SSC-N-203

Tracking Study of Coupling for the SSC CDR Clustered Lattice

G. F. Dell

7/3/86

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TRACKING STUDY OF COUPLING FOR THE SSC CDR CLUSTERED LATTICE.

G.F. DELL

TRACKING HAS BEEN PERFORMED ON THE SSC STORAGE LATTICE HAVING TWO INSERTIONS WITH $\beta^* = 0.5$ m AND TWO INSERTIONS WITH $\beta^* = 10$ m. TWO TUNES WERE CONSIDERED: OFF-DIAGONAL WITH $\nu_x = 78.265$, $\nu_y = 78.283$ AND ON-DIAGONAL WITH $\nu_x = 78.265$, $\nu_y = 78.265$.

MAGNET MULTIPOLES:

1. NO SYSTEMATICS
2. $\sigma a_1 = \sigma b_1 = 0.0$
3. $(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 5$ QUADS
4. $(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 10$ DIPOLES
5. ASSUMED 90% CORRECTION OF MULTIPOLES IN TRIPLETS Q1-Q3.

CONDITIONS:

1. CHROMATICITY = 0 IN BOTH PLANES
2. $\Delta P/P = 0.0\%$
3. DYNAMIC APERTURE
4. RANDOM NUMBER SEED #1

INITIAL CONDITIONS : 1. $\epsilon_x = \epsilon_y$, $(X, Y) \neq 0$ UNLESS NOTED
2. $\epsilon_x = \epsilon_y$ $X = (\epsilon_x \beta_x)^{1/2}$, $Y' = (\epsilon_y / \beta_y)^{1/2}$

PURPOSE:

1. TO SHOW EXCHANGE OF EMITTANCE IS PRONOUNCED FOR ON DIAGONAL TUNES. FIG. 3
2. TO SHOW INITIAL CONDITIONS CHANGE SENSE OF COUPLING - ie ϵ_x GROWS OR DECREASES FIG. 3 + FIG 6
3. TO SHOW COUPLING PRESERVES $\epsilon_x + \epsilon_y \sim$ CONST FOR RUNS OF 400, 1000, AND 4000 TURNS. FIGS. 3-5.
4. TO STUDY EFFECT OF REMOVING MULTIPOLES ON MAGNITUDE OF COUPLING.
   a). FIG 7 $(\sigma a_2, \sigma b_2) = 0$
   b). FIG 8 $(\sigma a_2, \sigma b_2) = (\sigma a_3, \sigma b_3) = 0$
   c). FIG 9. $(\sigma a_3, \sigma b_3) = 0$
   d). $\sigma a_n = \sigma b_n = 0$ $1 \leq n \leq 4$ (FIG 10)
   e). $\sigma a_n = \sigma b_n = 0$ $1 \leq n \leq 5$ (FIG 11)
   f). FIG 12. NO RANDOM MULTIPOLES.
   g). FIG 13. NO RANDOM MULTIPOLES, SF = SD = 0.0
   h). FIG 14 NO RANDOM MULTIPOLES IN QUADS; DIPOLES HAVE $(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 10$. STILL HAVE PRONOUNCED COUPLING.
   i). FIG. 15 NO RANDOM MULTIPOLES IN DIPOLES. QUADS HAVE $(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 5$. STILL HAVE PRONOUNCED COUPLING, BUT ϵ_x DECREASE AND ϵ_y INCREASES.

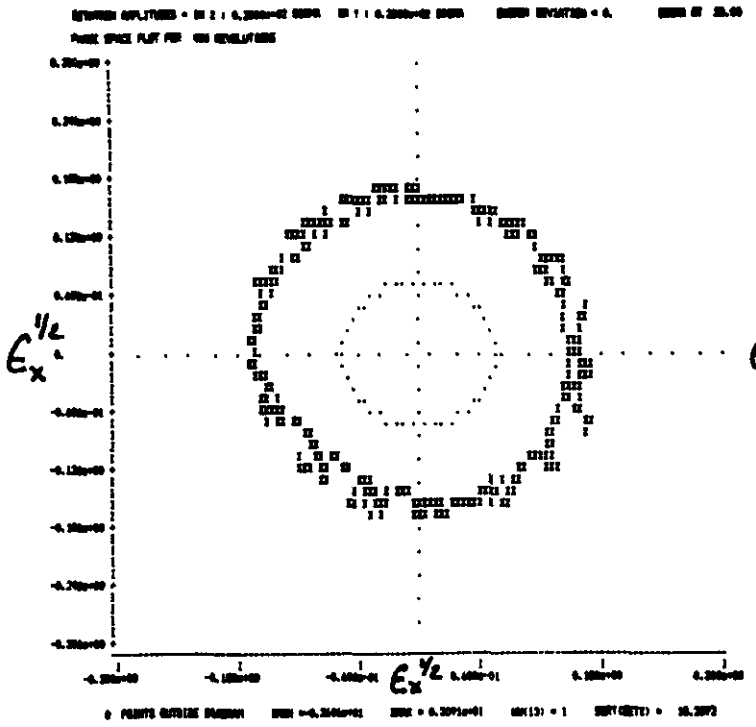
SMEAR: IN ALL CASES THE SMEAR AS DEFINED BY DON EDWARDS APPEARS AS I_{rms} ON THE SMEAR PLOTS. VALUES ARE LISTED BY HAND ON EACH FIGURE.

$$W_z = \epsilon_z = \frac{z^2 + (\alpha_z z + \beta_z z')^2}{\beta_z} \quad \text{WITH } z = x \text{ OR } y.$$

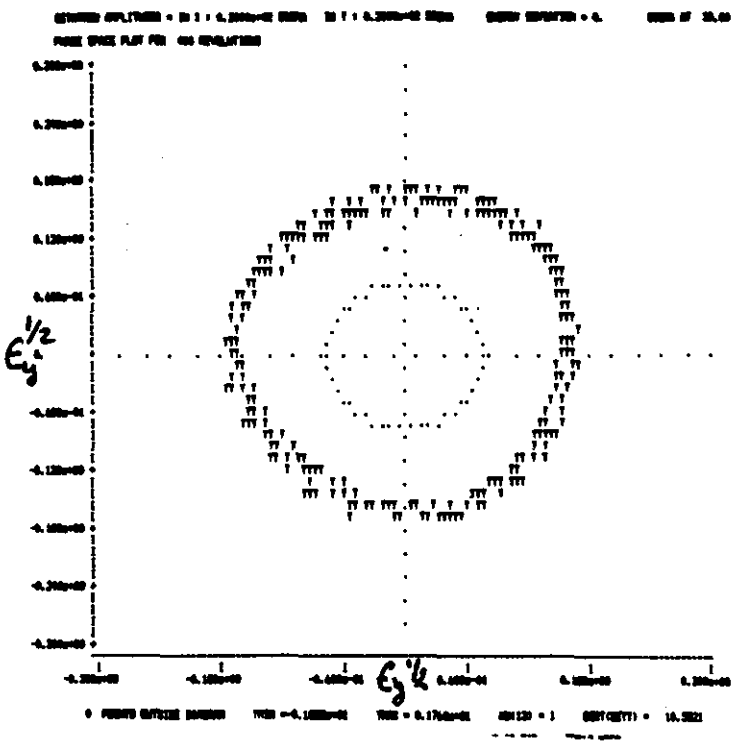
$$P_z = \text{SQRT}(W_z)$$

$$P_{z_{rms}} = \left[\frac{\sum_{i=1}^{NTURN} (P_{z_i} - \bar{P}_z)^2}{NTURNS} \right]^{1/2}$$

$$I_{rms} = \text{SMEAR} = \left[\frac{P_{x_{rms}}^2 + P_{y_{rms}}^2}{\bar{P}_x^2 + \bar{P}_y^2} \right]^{1/2}$$

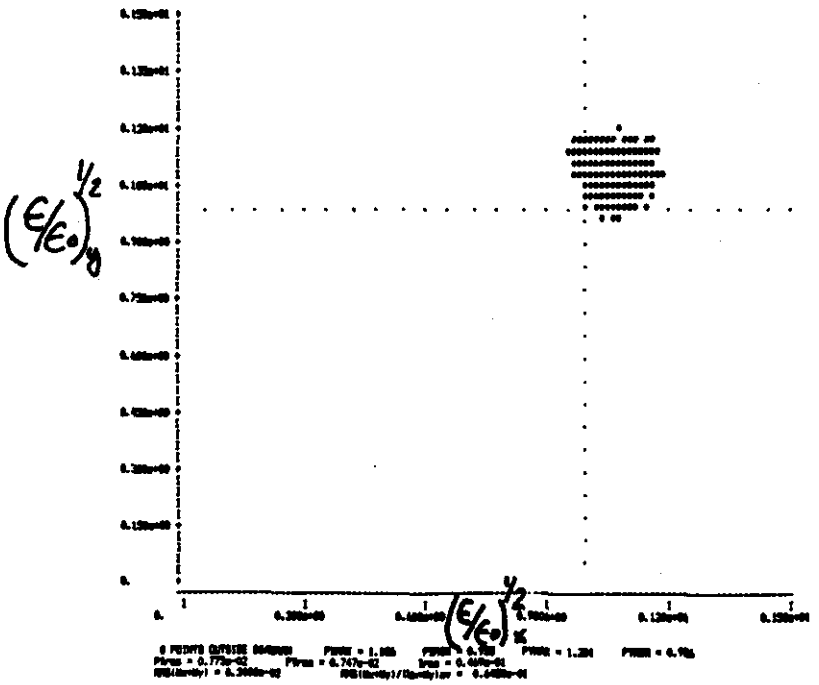


X PLANE



Y PLANE

FIG. 1



$\nu_x = 78.265$ $\nu_y = 78.283$

INITIAL CONDITIONS: $(x, y) \neq 0$, $\Delta p/p = 0$

$x_i^{\phi F} = 2.73$ mm $y_i^{\phi F} = 1.57$ mm

CHROMATICITY: CHX = CHY = 0.0

(INCLUDING EFFECTS OF σb_2)

MULTIPOLES INCLUDED IN INSERTION

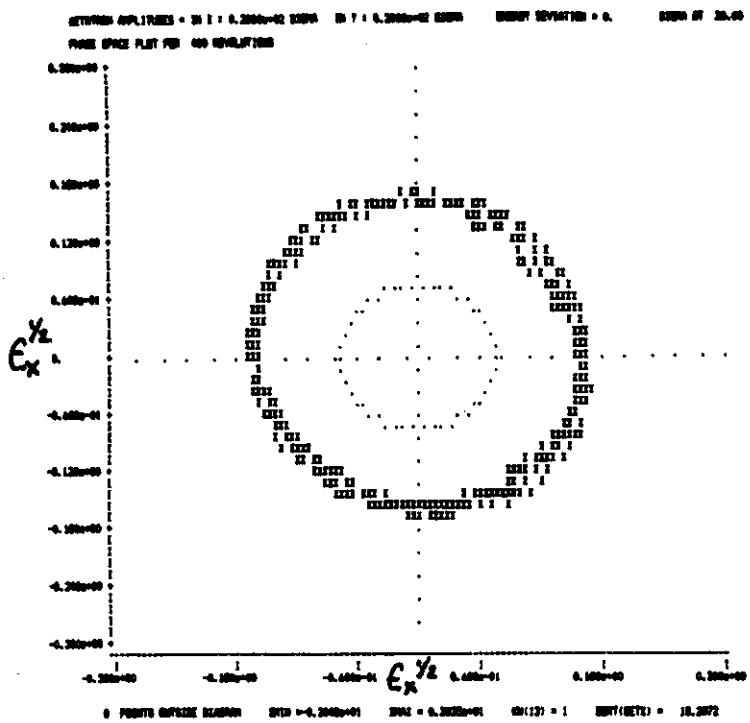
NO SYSTEMATIC MULTIPOLES.

$(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 5$ QUADS

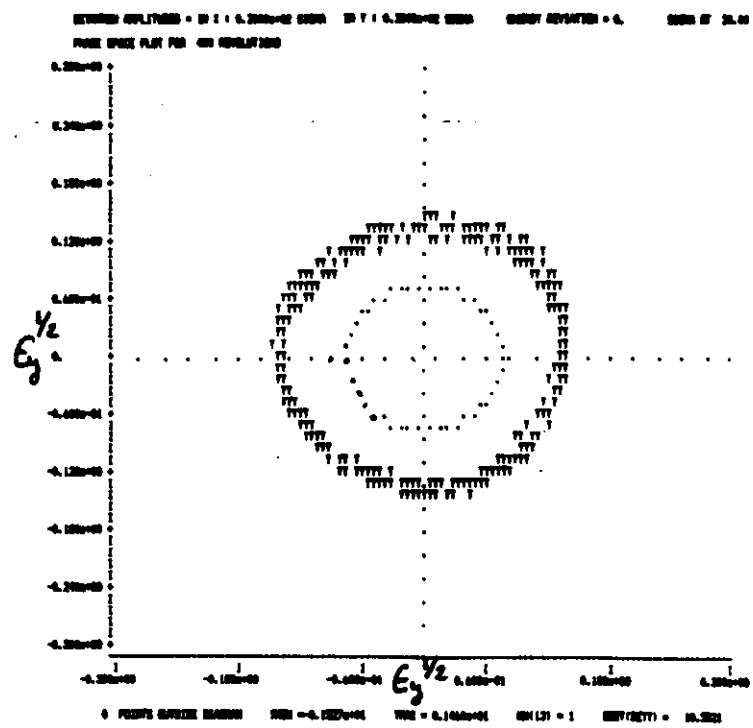
$(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 10$ DIPOLES

SMEAR (EDWARDS) = $4.7 \cdot 10^{-2}$

COMMENTS: 90% CORRECTION OF MULTIPOLES IN Q1-Q3. LITTLE COUPLING NEAR DYNAMIC APERTURE.

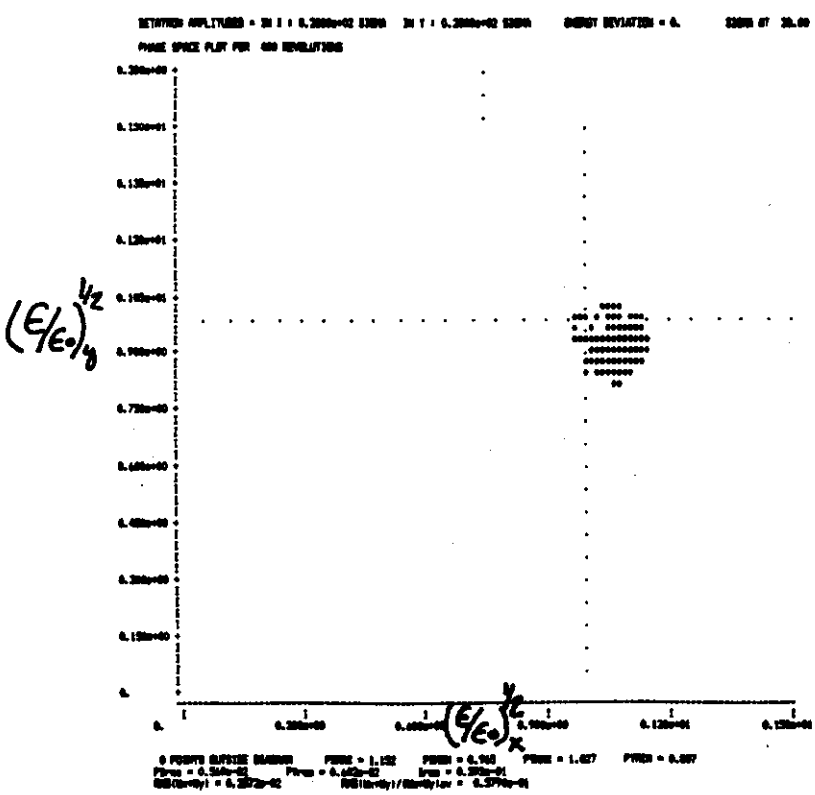


X PLANE



Y PLANE

FIG. 2



$\nu_x = 78.265$ $\nu_y = 78.283$

INITIAL CONDITIONS: $(X, Y') \neq 0$, $\Delta p/p = 0.0$

$X_i^{QF} = 2.73$ mm $y_i^{QF} = 1.57$ mm.

CHROMATICITY: CHX=CHY=0.0

(INCLUDING EFFECTS OF σb_2).

MULTIPOLES INCLUDED IN INSERTION

NO SYSTEMATIC MULTIPOLES.

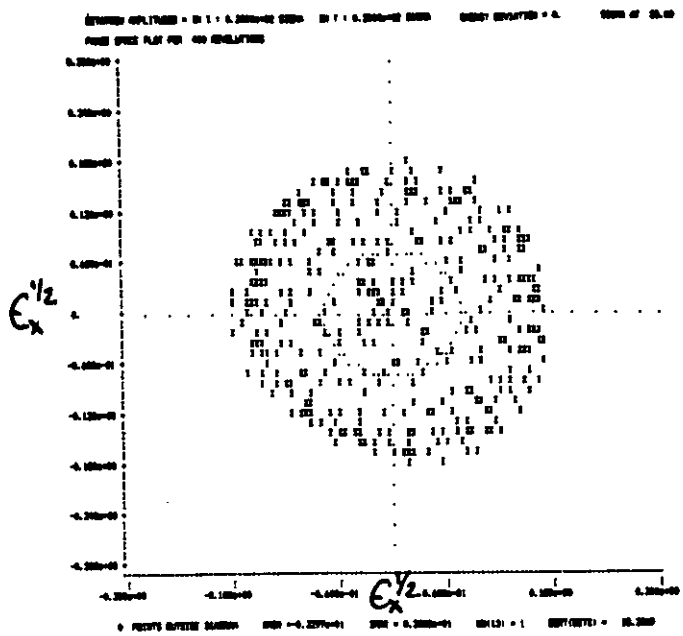
$(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 5$ QUADS.

$(\sigma a_n, \sigma b_n) \neq 0$ $2 \leq n \leq 10$ DIPOLES.

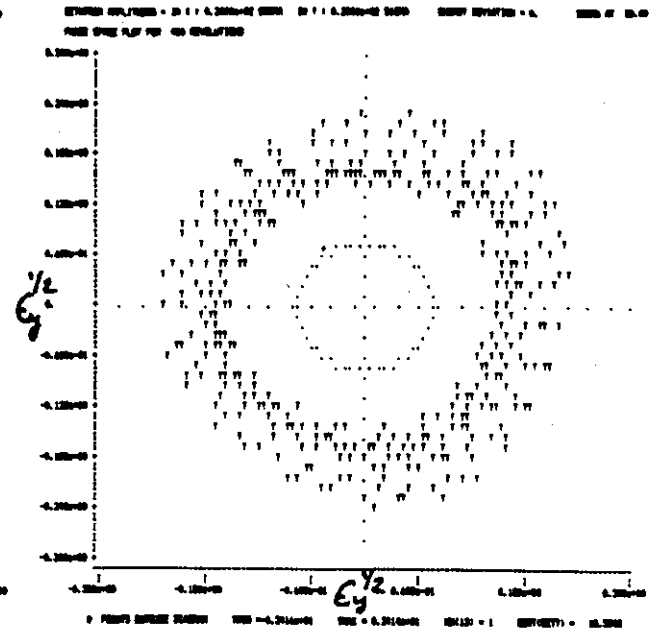
SMEAR(EDWARDS) = $3.9 \cdot 10^{-2}$

COMMENTS: 90% CORRECTION OF MULTIPOLES IN Q1-Q3.

$\Delta \epsilon_y < 0$ FOR $(X, Y') \neq 0$ INITIAL CONDITIONS.



X PLANE



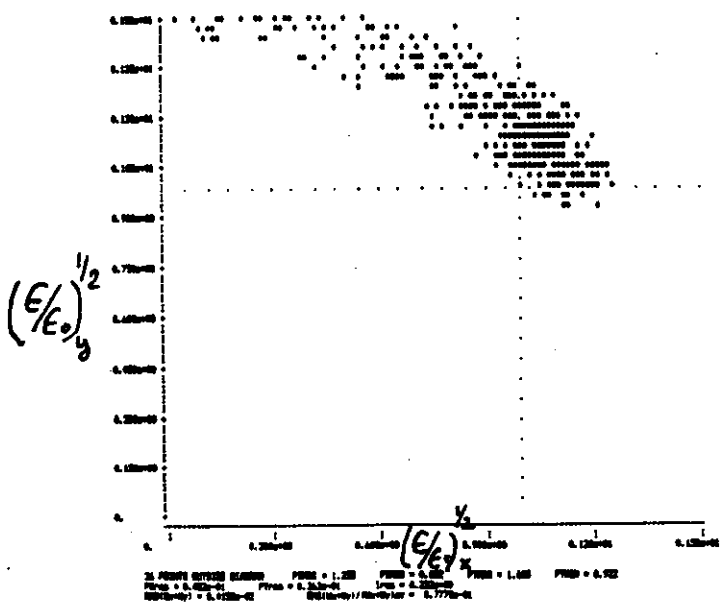
Y PLANE

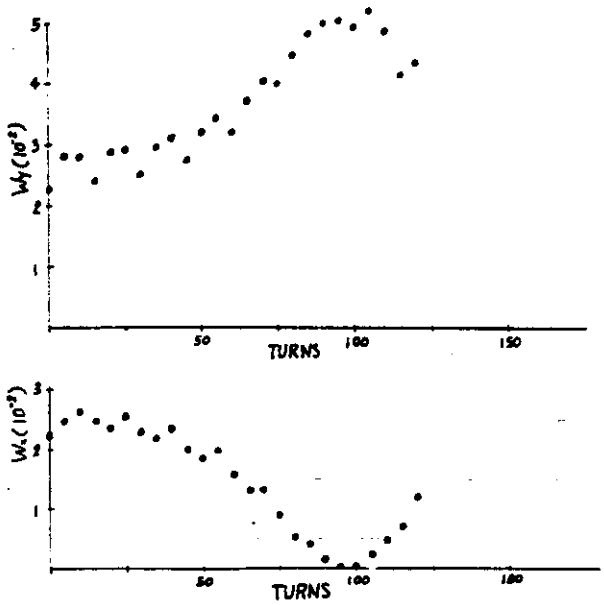
$\nu_x = 78.265$, $\nu_y = 78.265$ $\quad X_i^{QF} = 2.73\,mm$ $\quad Y_i^{QF} = 1.57\,mm$

$(\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 5$ QUADS

$(\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 10$ DIPOLES.

400 TURNS $\quad \Delta p/p = 0$





PRONOUNCED COUPLING

SMEAR (EDWARDS) = 0.232

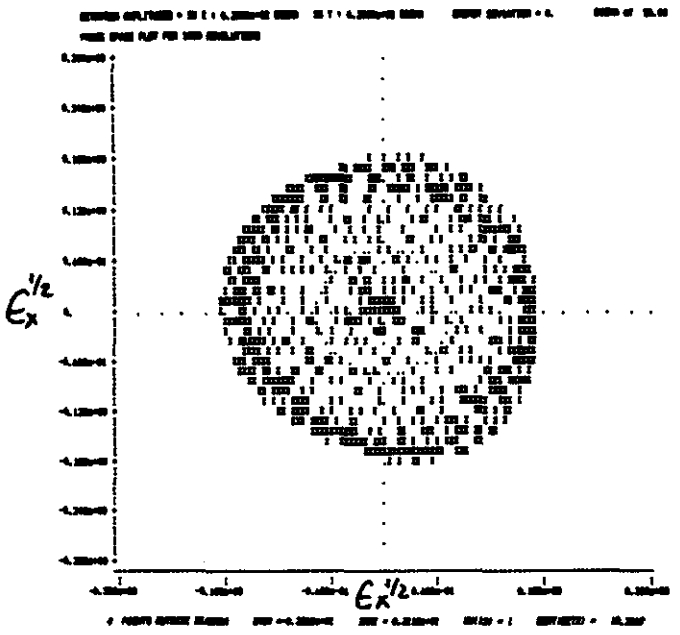
ϵ_x DECREASES

ϵ_y INCREASES

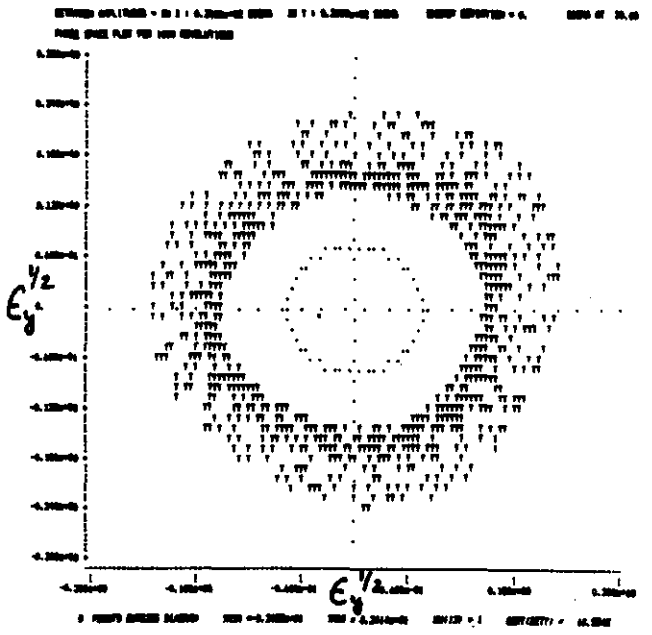
$-3.297\,mm \leq X \leq 3.088\,mm$

$-2.416\,mm \leq Y \leq 2.414\,mm$

FIG. 3



X PLANE

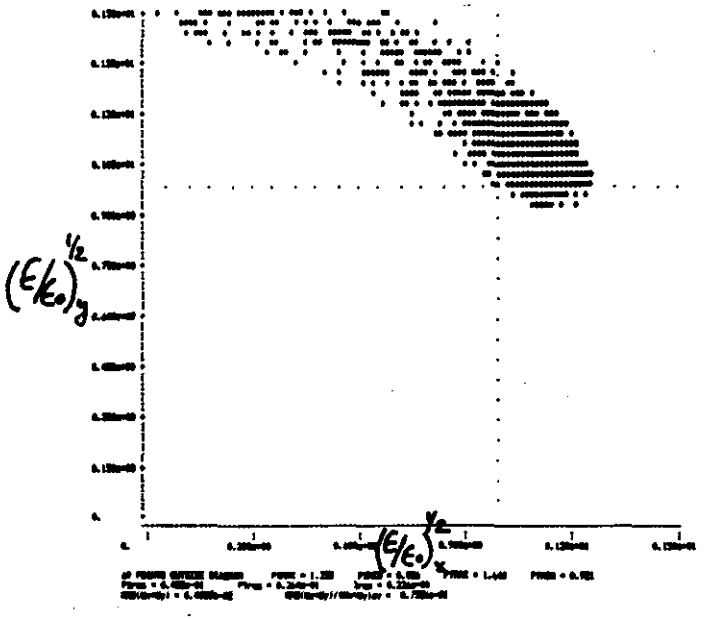


Y PLANE

$\nu_x = 78.265$, $\nu_y = 78.265$ $\quad X_i^{QF} = 2.73\,mm$ $\quad Y_i^{QF} = 1.57\,mm$

$(\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 5$ (QUADS) $\quad (\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 10$ DIPOLES.

1000 TURNS. $\Delta p/p = 0$



$-3.368 \leq X(mm) \leq 3.118$

$-2.435 \leq Y(mm) \leq 2.414$

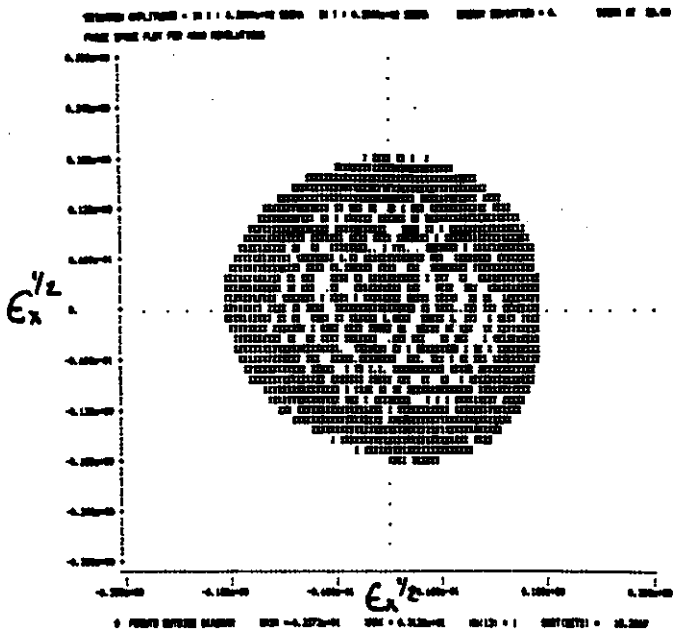
PRONOUNCED COUPLING.

ϵ_x DECREASES

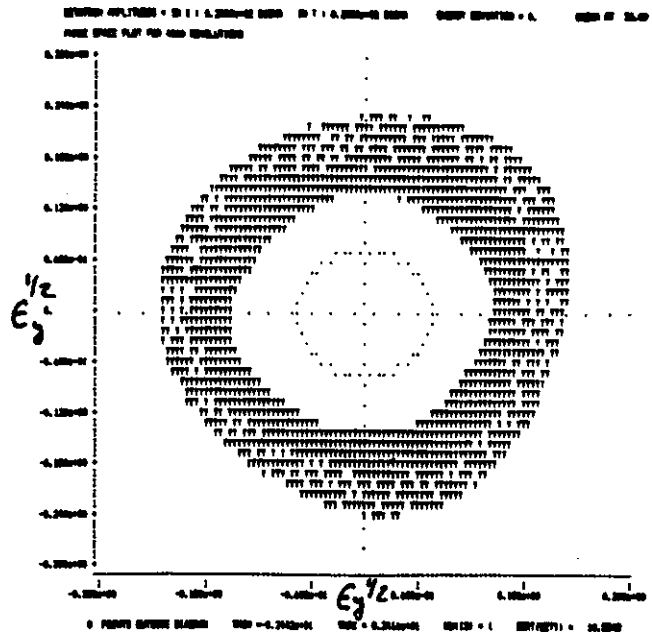
ϵ_y INCREASES

SMEAR (EDWARDS) = 0.226

FIG. 4



X PLANE

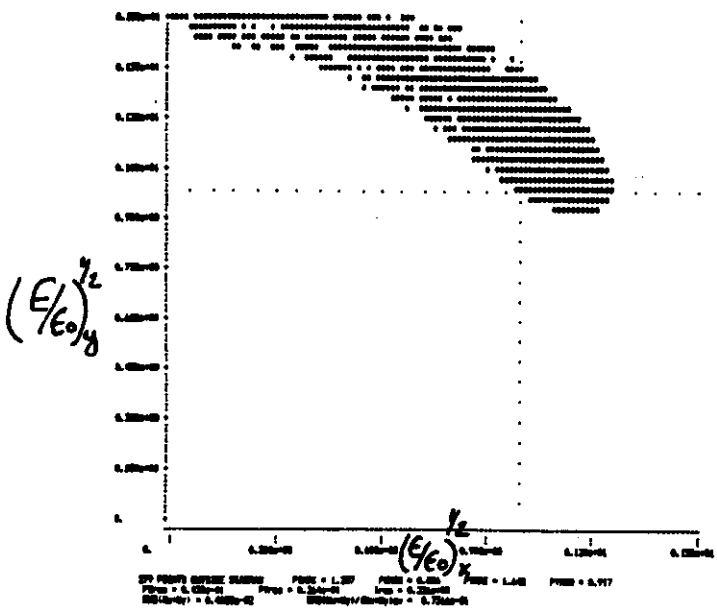


Y PLANE

$\nu_x = 78.265$, $\nu_y = 78.265$ $\quad X_i^{\phi F} = 2.73$ mm $\quad Y_i^{\phi F} = 1.57$ mm

$(\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 5$ (QUADS) $\quad (\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 10$ DIPOLES.

4000 TURNS $\Delta p/p = 0$



$-3.373 \leq X(mm) \leq 3.120$

$-2.442 \leq Y(mm) \leq 2.416$

PRONOUNCED COUPLING.

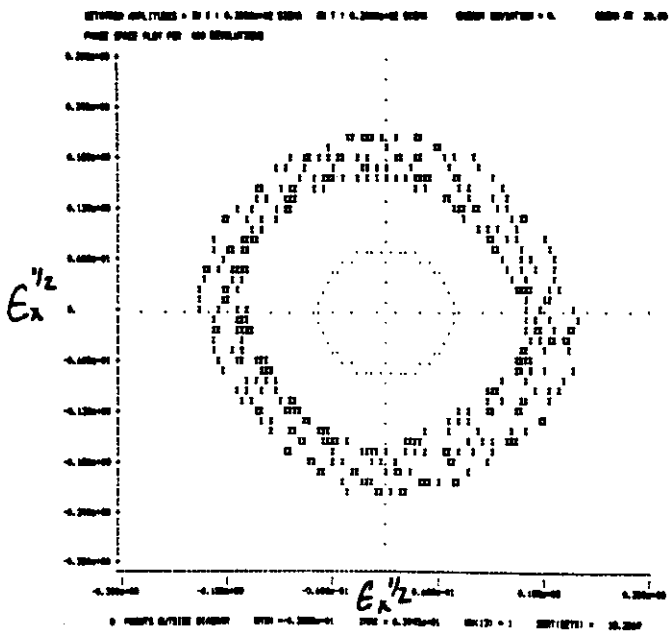
ϵ_x DECREASES

ϵ_y INCREASES.

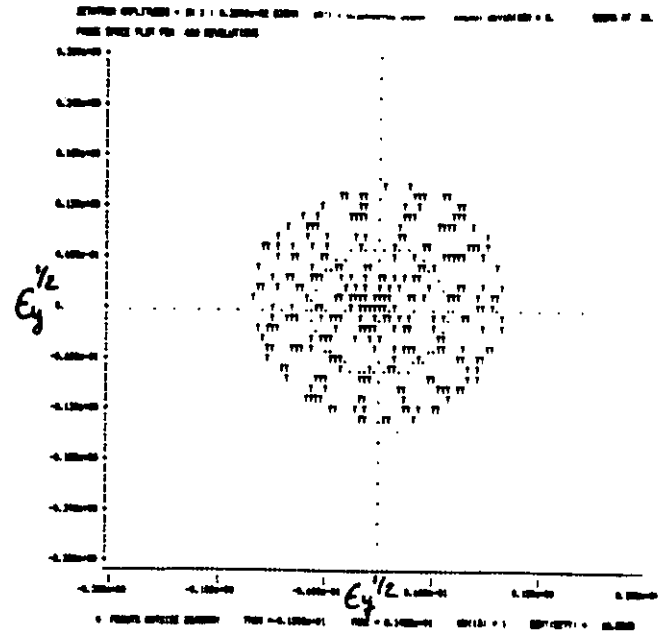
SMEAR(EDWARDS) = 0.226

CONCLUSION: AMPLITUDE OF X AND Y MOTION IS ESSENTIALLY CONSTANT FOR $400 \leq$ TURNS ≤ 4000

FIG. 5



X PLANE



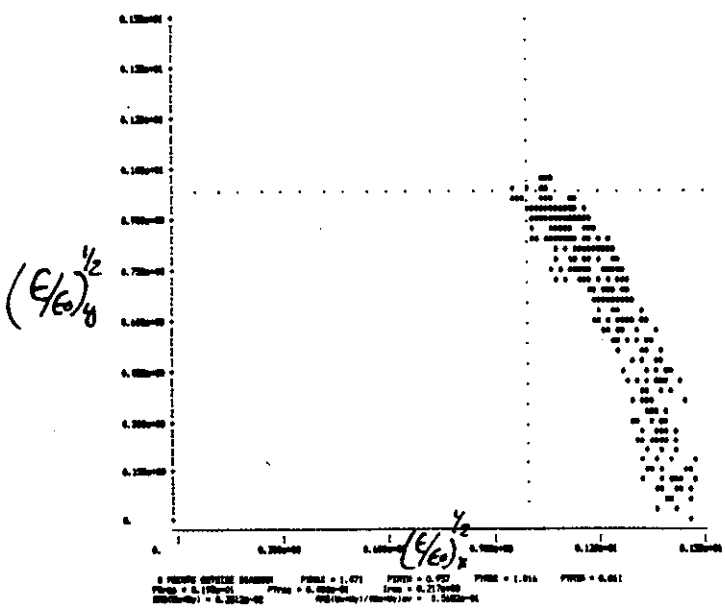
Y PLANE

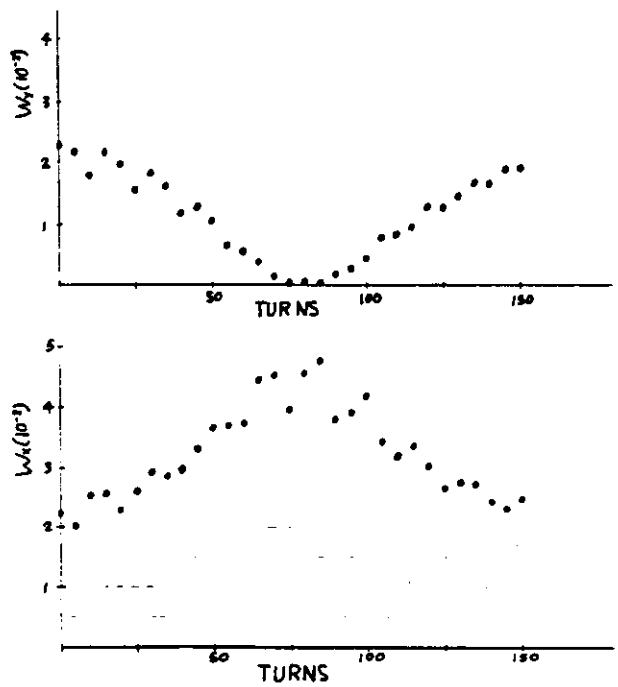
$\nu_x = 78.265$, $\nu_y = 78.265$

INITIAL CONDITIONS: $(X, Y') \neq 0$

$X_i^{QF} = 2.73$ mm $Y_i^{QF} = 1.57$ mm

400 TURNS $\Delta p/p = 0$





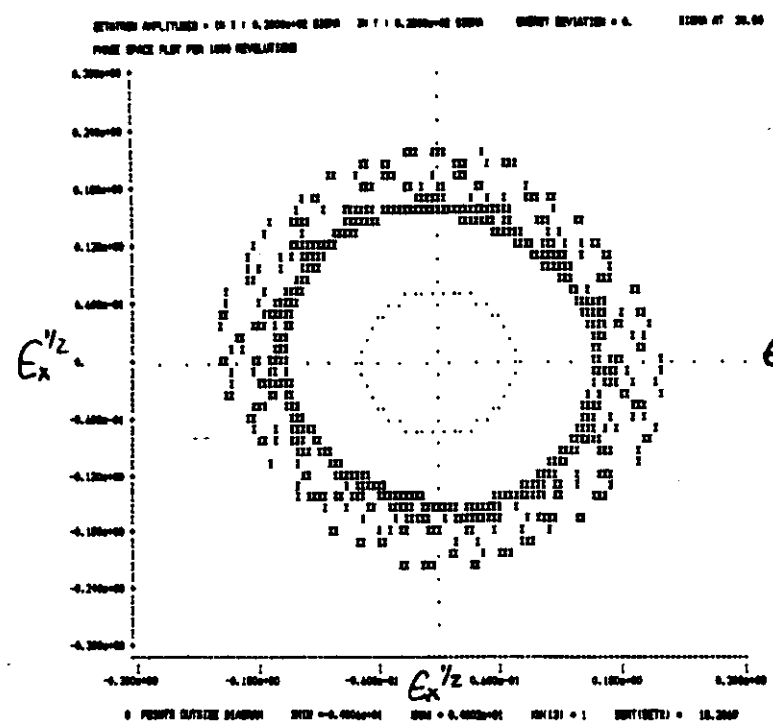
PRONOUNCED COUPLING WITH ϵ_x INCREASING AND ϵ_y DECREASING DUE TO INITIAL CONDITIONS.

SMEAR(EDWARDS) = 0.217

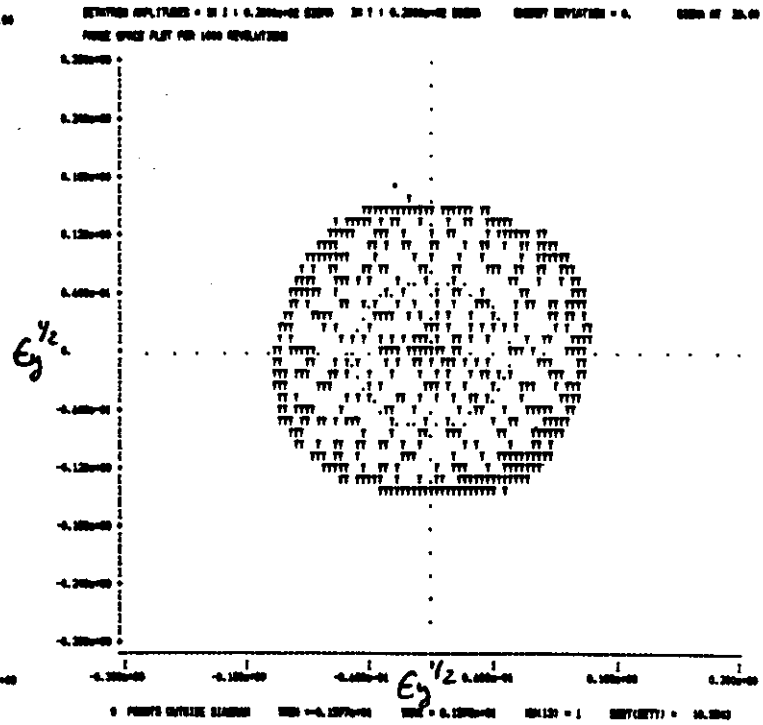
$-3.880 \leq X(mm) \leq 3.945$

$-1.503 \leq Y(mm) \leq 1.432$

FIG. 6



X PLANE



Y PLANE

$\nu_x = 78.265$, $\nu_y = 78.265$ $(X, Y)_i \neq 0$

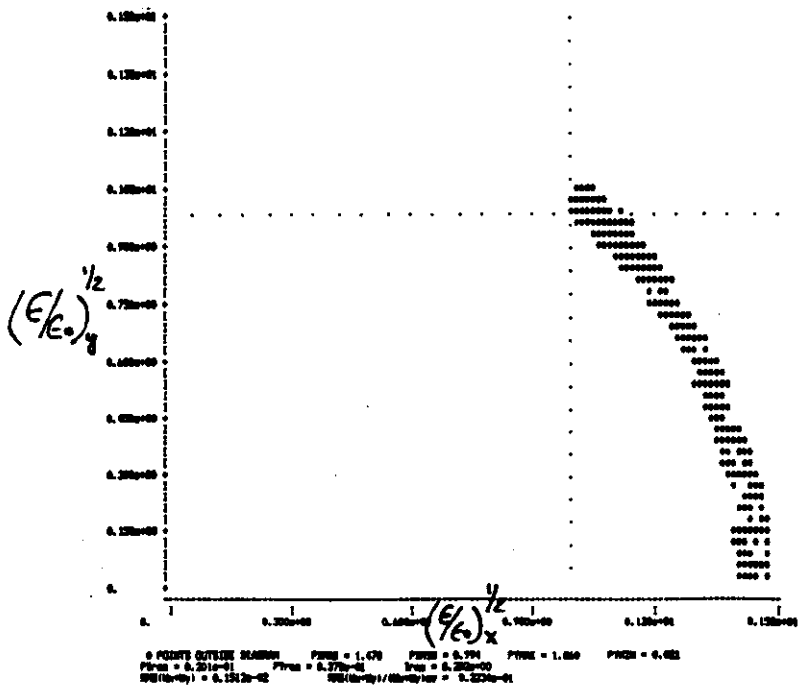
$(\sigma a_n, \sigma b_n) \neq 0$ $3 \leq n \leq 5$ QUADS

$(\sigma a_n, \sigma b_n) \neq 0$ $3 \leq n \leq 10$ DIPOLES.

$X_i^{QF} = 2.73\,mm$ $Y_i^{QF} = 1.57\,mm$

400 TURNS $\underline{\underline{\sigma a_2 = \sigma b_2 = 0}}$

$\Delta P/p = 0$



$-4.006 \leq X(mm) \leq 4.002$

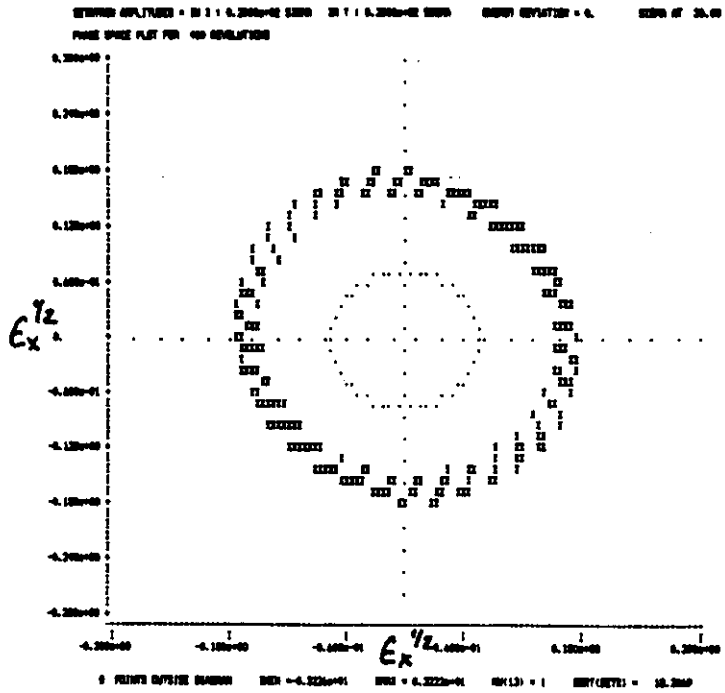
$-1.597 \leq Y(mm) \leq 1.598$

PRONOUNCED COUPLING

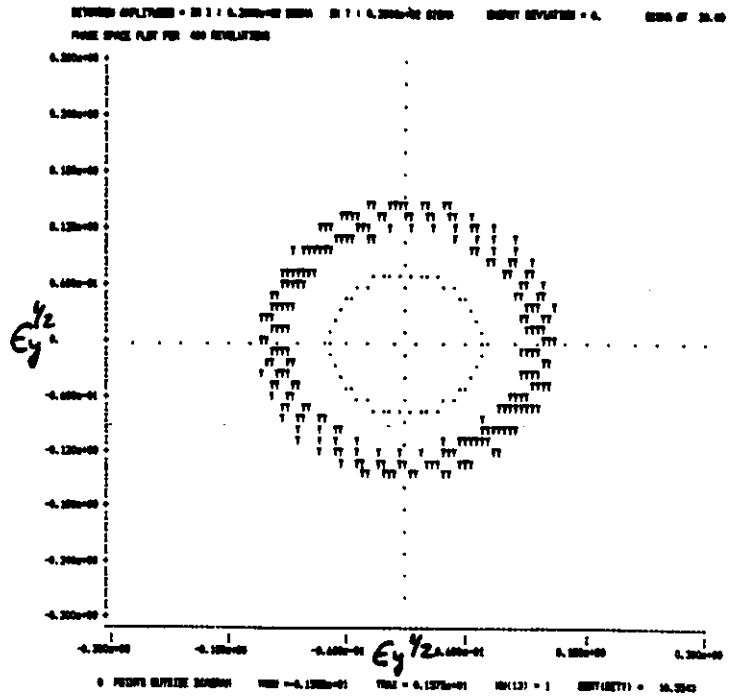
$\epsilon_x \uparrow$ $\epsilon_y \downarrow$

SMEAR = 0.202

FIG. 7



X PLANE



Y PLANE

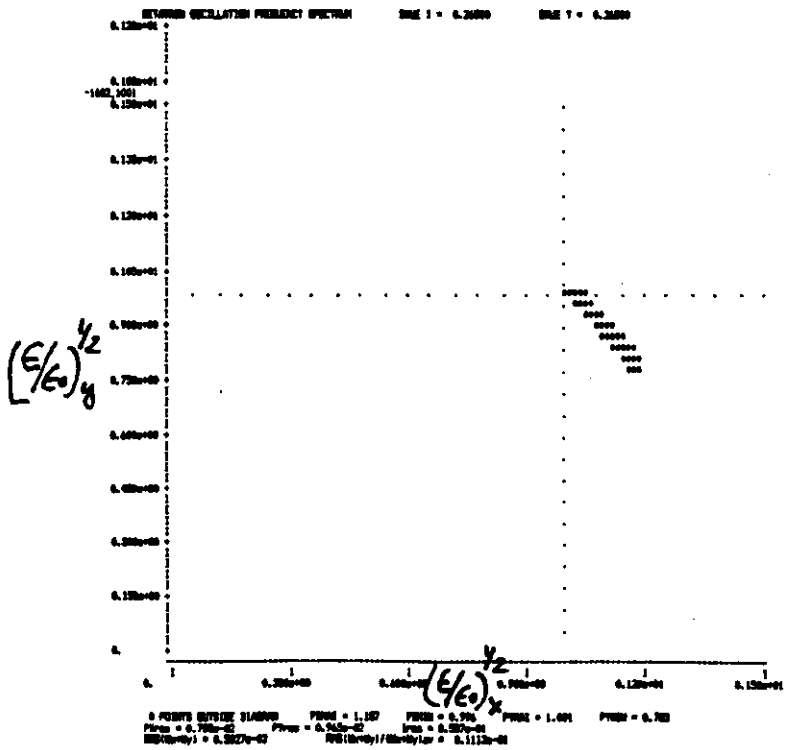
$\nu_x = 78.265$, $\nu_y = 78.265$ $\quad (X, Y)_i \neq 0 \quad X_i^{QF} = 2.73\,mm \quad Y_i^{QF} = 1.57\,mm$

$(\sigma a_n, \sigma b_n) \neq 0 \quad 4 \leq n \leq 5$ QUADS

$(\sigma a_n, \sigma b_n) \neq 0 \quad 4 \leq n \leq 10$ DIPOLES

400 TURNS $\underline{\underline{(\sigma a_n, \sigma b_n) = 0 \quad 1 \leq n \leq 3}}$

$\Delta P/P = 0$



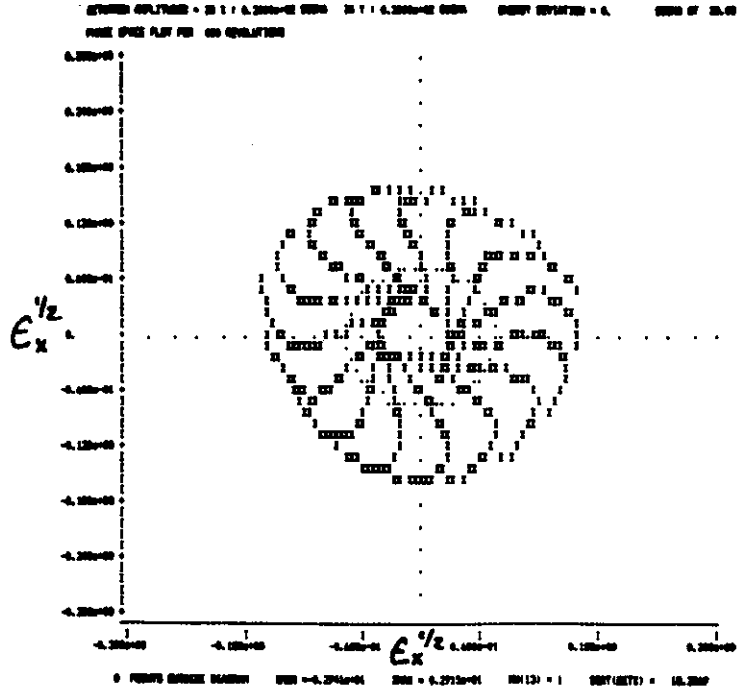
$-3.226 \leq X(mm) \leq 3.222$

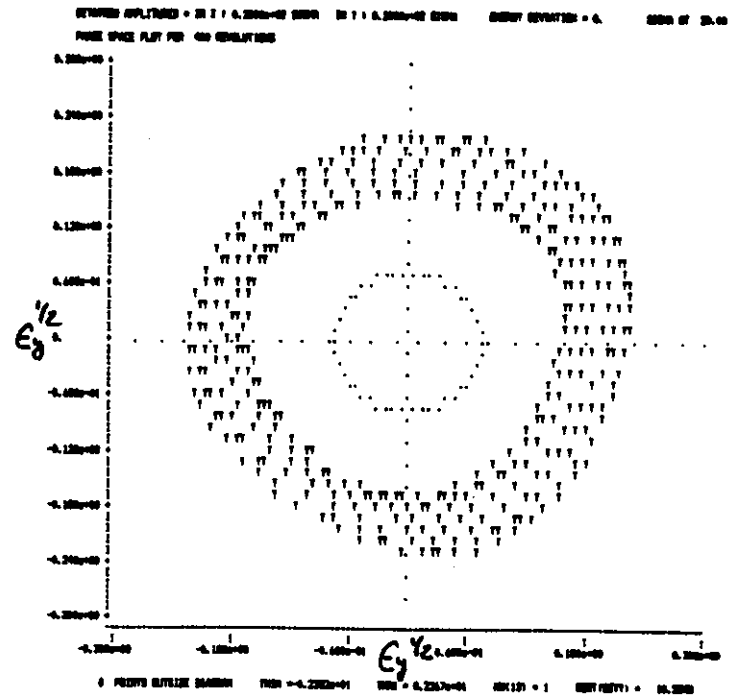
$-1.558 \leq Y(mm) \leq 1.575$

COUPLING SMALL

SMEAR = $5.9 \cdot 10^{-2}$

FIG. 8





X PLANE

$\nu_x = 78.265$ $\nu_y = 78.265$ $(X,Y)_i \neq 0$

$(\sigma a_n, \sigma b_n) \neq 0$ $n = 2,4,5$ QUADS

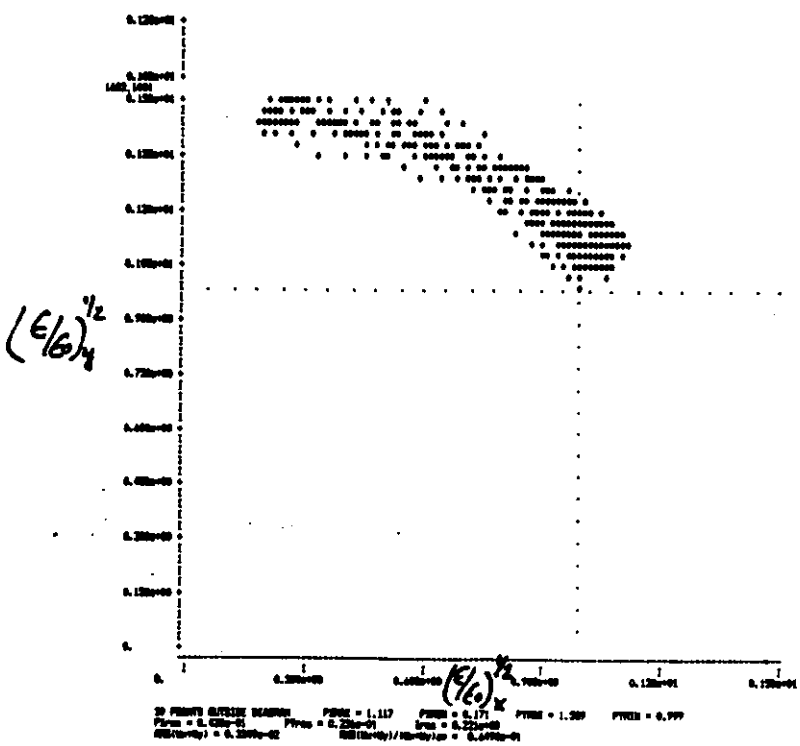
$(\sigma a_n, \sigma b_n) \neq 0$ $n = 2$ $4 \leq n \leq 10$ DIPOLES

Y PLANE

$X_i^{QF} = 2.73\,mm$ $Y_i^{QF} = 1.57\,mm$

400 TURNS $\underline{(\sigma a_3, \sigma b_3) = 0}$

$\Delta P/P = 0\,\%$



$-2.941 \leq X(mm) \leq 2.915$

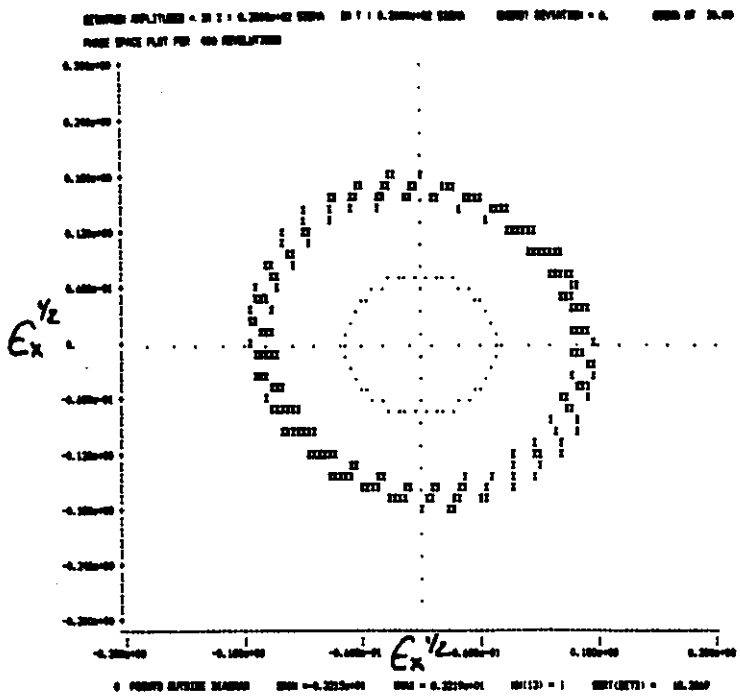
$-2.382 \leq Y(mm) \leq 2.367$

SMEAR = 0.221

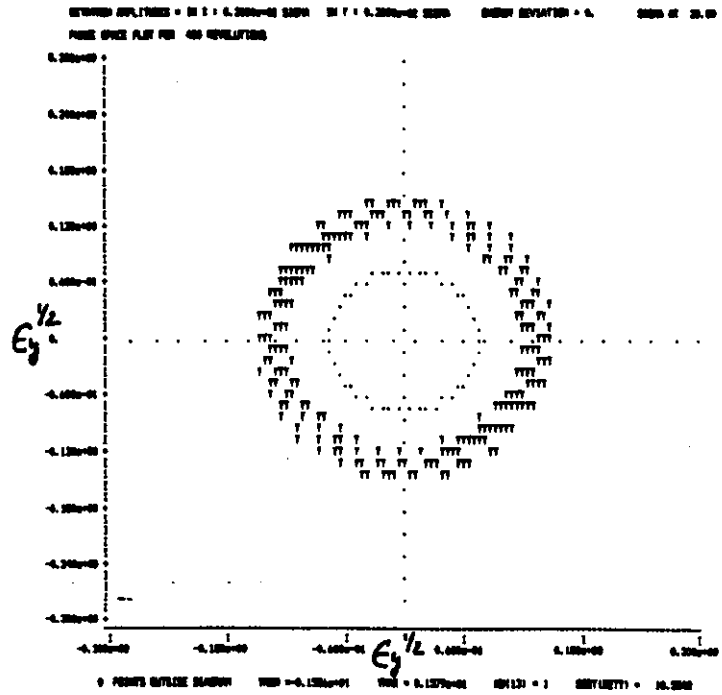
LARGE COUPLING

$\epsilon_x \downarrow$ $\epsilon_y \uparrow$

FIG. 9



X PLANE



Y PLANE

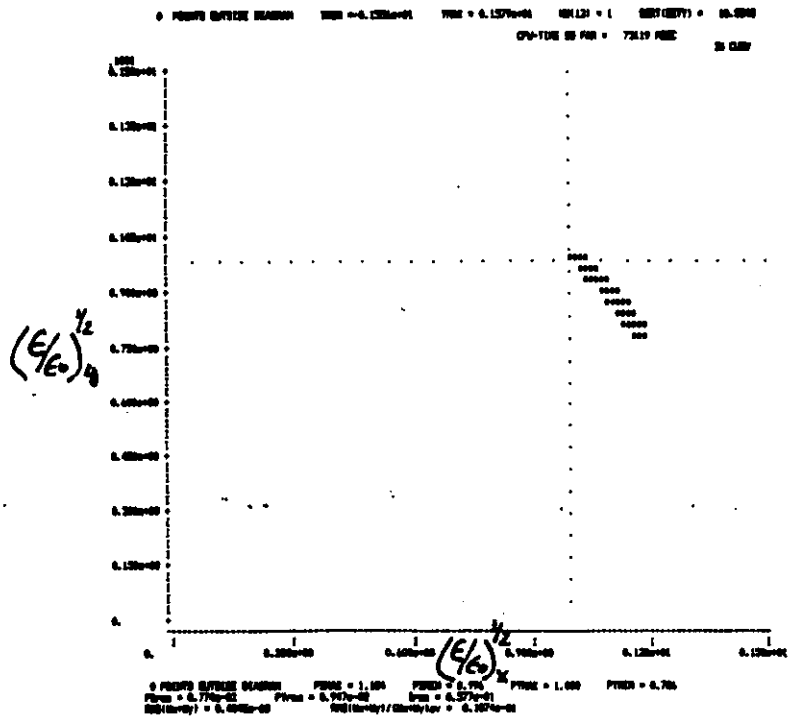
$\nu_x = 78.265$, $\nu_y = 78.265$ $(X, Y) \neq 0$

$(\sigma a_n, \sigma b_n) \neq 0$ $n = 5$ QUADS

$(\sigma a_n, \sigma b_n) \neq 0$ $5 \leq n \leq 10$ DIPOLES

$X_i^{\phi F} = 2.73\,mm$ $Y_i^{\phi F} = 1.57\,mm$

400 TURNS $\Delta P/p = 0$



$-3.215 \leq x \leq 3.219$

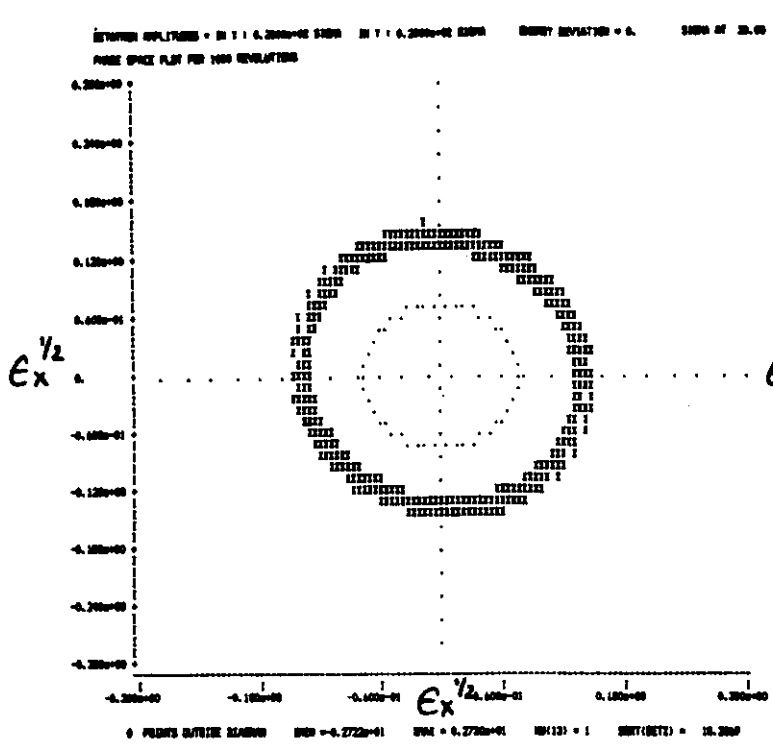
$-1.556 \leq Y \leq 1.579$

SMEAR $= 5.8 \cdot 10^{-2}$

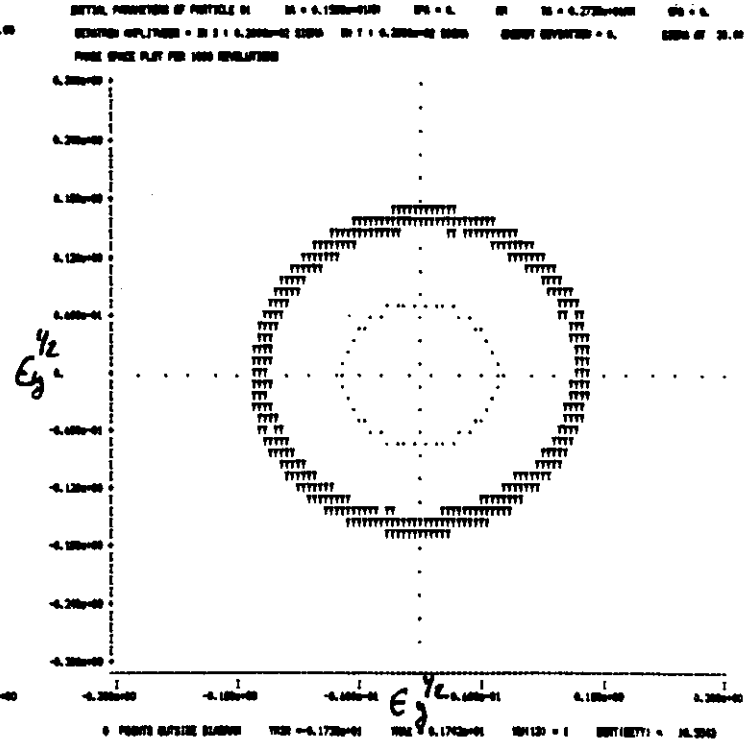
SMALL COUPLING

$\epsilon_x \uparrow$ $\epsilon_y \downarrow$

FIG. 10



X PLANE



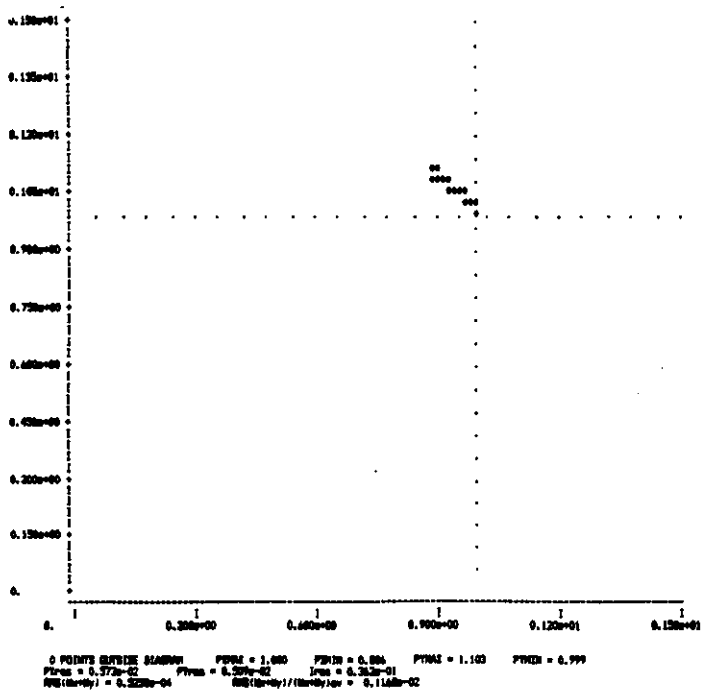
Y PLANE

$\nu_x = 78.265$, $\nu_y = 78.265$ $(X,Y)_i \neq 0$ $X_i^{\psi F} = 2.73$ mm $Y_i^{\psi F} = 1.57$ mm

$(\sigma a_n, \sigma b_n) = 0$ IN QUADS

$(\sigma a_n, \sigma b_n) \neq 0$ $6 \leq n \leq 10$ DIPOLES

400 TURNS $\Delta p/p = 0$



$-2.722 \leq X(mm) \leq 2.730$

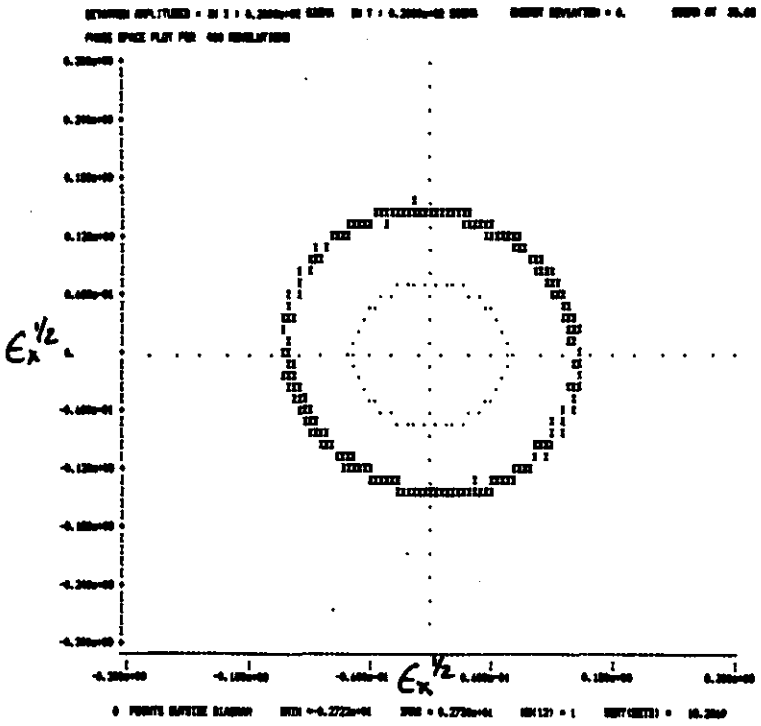
$-1.738 \leq Y(mm) \leq 1.742$

SMALL COUPLING

$\epsilon_x \downarrow$, $\epsilon_y \uparrow$

SMEAR = $3.6 \cdot 10^{-2}$

FIG. 11

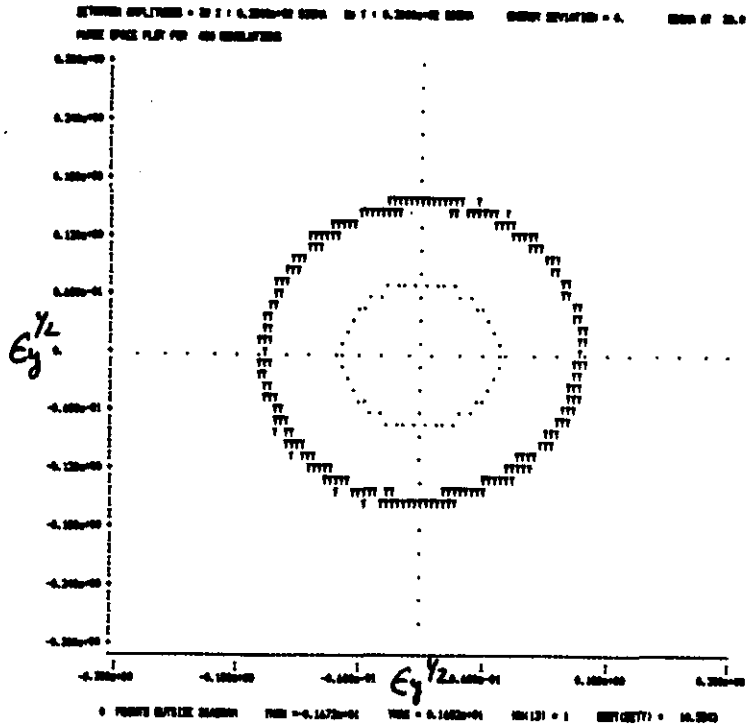


X PLANE

$\nu_x = 78.265 \quad \nu_y = 78.265$

$(\sigma a_n, \sigma b_n) = 0$ QUADS

$(\sigma a_n, \sigma b_n) = 0$ DIPOLES

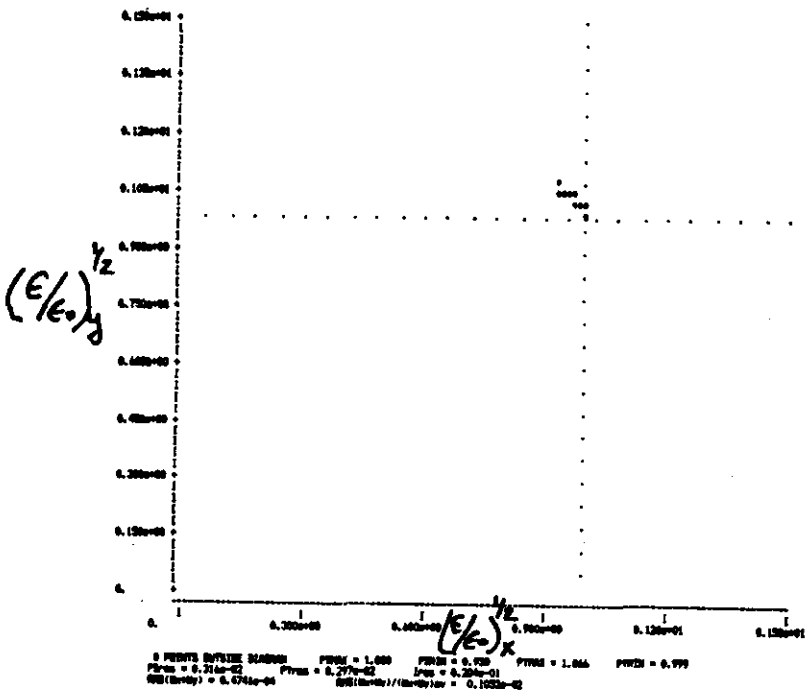


Y PLANE

$X_i^{PF} = 2.73$ mm $\quad Y_i^{PF} = 1.57$ mm

400 TURNS <u>NO MULTIPOLES</u>

$\Delta P/P = 0.0$

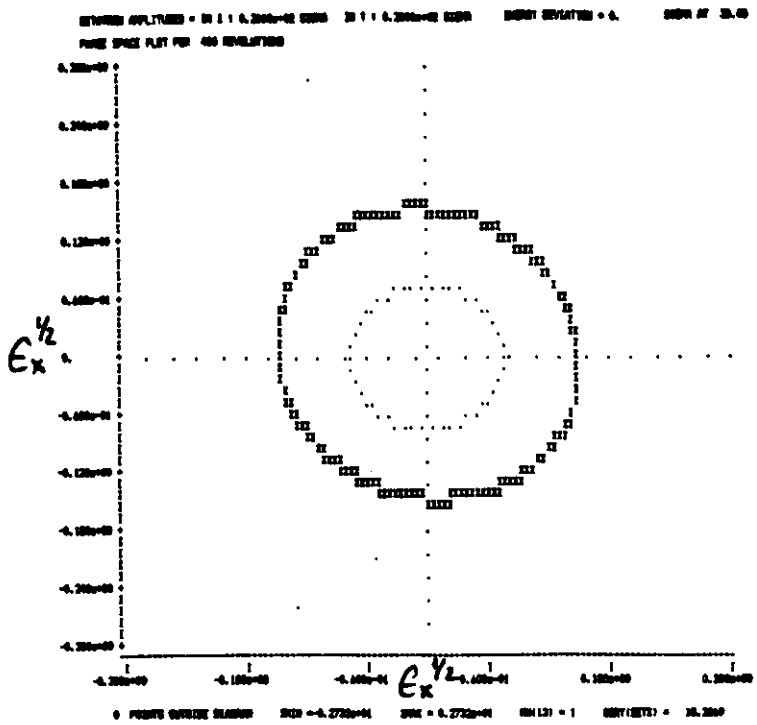


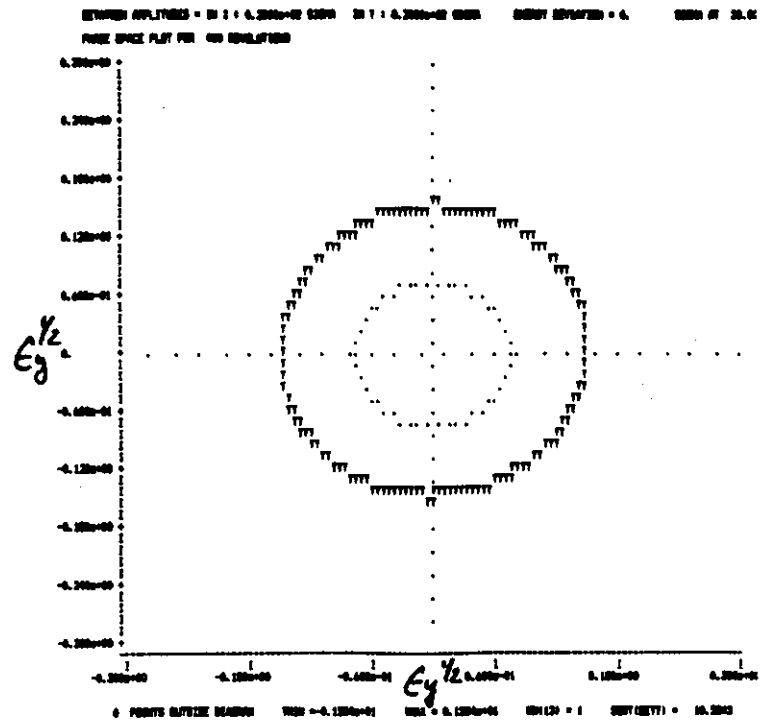
$-2.722 \leq X(mm) \leq 2.730$

$-1.672 \leq Y(mm) \leq 1.682$

SMEAR $= 2.04 \cdot 10^{-2}$

FIG. 12





X PLANE

$\nu_x = 78.265, \quad \nu_y = 78.265$

$\sigma a_n = \sigma b_n = 0 \quad 1 \le n \le 5$ QUADS

$\sigma a_n = \sigma b_n = 0 \quad 1 \le n \le 10$ DIPOLES

Y PLANE

$(X, Y)_i \neq 0 \quad X_i^{QF} = 2.73 \quad Y_i^{QF} = 1.57\,mm$

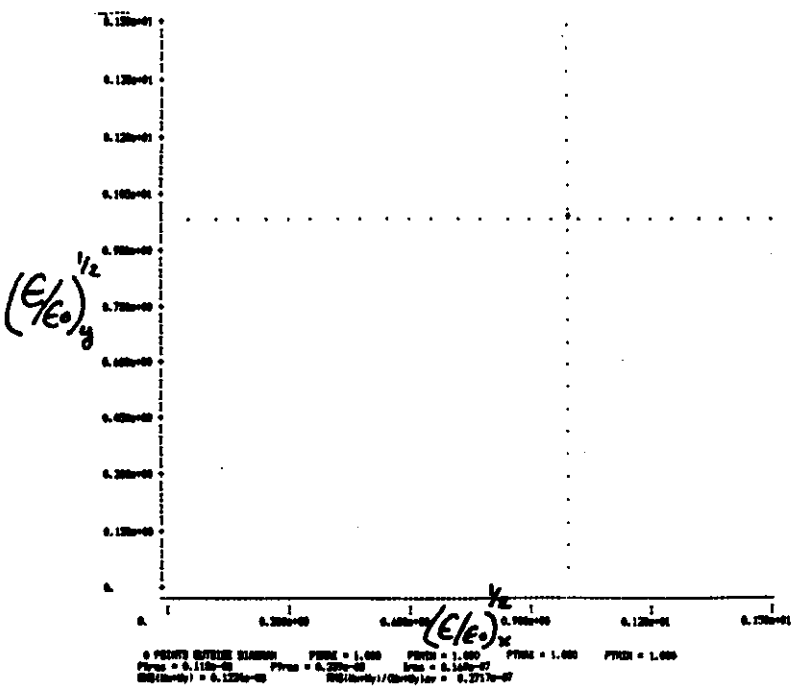
400 TURNS $\quad \Delta P/p = 0$

NO MULTIPOLES.

CHROMATICITY: $X = Y = -221.55$

SEXTUPOLES: $SF = -2 \cdot 10^{-7} \approx 0$

$SD = 5 \cdot 10^{-7} \approx 0$

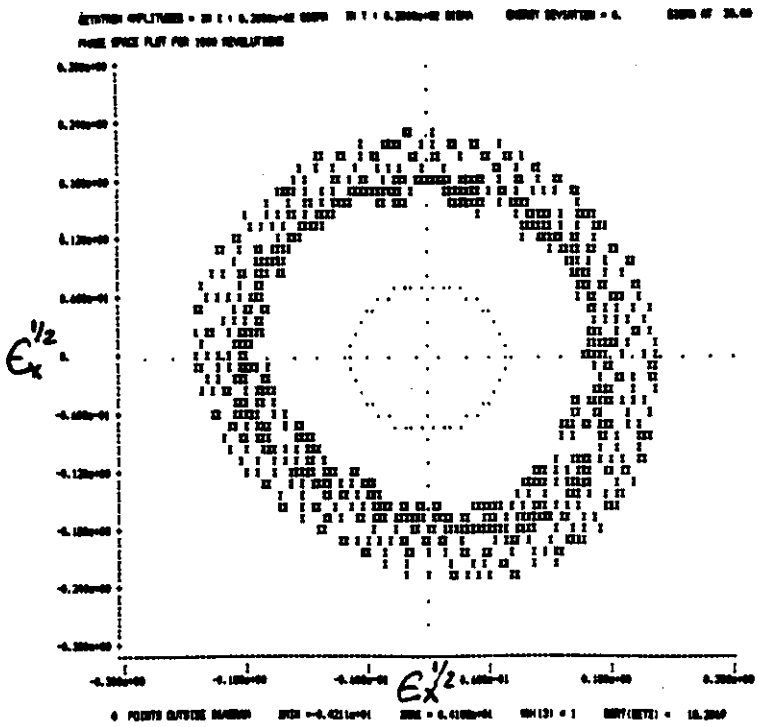


$-2.732 \le X(mm) \le 2.732$

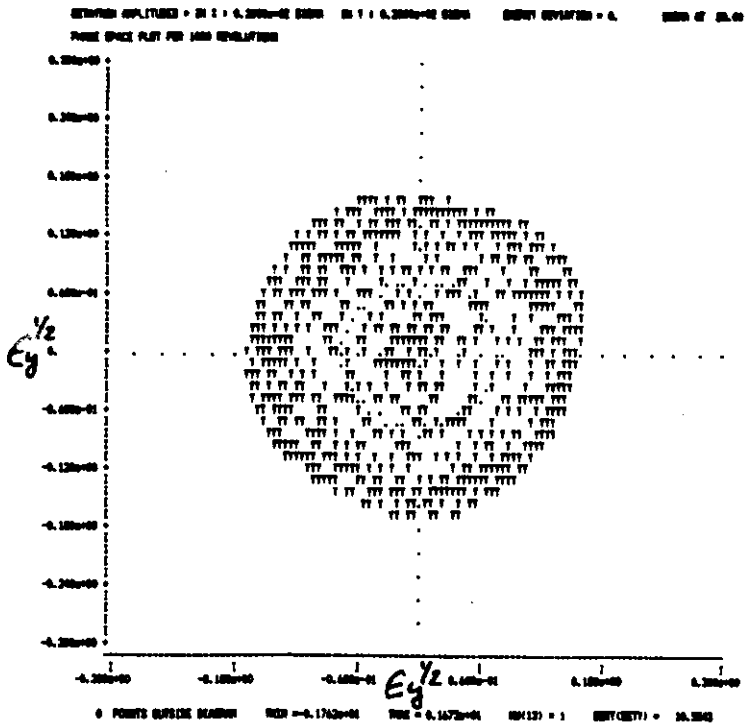
$-1.584 \le Y(mm) \le 1.584$

SMEAR $= 1.7 \cdot 10^{-8}$

FIG. 13



X PLANE



Y PLANE

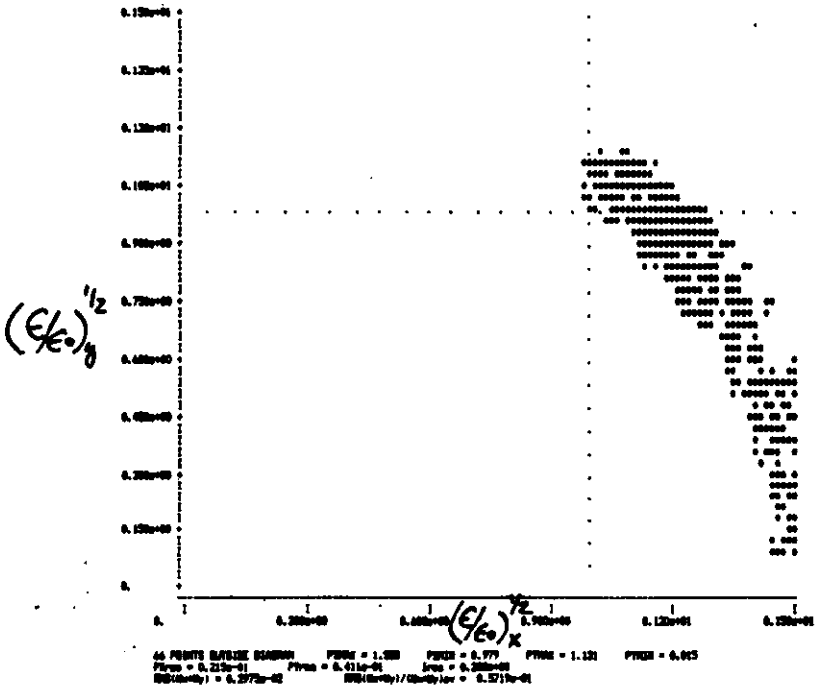
$\nu_x = 78.265$, $\nu_y = 78.265$

$(\sigma a_n, \sigma b_n) = 0 \quad 2 \leq n \leq 5$ QUADS

$(\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 10$ DIPOLES

$(X, Y)_i \neq 0 \quad X_i^{PF} = 2.73\,mm \quad Y_i^{PF} = 1.57\,mm$

1000 TURNS $\Delta P/P = 0.0\%$



$-4.211 \leq X(mm) \leq 4.108$

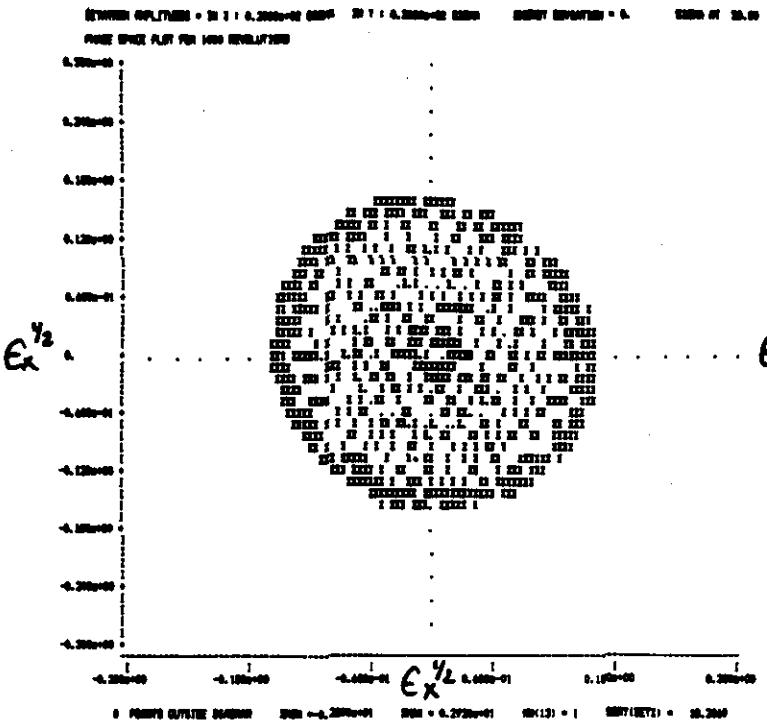
$-1.762 \leq Y(mm) \leq 1.673$

SMEAR = 0.208

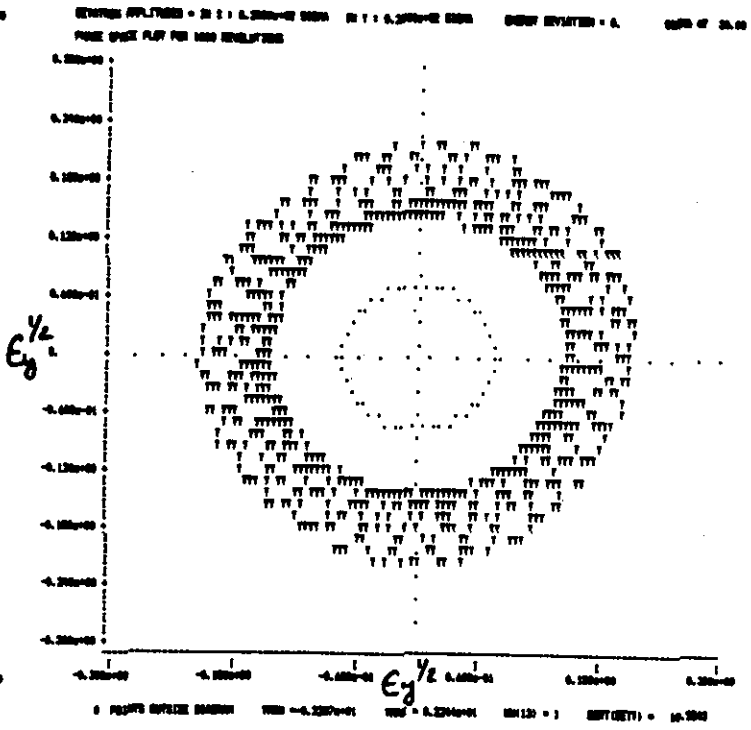
LARGE COUPLING

$\epsilon_x \uparrow$, $\epsilon_y \downarrow$

FIG. 14



X PLANE



Y PLANE

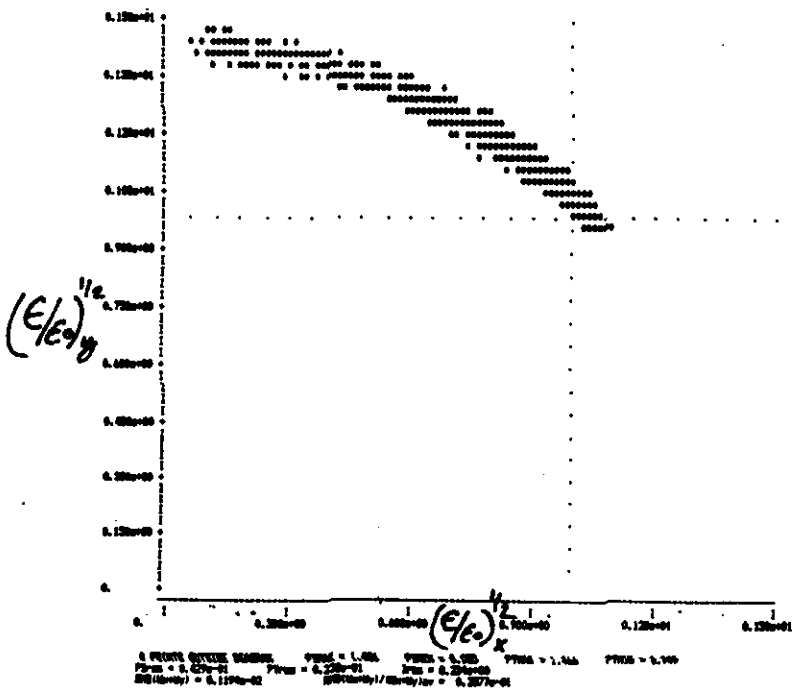
$(\sigma a_n, \sigma b_n) \neq 0 \quad 2 \leq n \leq 5$ QUADS

$(\sigma a_n, \sigma b_n) = 0 \quad 1 \leq n \leq 10$ DIPOLES

$\nu_x = 78.265 \quad \nu_y = 78.265$

$(X, Y)_i \neq 0 \quad X_i^{QF} = 2.73\,mm, \; Y_i^{QF} = 1.57\,mm$

1000 TURNS $\quad \Delta P/P = 0.0$



$-2.89 \leq X(mm) \leq 2.92$

$-2.287 \leq Y(mm) \leq 2.244$

SMEAR = 0.234

LARGE COUPLING

$\epsilon_x \downarrow, \; \epsilon_y \uparrow$

FIG. 15