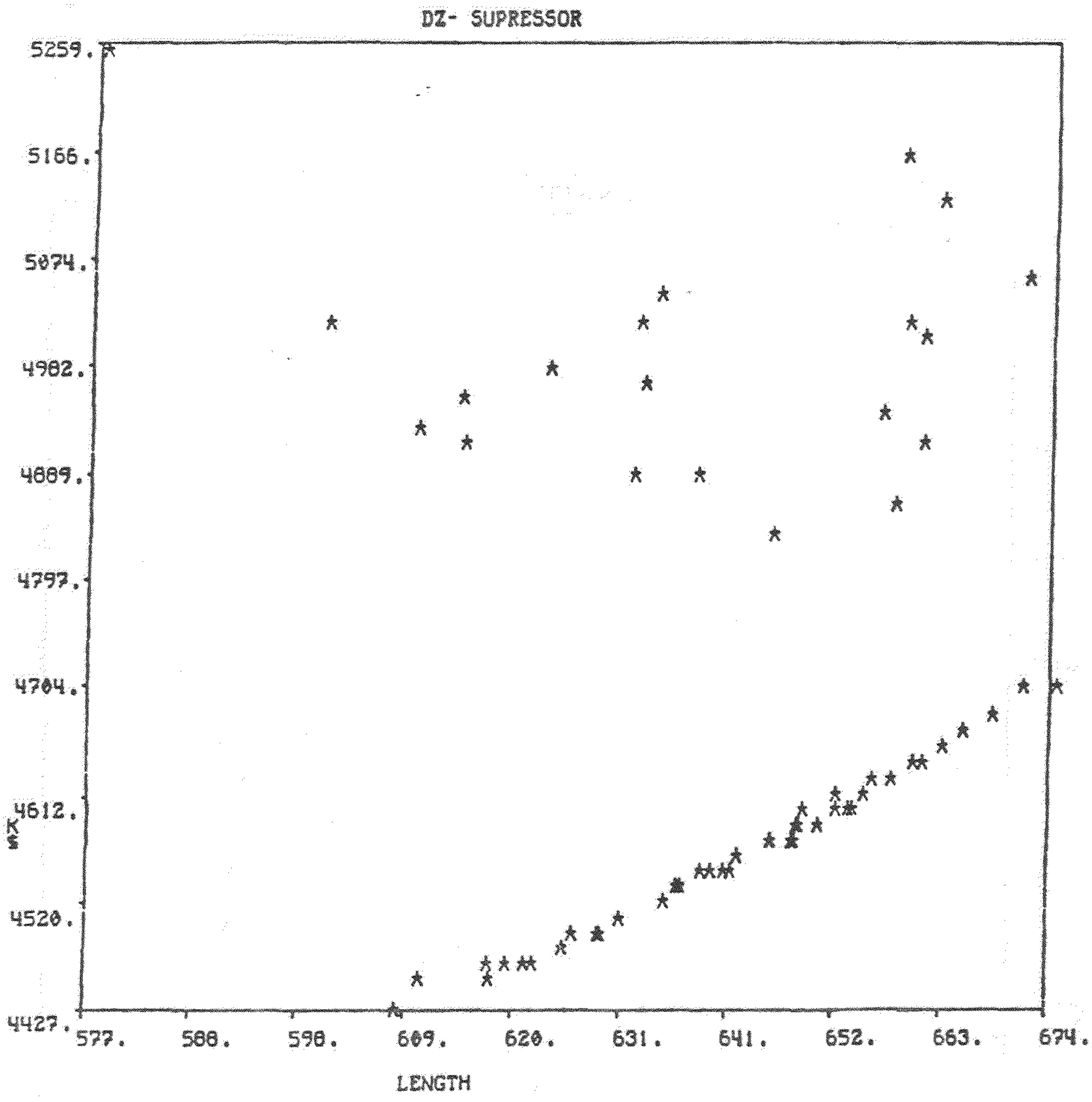
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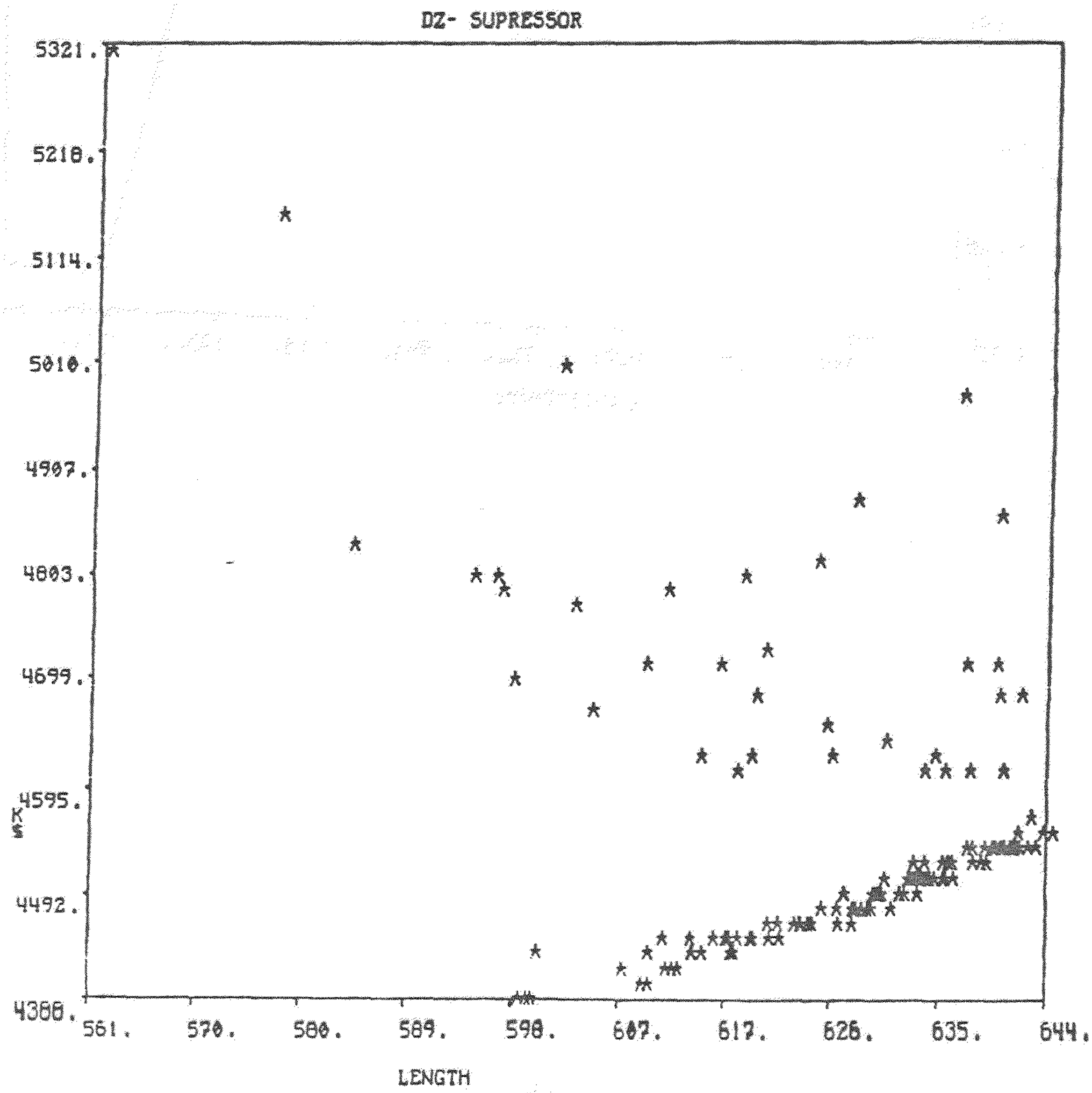
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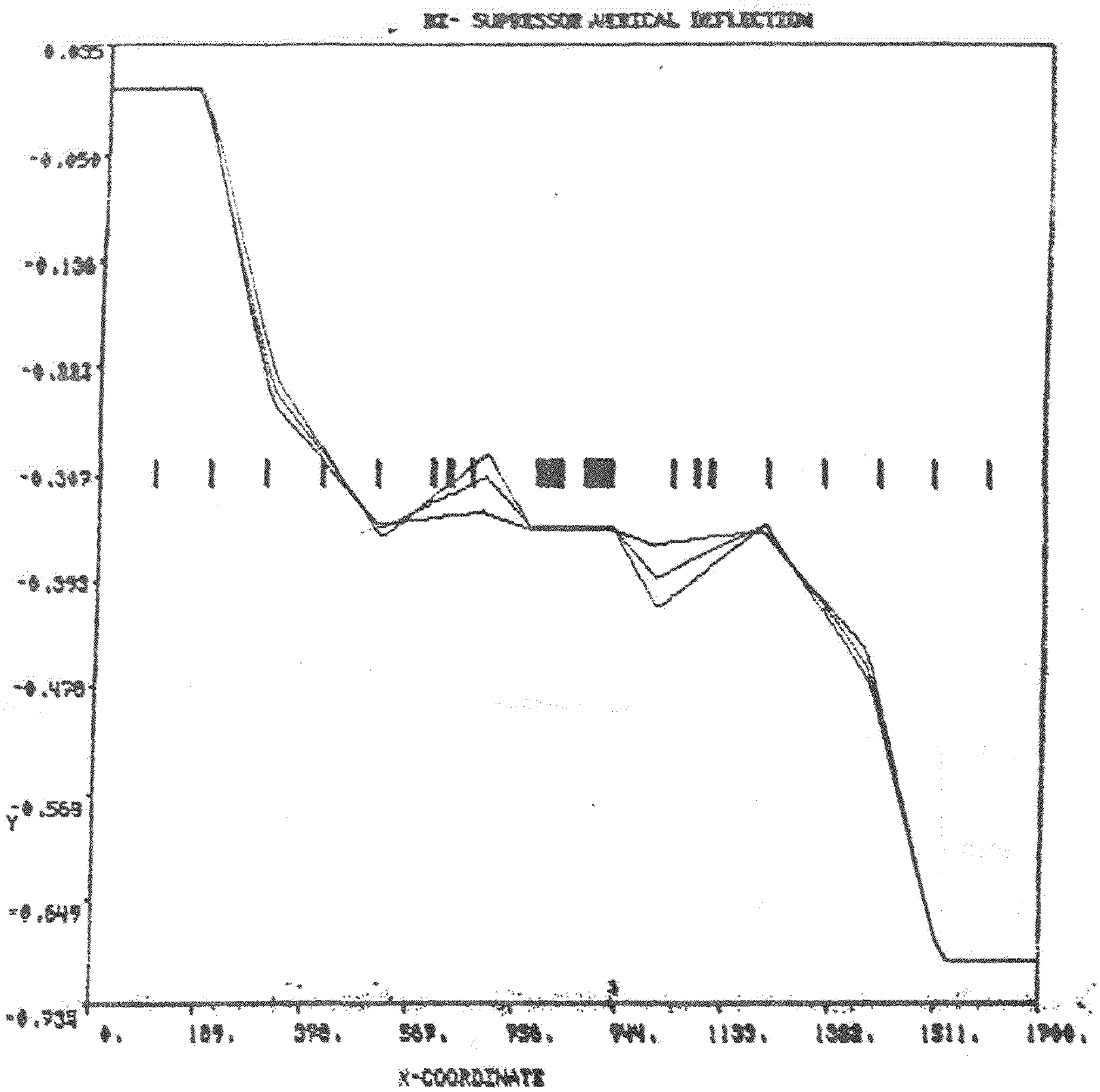
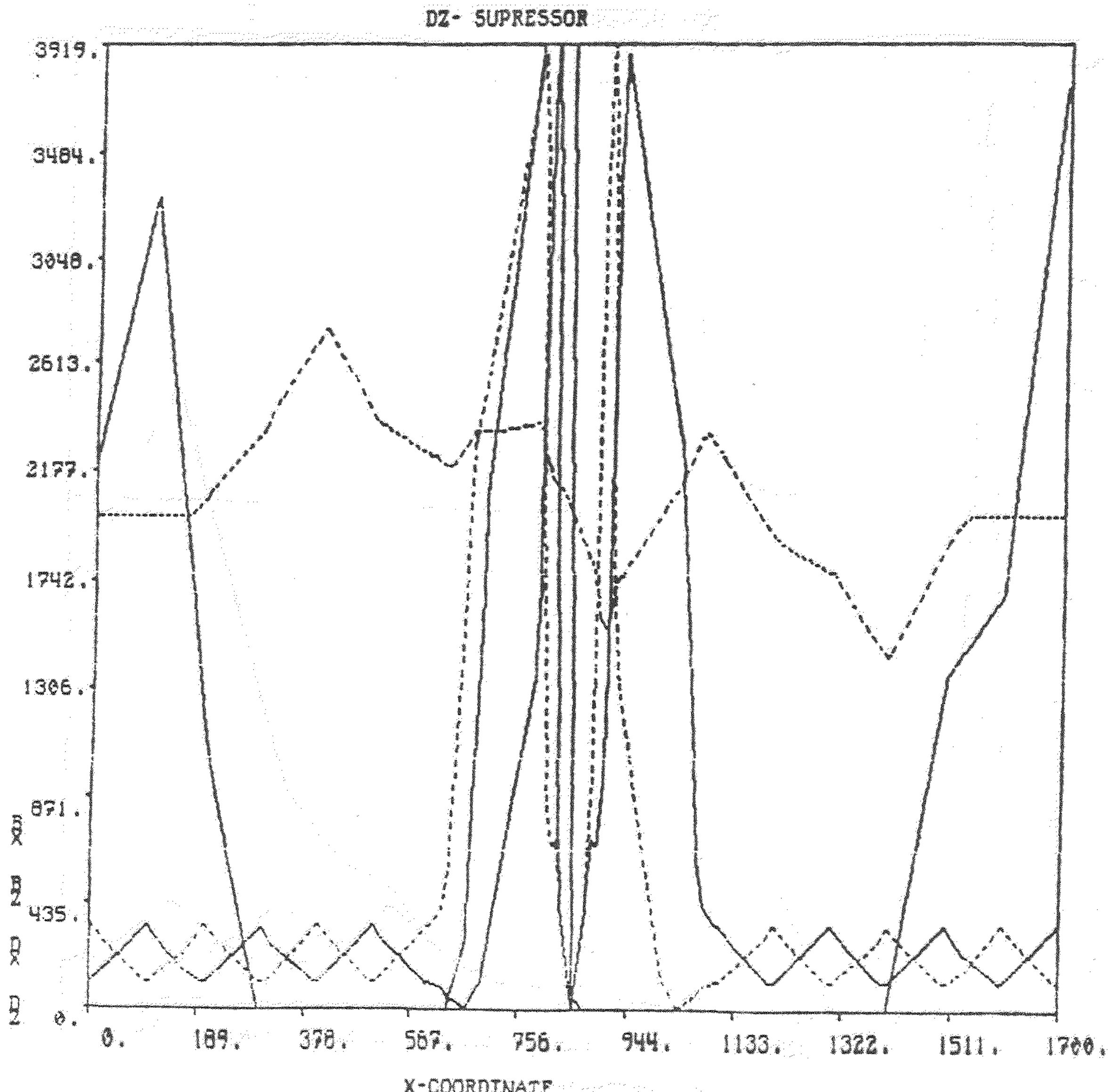

SUPRESSOR
X-COORDINATE
Y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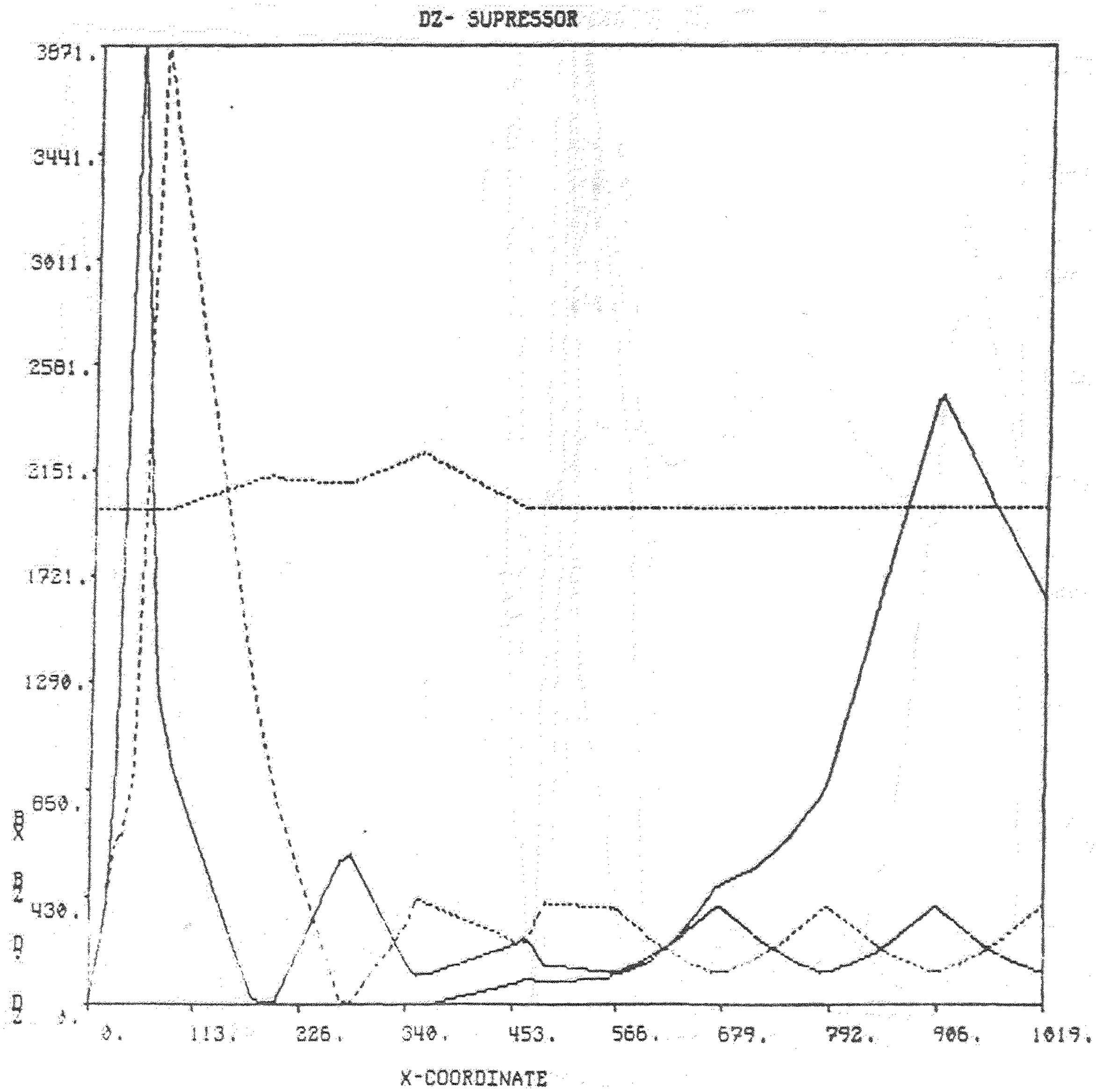
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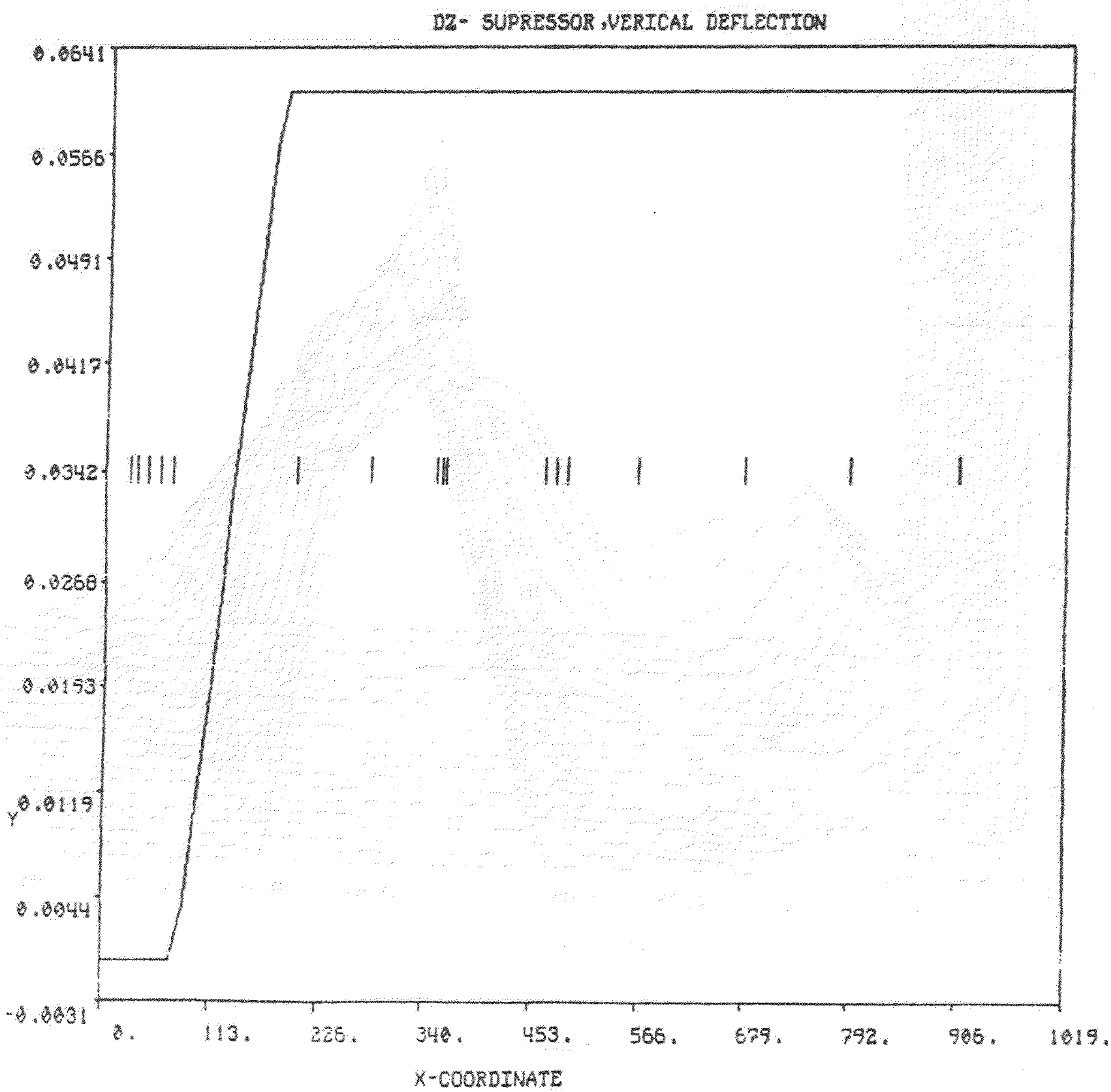
566.
679.
792.
906.
1019.
X-COORDINATE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0.0044
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Y
0.
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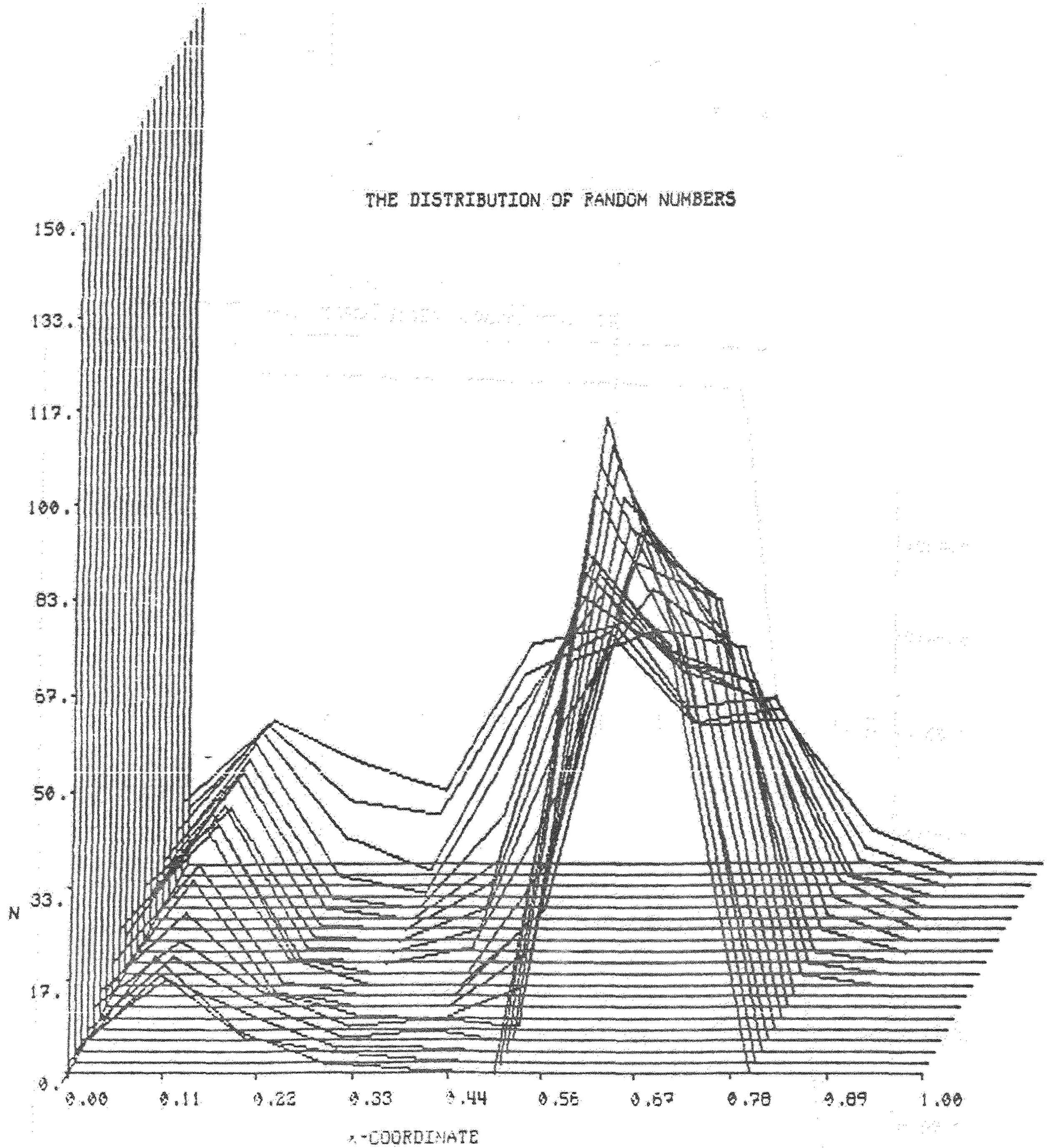
226.
340.
453.
566.
679.
792.
906.
1019.
X-COORDINATE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33.
N
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0.22
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0.44
0.56
0.67
0.78
0.89
1.00
X-COORDINATE

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PARA.LH = 100.
![illegible] LENGTH
PARA.LSLOT = [illegible].0
!QUAD LENGTH
PARA.LQ = 2.50
!SEXTUPOLE LENGTH
PARA.LS = 2.0

!VARIOUS DRIFT LENGTHS
!CELLS
PARA.LOOC = (LH-LSLOT)/2 - LQ
PARA.LOO = LOOC/2.
PARA.LOS = (LOOC - 2.0)/2.
!DISPERSION SUPPRESSORS
PARA.LOOO = LH - 3*LQ
!PHASE TROMBONE
PARA.LOOT = LOOO - 0.25
!LOW BETA
PARA.LTOT=156.7
PARA.LD34=106.21124
PARA.LD56=18.0

PARA,RHO = 11607.17

!QUAD LENGTHS FOR LOW BETA
PARA,LQ1 = 3.4
PARA,LQ2 = 5.45
PARA,LQ3 = 6.05
PARA,LQ4 = 2.9
PARA,LQ5 = 6.0
PARA,LQ6 = 4.0

!K1 FOR QUADS
!CELLS AND DISPERSION SUPPRESSORS
PARA.KF = 0.00203404516
PARA.KD = -0.00203416116
!PHASE TROMBONE
PARA.KAA = 0.0020446977
PARA.KBB = -0.0020497175
PARA.KCC = 0.0020390448
PARA.KDD = -0.0020404796
!LOW BETA
PARA.K1 = 0.0036406692
PARA,K2 = -0.0035998848
PARA.K3 = 0.003448184
PARA.K4 = 0.0018788141
PARA,K5 = -0.0021203336
PARA,K6 = -0.0011428766

!K2 FOR SEXTUPOLES
PARA.KSF = 0.004288533647?175
PARA.KSD [illegible]

!ANGLES FOR SEPARATOR BEND MAGNETS
PARA.ANGLE1 [illegible].15E-03
PARA.ANGLE2=0.214496E-03
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PARA.ANGLE1 (ANGLE1A2.34244 ANGLE2A2.801960 ANGLE3A1.6430908 1.  1055E 03)
PARA.ANGLE4=0.129794E-02
PARA.ANGLE5=0.179963E-02
!PARA.ANGLE5=-(ANGLE1+ANGLE2+ANGLE3+ANGLE4)
PARA.ANGLE6=0.0

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QFM: MARKER;        QDM: MARKER

QF1M: MARKER;       QD2M: MARKER;       QF3M: MARKER;       QF4M: MARKER
QD5M: MARKER;       QF6M: MARKER;       QD1M: MARKER;       QF2M: MARKER
QD3M: MARKER;       QD4M: MARKER;       QF5M: MARKER;       QD6M: MARKER

QFAM: MARKER;       AQDM: MARKER;       QDBM: MARKER;       BQFM: MARKER
QFCM: MARKER;       CQDM: MARKER;       DQFM: MARKER;       QDDM: MARKER

IPM: MARKER

!DRIFT SPACES
!CELLS
OO: DRIFT, L=LOO
OS: DRIFT, L=LOS
!DISPERSION SUPPRESSOR
OOO: DRIFT, L=LOOO
!PHASE TROMBONE
OOT: DRIFT, L=LOOT
OT: DRIFT, L=0.75
!LOW BETA
D: DRIFT, L=1.0
DO: DRIFT, L=20.0
D34: DRIFT, L=LD34
D56: DRIFT, L=LD56
D45: DRIFT, L=LTOT-LD34-LD56

DS1: DRIFT,L=0.5
DS2: DRIFT,L=79.6806
DS3: DRIFT,L=87.55
DS4: DRIFT,L=21.0304
DS5: DRIFT,L=13.750
DS6: DRIFT,L=77.25
DS7: DRIFT,L=2.5
DS8: DRIFT,L=60.00
DS9: DRIFT,L=94.750

!BEND
B: SBEND, L=LSLOT, ANGLE=LSLOT/RHO

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B2: SBEND,L=3.0,ANGLE=ANGLE2,K1=(ANGLE2/RHO)*(ANGLE2/RHO),TILT
B3: SBEND,L=6.7,ANGLE=ANGLE3,K1=(ANGLE3/RHO)*(ANGLE3/RHO),TILT
B4: SBEND,L=15.0,ANGLE=ANGLE4,K1=(ANGLE4/RHO)*(ANGLE4/RHO),TILT
B5: SBEND,L=21.0,ANGLE=ANGLE5,K1=(ANGLE5/RHO)*(ANGLE5/RHO),TILT
!B6: SBEND,L=18.0,ANGLE=ANGLE6,K1=(ANGLE6/RHO)*(ANGLE6/RHO),TILT

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B2R: SBEND,L=3.0,ANGLE=-ANGLE2,K1=(ANGLE2/RHO)*(ANGLE2/RHO),TILT
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B4R: SBEND,L=15.0,ANGLE=-ANGLE4,K1=(ANGLE4/RHO)*(ANGLE4/RHO),TILT
B5R: SBEND,L=21.0,ANGLE=-ANGLE5,K1=(ANGLE5/RHO)*(ANGLE5/RHO),TILT
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SD: SEXTUPOLE, L=LS, K2=KSD

!FODO CELLS
QF: QUADRUPOLE, L=LQ, K1=KF
QD: QUADRUPOLE, L=LQ, K1=KD

!PHASE TROMBONE
QFA: QUADRUPOLE, L=LQ, K1=KAA;      AQD: QUADRUPOLE, L=LQ, K1=-KAA
QDB: QUADRUPOLE, L=LQ, K1=KBB;      BQF: QUADRUPOLE, L=LQ, K1=-KBB
QFC: QUADRUPOLE, L=LQ, K1=KCC;      CQD: QUADRUPOLE, L=LQ, K1=-KCC
QDD: QUADRUPOLE, L=LQ, K1=KDD;      DQF: QUADRUPOLE, L=LQ, K1=-KDD

!LOW BETA QUADS
QF1: QUADRUPOLE, L=LQ1, K1=K1;      QD1: QUADRUPOLE, L=LQ1, K1=-K1
QD2: QUADRUPOLE, L=LQ2, K1=K2;      QF2: QUADRUPOLE, L=LQ2, K1=-K2
QF3: QUADRUPOLE, L=LQ3, K1=K3;      QD3: QUADRUPOLE, L=LQ3, K1=-K3
QF4: QUADRUPOLE, L=LQ4, K1=K4;      QD4: QUADRUPOLE, L=LQ4, K1=-K4
QD5: QUADRUPOLE, L=LQ5, K1=K5;      QF5: QUADRUPOLE, L=LQ5, K1=-K5
QF6: QUADRUPOLE, L=LQ6, K1=K6;      QD6: QUADRUPOLE, L=LQ6, K1=-K6

!BEAMLINES FOR CELLS
FD: LINE=(QFM, QF, OO, OO, B, OO, OO, QD)
DF: LINE=(QDM, QD, OO, OO, B, OO, OO, QF)
DFSTAR: LINE=(QDM, QD, OS, SD, OS, B, OS, SF, OS, QF)
C: LINE=(FD, DFSTAR)
!ARC: LINE=(DF, FD, DF, 66*C, FD, DF, FD, DF)


!DISPERSION SUPPRESSOR
FDO: LINE=(QFM, QF, OOO, QD)
DFO: LINE=(QDM, QD, OOO, QF)
DSO: LINE=(FDO, DFO, FD, DF)
DSI: LINE=(DF, FD, DFO, FDO)

!SUPRESSOR
SPR1: LINE=(DS1,B1,DS2,B2,DS4)
!SPR2: LINE=(DS1,B3,DS1,B4,DS4)
SPR3: LINE=(DS3,B3,DS1)
SPR4: LINE=(DS6,B4,DS7)
SPR5: LINE=(DS5,B5,DS8)
SPR1R: LINE=(DS1,B1R,DS2,B2R,DS4)
!SPR2R: LINE=(DS1,B3R,DS1,B4R,DS4)
SPR3R: LINE=(DS3,B3R,DS1)
SPR4R: LINE=(DS6,B4R,DS7)
SPR5R: LINE=(DS5,B5R,DS8)

!PHASE TROMBONE
TFH: LINE=(OT, QFAM, QFA, OOT, QDB, QDBM, QDB, -SPR5R, QFC, QFCM, &
          QFC, OOT, QDD, QDDM)
TFHS: LINE=(OT, QFAM, QFA, SPR3R, QDB, QDBM, QDB, DS9, QFC, QFCM, &
          QFC, SPR4R, QDD, QDDM)
[illegible]: LINE=(OT, AQDM, AQD, OOT, [illegible] &
          CQD, OOT, DQF, DQFM)
TDHS: LINE=(OT, AQDM, AQD, SPR3, BQF, BQFM, BQF, DS9, CQD, CQDM, &
          CQD, SPR4, DQF, DQFM)
TRBF: LINE=(TFH, -TFHS)
```

```
TRPO: LINE=(IPM, DO, 2*(QF1, QF1M, QF1, D), 2*(QD2, QD2M, QD2, D),   &
            QF3, QF3M, QF3)
TRPI: LINE=(IPM, DO, 2*(QD1, QD1M, QD1, D), 2*(QF2, QF2M, QF2, D),   &
            QD3, QD3M, QD3)
SSO: LINE=(QF4, QF4M, QF4, D45, QD5, QD5M, QD5, D56, QF6, QF6M)
SSI: LINE=(QD4, QD4M, QD4, D45, QF5, QF5M, QF5, D56, QD6, QD6M)
INSO: LINE=(-SSO, -SPR1R, -TRPO)
INSI: LINE=(-SSI, -SPR1, -TRPI)

!SUPERPERIOD
!SP: LINE=(-INSI, TRBD, DSI, ARC, DSO, TRBF, INSO)
SP: LINE=(TRBF,INSO,-INSI,TRBD)
LINE: LINE=(FD,DF)
!MATCH,SP,BETX=115.936,BETZ=344.984,DX=2.204
!VARY,ANGLE3,STEP=0.1E-02,LOWER=-0.2E-01,UPPER=0.2E-01
!CONSTRAINE,#E,DZ=0,DZ'=0
!LEVEL,1
!SIMPLEX,CALLS=24000,TOLERAN=1.0E-09
!ENDMATCH
USE,SP
PRINT,SP
TWISS,BETX=115.936,BETZ=344.984,DX=2.204   !LINE=LINE
USE,SP
PRINT,SP
SURVEY
STOP
```

```
!TITLE
[illegible] RACETRACK LATTICE 110M.60 DEGREE,REF.DES.LBTR

!DRIFT
DRIFT.DRSFW,L=98.1814
DRIFT,DRM1.L=65.0646
DRIFT.DRM2.L=68.0689
DRIFT.DRLBO.L=20.0
DRIFT.DRLB,L=1.0
DRIFT.DRS1.L=0.5*(LBEND*(1-LS1)*SM+DRCO[L]+LSEXT)
DRIFT.DRS2,L=0.5*(LBEND*(1-LS2)*SM+DRCO[L]+LSEXT)
DRIFT,DRB1,L=LNG2
DRIFT,DRB2,L=LH
DRIFT.DRSM1,L=0.5
DRIFT,DRSM2,L=2.24112
DRIFT.DRSM3.L=72.0472

!QUADRUPOLES

QUAD.QSK1.L=LM.K1=0.205954E-02.TILT
QUAD.QSK2.L=LM,K1=0.200088E-02

QUAD.QFH,L=LM/2,K1=-FOC
QUAD,QDH,L=LM/2,K1=FOC
QUAD.QF,L=LM,K1=-FOC
QUAD,QD,L=LM,K1=FOC

QUAD.QM1,L=7.47577,K1=0.101692E-02
QUAD.QM2,L=10.0,K1=-0.2E-02
QUAD.QM3,L=10.0,K1=0.287507E-03

QUAD,QSM1,L=11.3392,K1=-0.200262E-02
QUAD.QSM2,L=9.25029.K1=0.197259E-02

QUAD.QDLB1R,L=LBD1,K1=0.3673E-02
QUAD.QFLBR,L=LBF,K1=-0.3658E-02
QUAD,QDLB2R.L=LBD2.K1=0.3617E-02

!MAGNETS

SBEND.BDS1,L=LBEND*LS1,ANGLE=LS1*LBEND/RADIUS,HGAP=0.0125
SBEND.BDS2,L=LBEND*LS2,ANGLE=LS2*LBEND/RADIUS,HGAP=0.0125
SBEND.BDD.L=LNG,ANGLE=LNG/RADIUS.HGAP=0.0125,TILT
SBEND.BDU.L=LNG.ANGLE=-LNG/RADIUS.HGAP=0.0125,TILT

!MARKER

MARKER.M

!PARAMETER
PARAMETE.N=651
PARAMETE.PI=3.1415926559
PARAMETE.SM=3
PARAMETE.LBEND=[illegible].0
PARAMETE.[illegible]376[illegible]
PARAMETE.[illegible].7736
PARAMETE.LS1=0.0993873
PARAMETE.LS2=0.963085
PARAMETE.RADIUS=SM*(N+12*(LS1+[illegible]))*LBEND/PI
PARAMETE.LBD1=12.]
```

```
[illegible]
PARAMETE.LBPS=6.8
PARAMETE.LSEXT=1.0
PARAMETE.LU=0.5*(LSEXT+DRCOLL1)
PARAMETE.LQ=LBEND*SM+LSEXT+DRCOLL1
PARAMETE.LNG=13.5
PARAMETE.LH=0.0619125*RADIUS/LNG-LNG
PARAMETE.LNG2=0.5*(120.0-LH-2*LNG)

!LINES

LINE,BEND1=(BDS1,BDS1,BDS1)
LINE.BEND2=(BDS2,BDS2,BDS2)
LINE.DSUPR=(QDH,DRS1,BEND1,DRS1,QF,DRS1,BEND1,DRS1,QD,&
            DRS2,BEND2,DRS2,QF,DRS2.BEND2,DRS2.QDH)
LINE.LBTR=(QDLB1R,DRLB,QFLBR,DRLB,QFLBR.DRLB,QDLB2R,DRLB,QDLB2R.DRLBO)
LINE.SEPAR=(DRB1,BDD,DRB2,BDU,DRB1)
LINE.MATCH=(QM1,DRM1.QM2.DRM2,QM3)
LINE.SKEW=(QSK2,QSK1,DRSKW.QSK1)
LINE.MATCH1=(DRSM1,QSM1.DRSM2:QSM2,DRSM3)
LINE.INS=(-1*(LBTR),SEPAR.-1*(MATCH),SKEW.MATCH1,-1*(DSUPR))
 USE.INS
!PRINT.INS
!TWISS.BETX=1.0.BETZ=1.0
USE.INS
PRINT.INS
SURVEY
STOP
```