

# Some Results for the Chromatic Correction of the Antisymmetric RHIC Lattice

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**U.S. Department of Energy**

USDOE Office of Science (SC)

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Some Results for the Chromatic Correction  
of the Antisymmetric RHIC Lattice

Armando Antillon

February 24, 1986

ABSTRACT

The sextupole scheme proposed in RHIC-AP-21 is tested for the currently antisymmetric lattice.

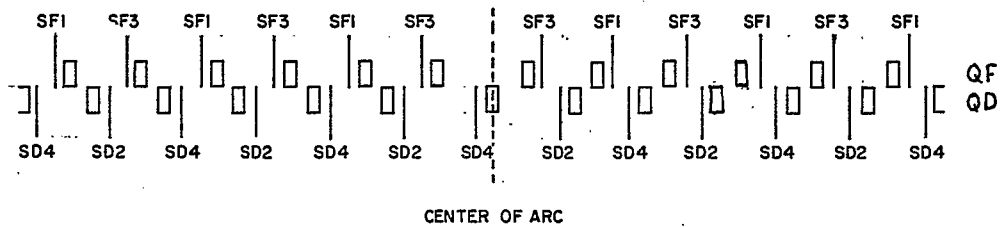
## I. Introduction

In this note we are testing a sextupole scheme that has given good results in other cases<sup>1,2</sup>. In the present case sextupoles have been placed out of quadrupoles and the process of optimization has been exercised manually and with the help of HARMON<sup>3</sup>. Unfortunately, HARMON has shown some weakness and none run has been better than those in which sextupoles have been chosen manually.

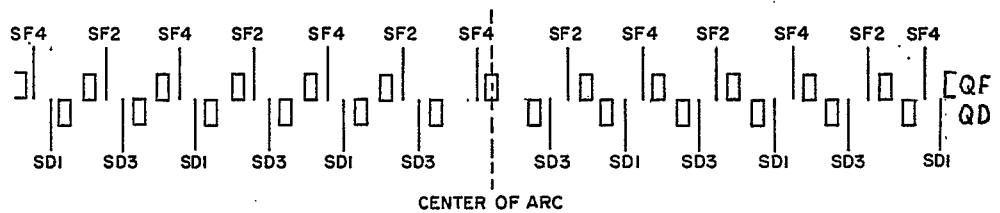
## II. The Lattice

In order to identify the lattice we are going to address some of its parameters and structure. Let us first place the sextupoles in the arcs. Following Brown and Servranckx<sup>4</sup>, the focusing structure is as follows:

Outer Arc:



Inner Arc:



All the sextupoles families have been placed just aside the quadrupoles, with zero distance in between. The length of sextupoles is 0.1 m. There are four families in the inner arc, and four families in the outer arc. The total number is eight families.

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1. A. Antillon, RHIC-8, BNL (1985).
  2. A. Antillon, RHIC-AP-21, BNL (1985).
  3. M. H. Donald.
  4. IEEE Trans. on Nucl Sci NS-32 No. 5, (1985).

Some lattice parameters<sup>5</sup>.

$$\beta_x^{QF} / \beta_x^{QD} = 49.7/8.6$$

$$\beta_y^{QF} / \beta_y^{QD} = 8.6/49.8$$

$$\eta_x^{QF} / \eta_x^{QD} = 1.5/0.7$$

$$\epsilon_x / \epsilon_y = -57.5/-57.4$$

$$v_x / v_y = 28.851725/28.843547$$

SF/SD (two families) = 1.69783/-3.32157 for  $\xi_{x,y} = 0$

$$\beta_x^* / \beta_y^* = 3.039/3.042$$

### III. Chromatic Results

#### a. Two families.

In the next figure we are using this notation for the values of  $\beta$ -function.

Inner Arc:

$\beta_x^B$  - Begin of MAD. Center of first QF quadrupole at the center. of the inner arc.

$\beta_y^5$  - Center of the 1st QD

$\beta_x^{14}$  - Center of the 2nd QF

$\beta_y^{19}$  - Center of the 2nd QD

Outer Arc:

$\beta_x^{162}$  - Center of the first QF

$\beta_y^{167}$  - Center of the 2nd QD

$\beta_y^{239}$  - Center of the 7th QD.

The machine function has been calculated only with two families of sextupoles.

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<sup>5</sup>From MAD (F. CH. Iselin)

The figure shows a clear bad behaviour of the  $\beta$ 's at the arcs. (Fig. 1)

b. Eight families:

In order to reduce the bad behaviour of the  $\beta$ 's at the arcs, we decouple SF, SD into 8 families, 4 in the inner and 4 in the outer arc. The  $\beta$ 's are reduced at expenses of the other parameters.

The sextupoles values are

$$\left( \frac{B''}{B_0 \rho}, \text{MAD units} \right).$$

Inner arc:

$$\begin{aligned} \text{SF2} &= 1.148 \\ \text{SF4} &= 1.738 \\ \text{SD1} &= -4.0 \\ \text{SD3} &= -2.5135 \end{aligned}$$

Outer arc:

$$\begin{aligned} \text{SF1} &= 1.426 \\ \text{SF3} &= 2.474 \\ \text{SD2} &= -2.6541 \\ \text{SD4} &= -4.0 \end{aligned} \quad (\text{Fig. 2}).$$

#### IV. Tune versus Amplitude

HARMON was used to calculate the linear change of tune with amplitude.

They are

$$\begin{aligned} \Delta Q_x / \Delta \epsilon_x &= -145 \\ \Delta Q_y / \Delta \epsilon_y &= 579 \\ \Delta Q_y / \Delta \epsilon_x &= -960. \end{aligned}$$

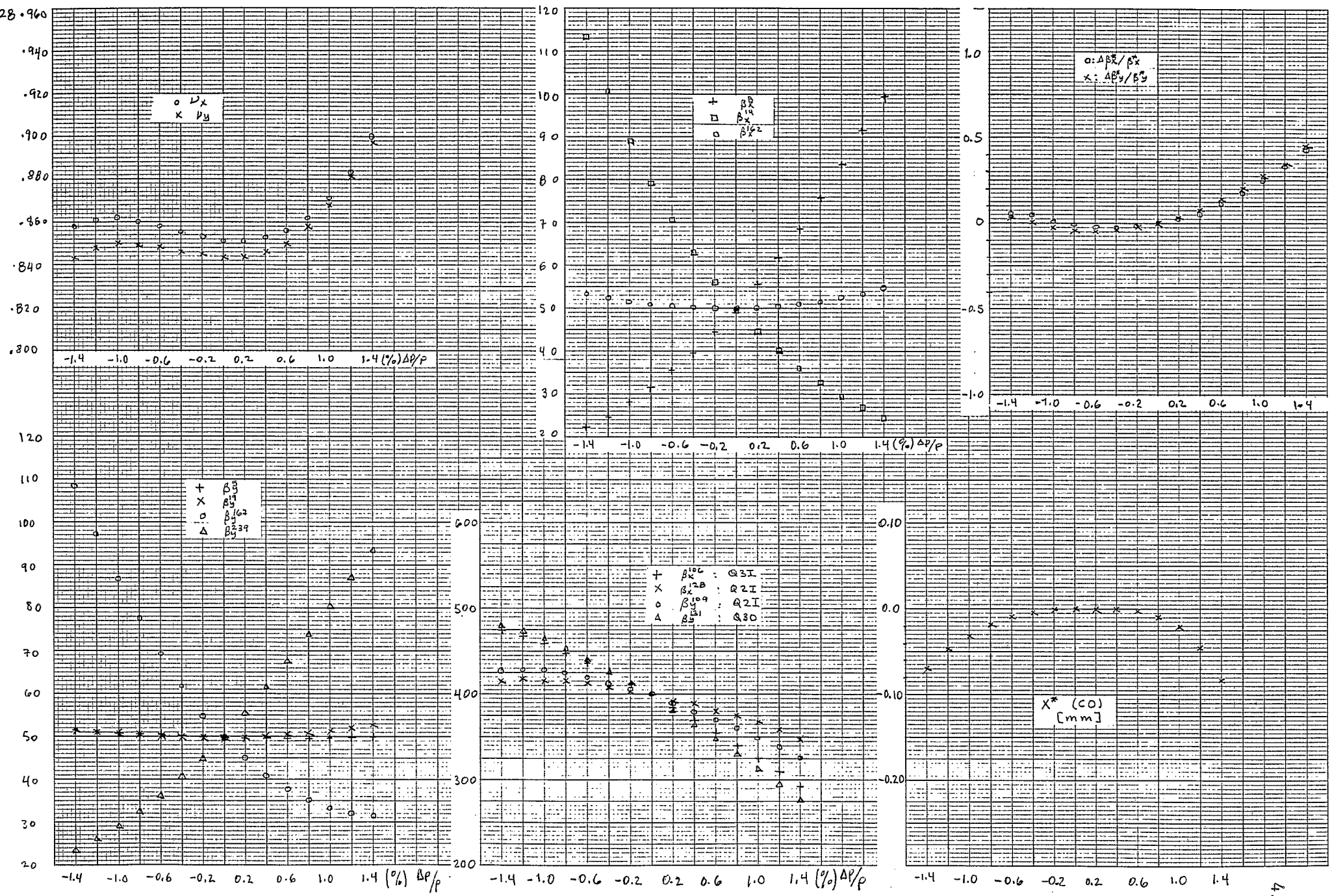


Fig. 1

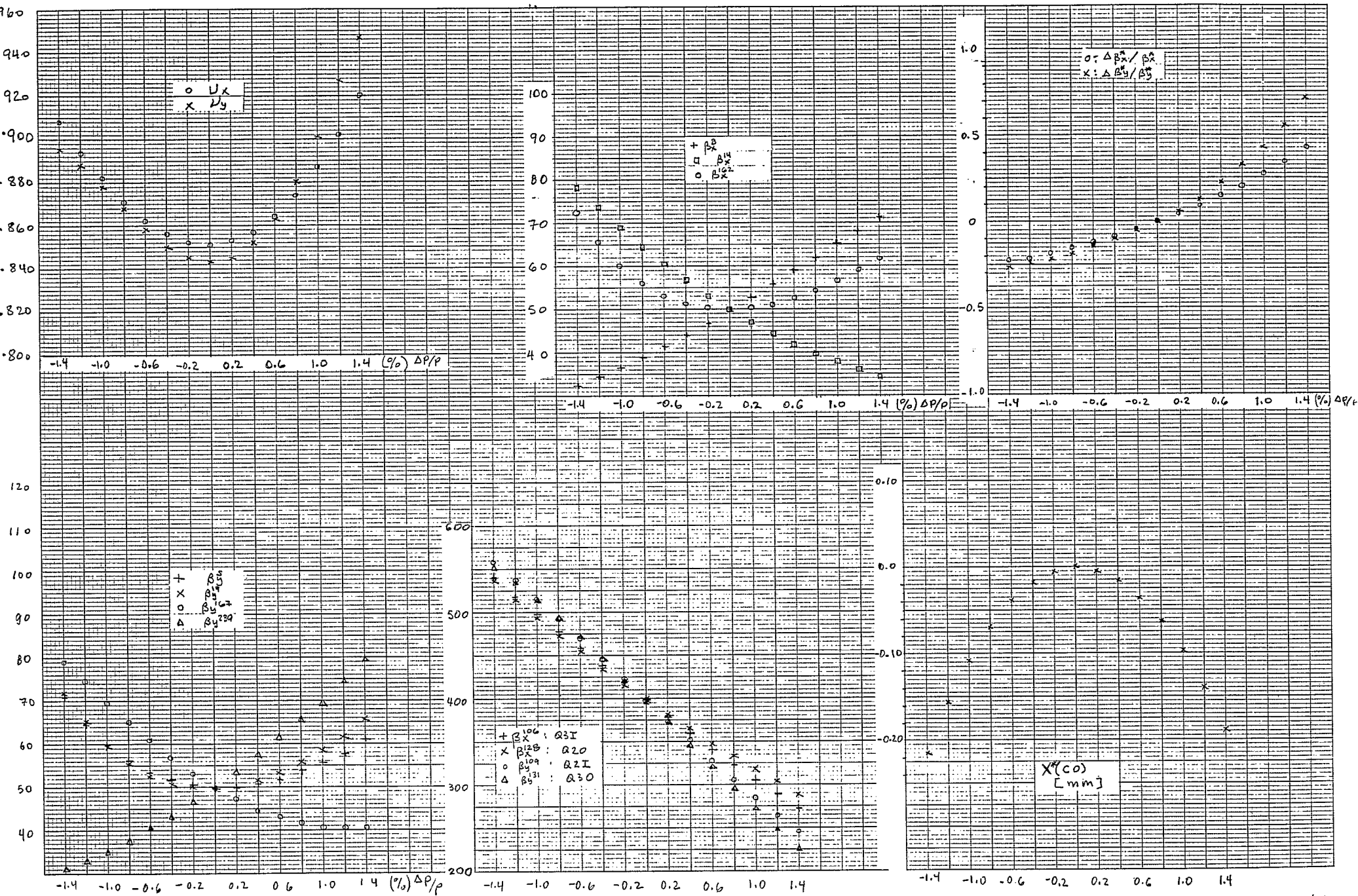


Fig. 2



So, for an emittance of 0.3 mm-mrad

$$\Delta v_x \sim 3.3 \times 10^{-4}$$

$$\Delta v_y \sim 1.14 \times 10^{-4}$$

that is inside the range of tolerance.

#### V. Change with respect to distance to the quadrupole.

The next figure shows how the  $\beta$ 's and the tune change as a function of the distance to the immediate quadrupole. In general, for  $\Delta p/p < 0$   $\beta$ 's and tune are constant, but not for  $\Delta p/p > 0$ . The calculation was done for 2 families, but the general behaviour is analogous for 8 families. (Fig. 3).

#### VI. Tracking

Finally we are going to show tracking results for the case of 8 families. We are using PATRICIA with 4 particles with emittances  $0.5\pi$ ,  $1\pi$ ,  $1.5\pi$  and  $2\pi$  mm-mrad.

- a.  $\Delta p/p = 0$  (Figure 4)
- b.  $\Delta p/p = +1\%$  (Figure 5)
- c.  $\Delta p/p = -1\%$  (Figure 6)

The phase space plots seem to be good for  $\Delta p/p = 0$  and  $+1\%$ , and it seems to be a small coupling resonance for  $\Delta p/p = -1\%$ .

#### Acknowledgements:

I am very grateful to Dr. Martin H. Donald from SLAC for his help and suggestions for the program HARMON, and to R. Gupta, S. Y. Lee and Z. Parsa for their help with the first version of MAD/HARMON.

Betas

140

120

100

80

60

40

20

0

fines

28.98

.94

.90

.86

.82

.78

.740

.70

46 1323

10 X 10 TO 1/2 INCH 7 X 10 INCHES  
KEUFFEL & ESSER CO. MADE IN U.S.A.

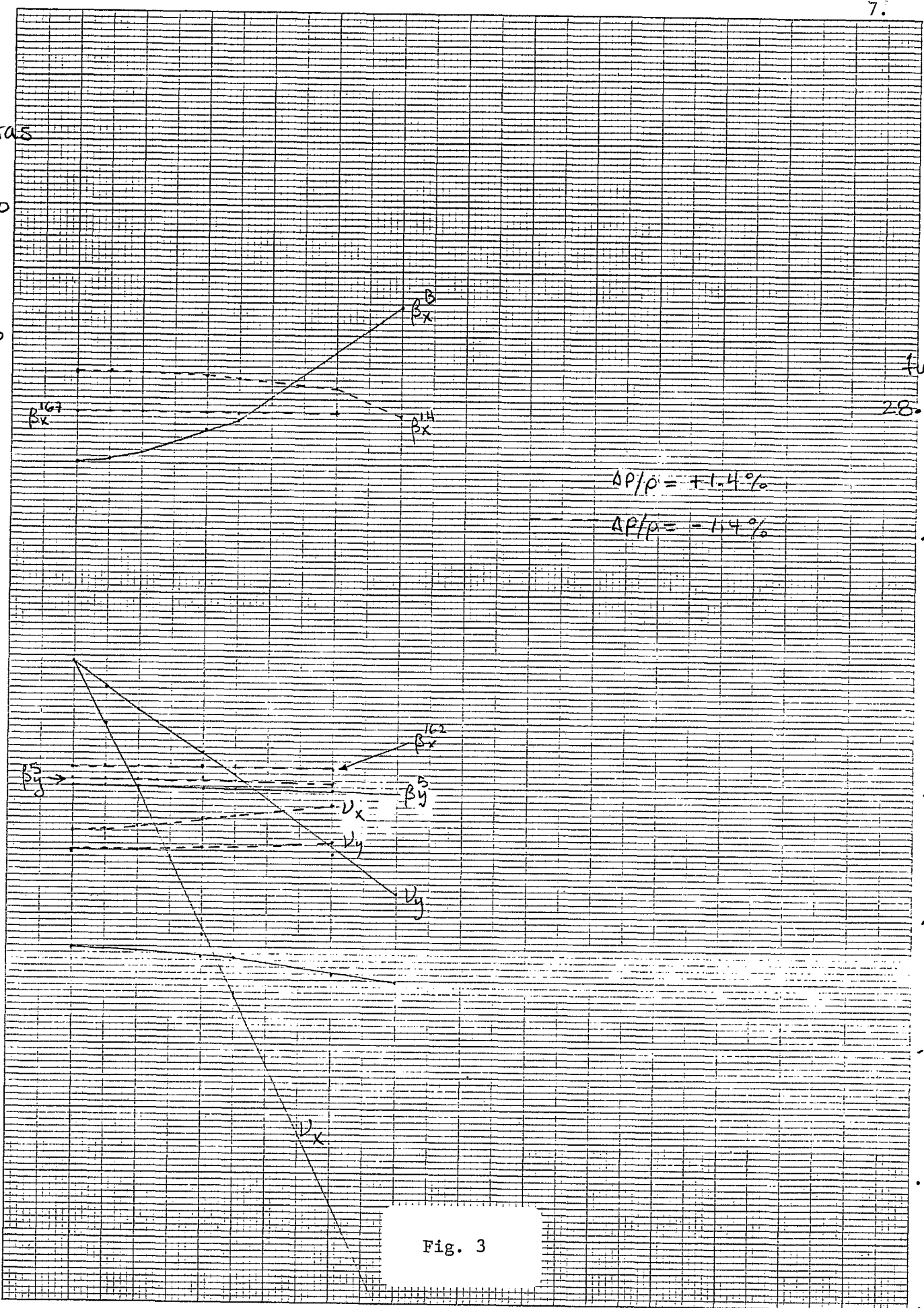
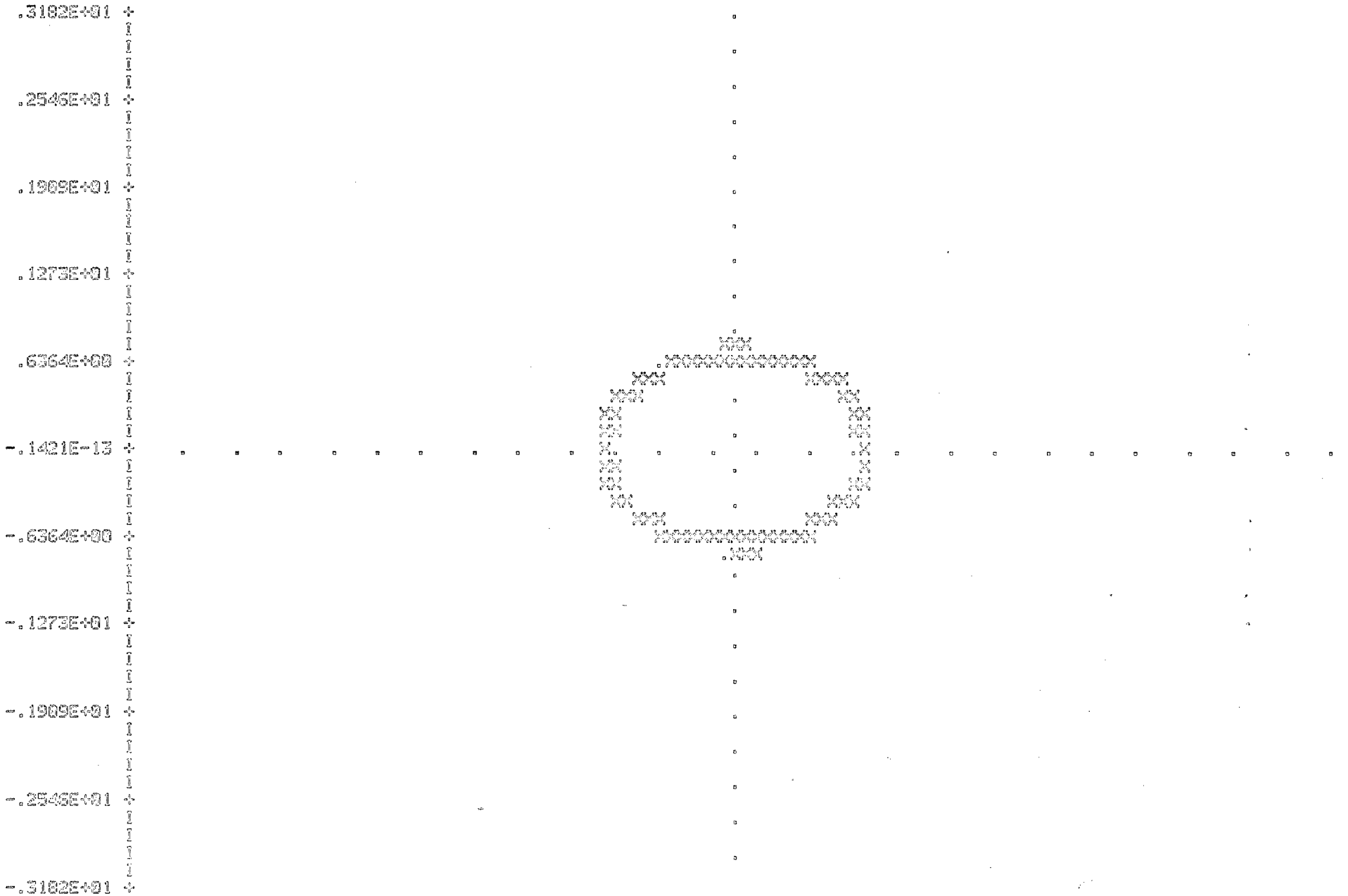


Fig. 3

0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 distance in between [m]

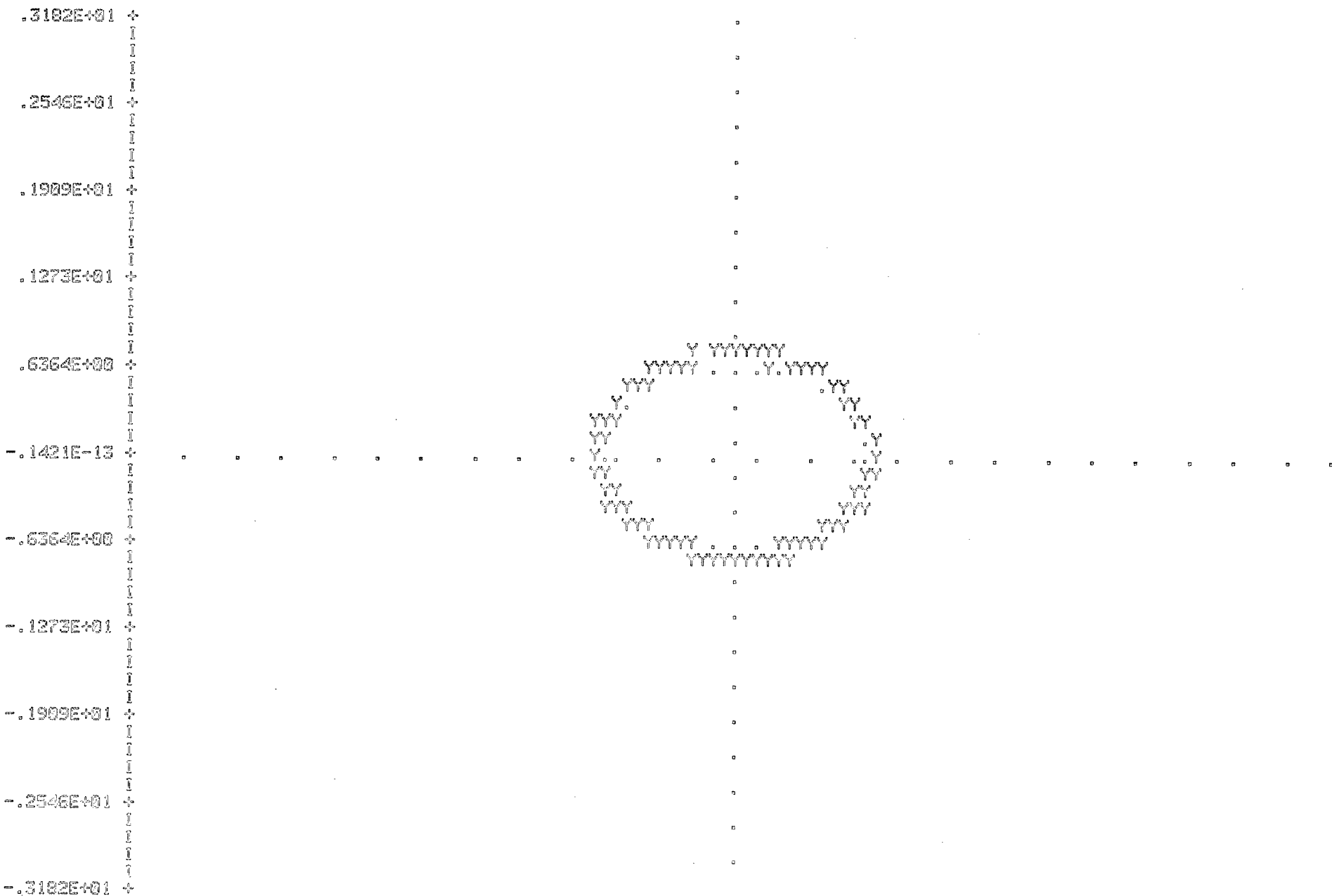
INITIAL PARAMETERS OF PARTICLE 01    XA = .499E+01MM    XPA = 0.    MM    YA = .209E+01MM    YPA = 0.    NR  
 BETATRON AMPLITUDES = IN X : .100E+02 SIGMA    IN Y : .100E+02 SIGMA    ENERGY DEVIATION = 0.    SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I                    I                    I                    I                    I  
 - .3182E+01           - .1909E+01           - .6364E+00           .6364E+00           .1909E+01           .3182E+01  
 0   POINTS OUTSIDE DIAGRAM    NMIN = -.8033E+01    NMAX = .4078E+01    (NMIN) = 1    SORT(BETA) = 7.8513

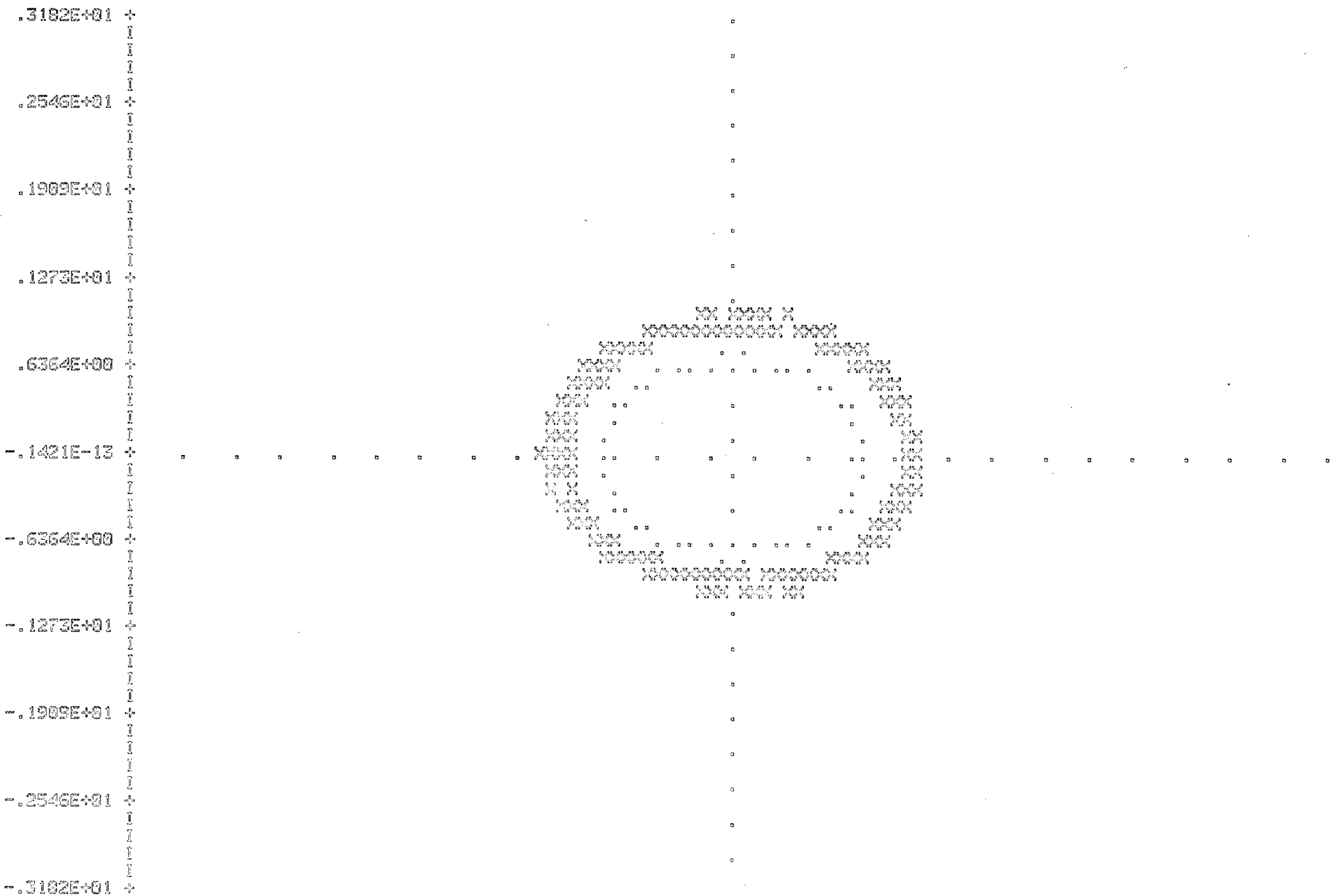
Fig. 4

INITIAL PARAMETERS OF PARTICLE #1 XA = .499E+01MM XPA = 0. MM YA = .208E+01MM YPA = 0. MR  
 BETATRON AMPLITUDES = IN X : .100E+02 SIGMA IN Y : .100E+02 SIGMA ENERGY DEVIATION = 0. SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I I I I I I I  
 -0.3182E+01 -0.1909E+01 -0.6364E+00 -0.6364E+00 .1909E+01 0.3182E+01  
 0 POINTS OUTSIDE DIAGRAM NMIN = -0.2316E+01 NMAX = 0.2308E+01 NUN(13) = 1 SORT(BETV) = 2.9491

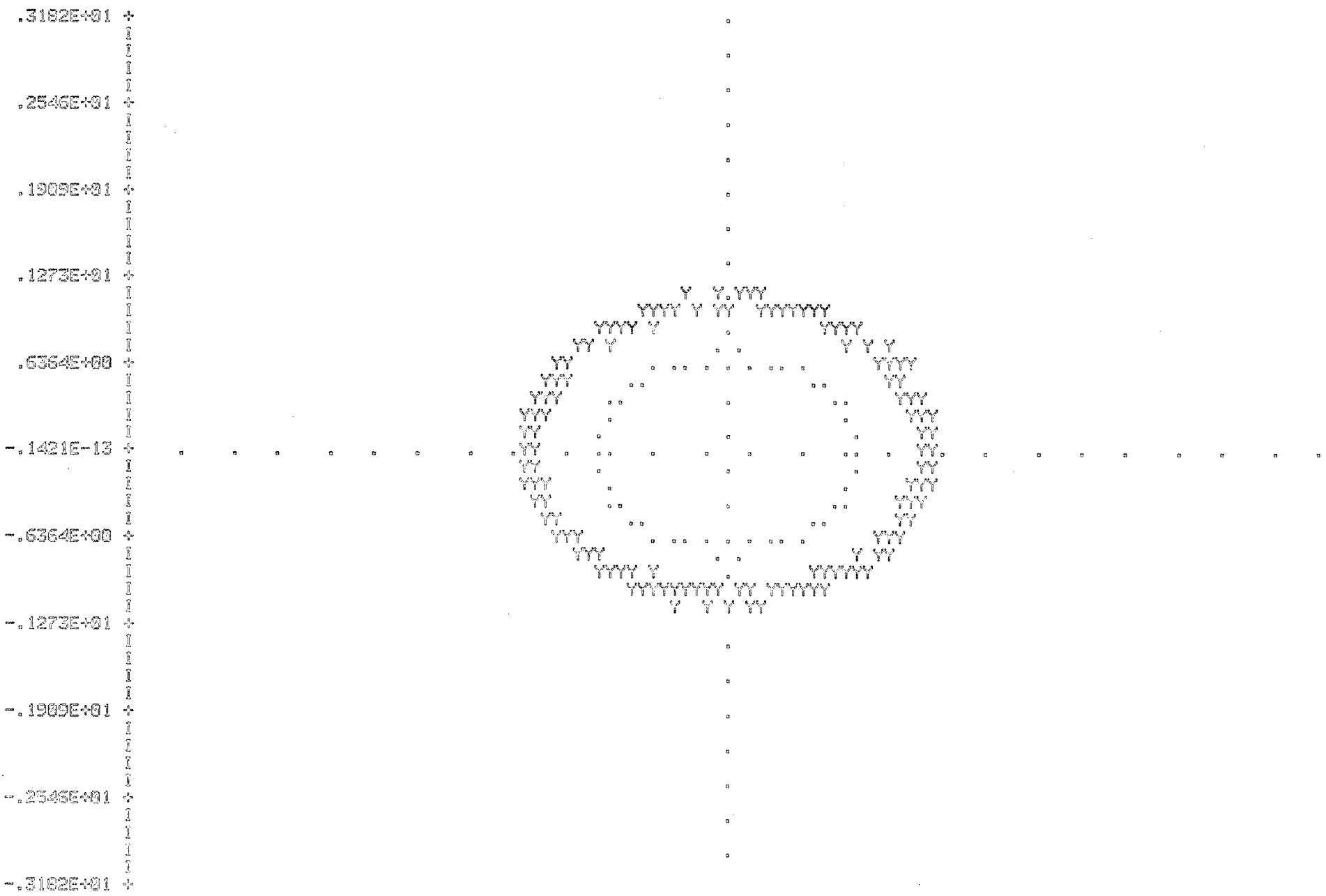
INITIAL PARAMETERS OF PARTICLE C2 XA = .705E+01MM XPA = 0. MM YA = .294E+01MM YPA = 0. MR  
 BETATRON AMPLITUDES = IN X : .141E+02 SIGMA IN Y : .141E+02 SIGMA ENERGY DEVIATION = 0. SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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I	I	I	I	I	I	I
-3.182E+01	-1.909E+01	-6.364E+00	6.364E+00	1.909E+01	3.182E+01	
0	POINTS OUTSIDE DIAGRAM	XMIN = -.7149E+01	XMAX = .7001E+01	NUM(I) = 1	SORT(IGETS) =	7.0513

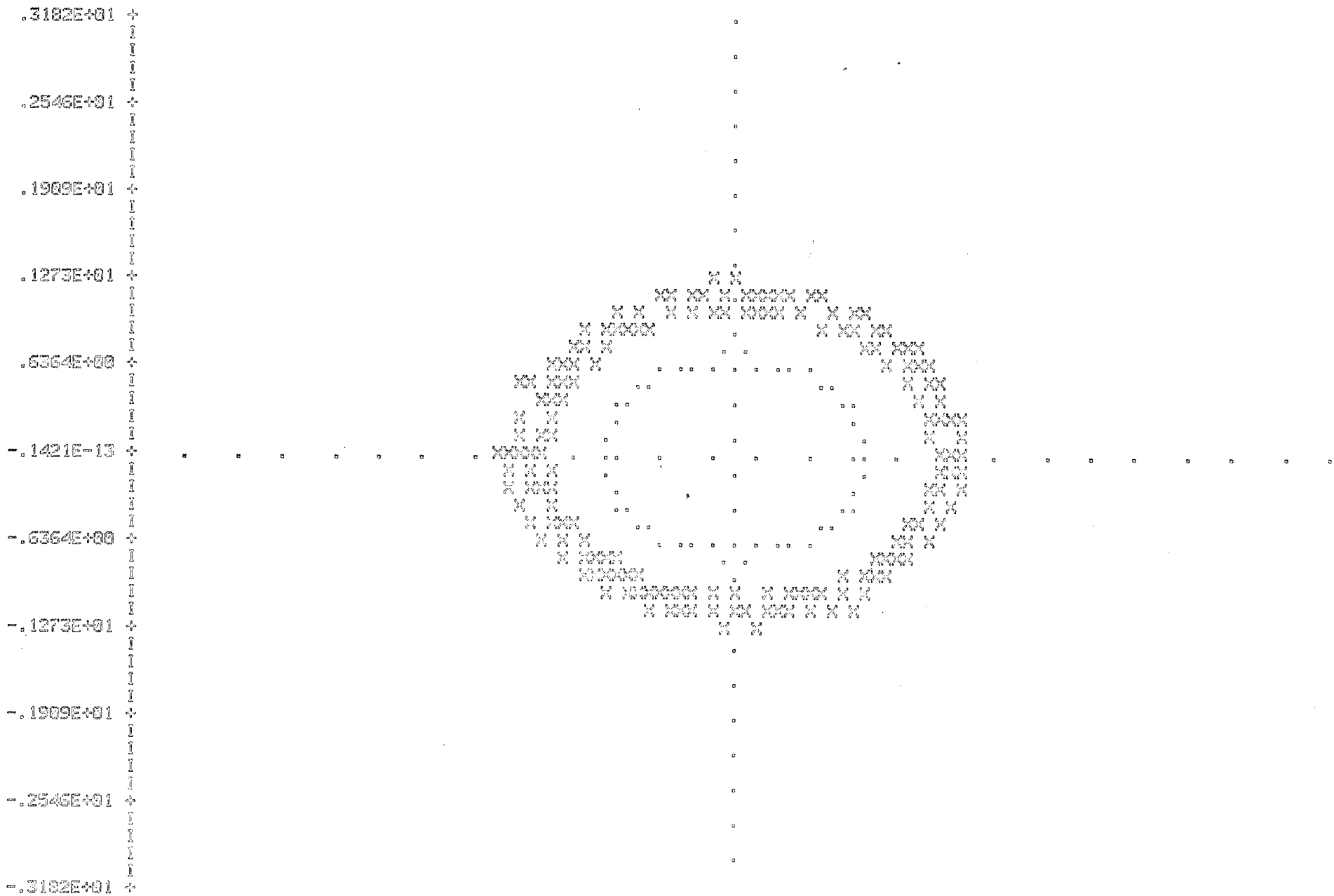
INITIAL PARAMETERS OF PARTICLE #2     $X_A = .705E+01$ MM     $XPA = 0.$ MM     $Y_A = .294E+01$ MM     $YPA = 0.$ MM     $\sigma$  AT 30.00 GEV  
 BETATRON AMPLITUDES = IN X :  $.141E+02$  SIGMA    IN Y :  $.141E+02$  SIGMA    ENERGY DEVIATION = 0.  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 - .3182E+01                    - .1909E+01                    - .6364E+00                    - .6364E+00                    .1909E+01                    .3182E+01  
 0 POINTS OUTSIDE DIAGRAM    MIN = - .5298E+01                    MAX = .5278E+01                    KW(13) = 1                    SORT(BET) = 2.9451

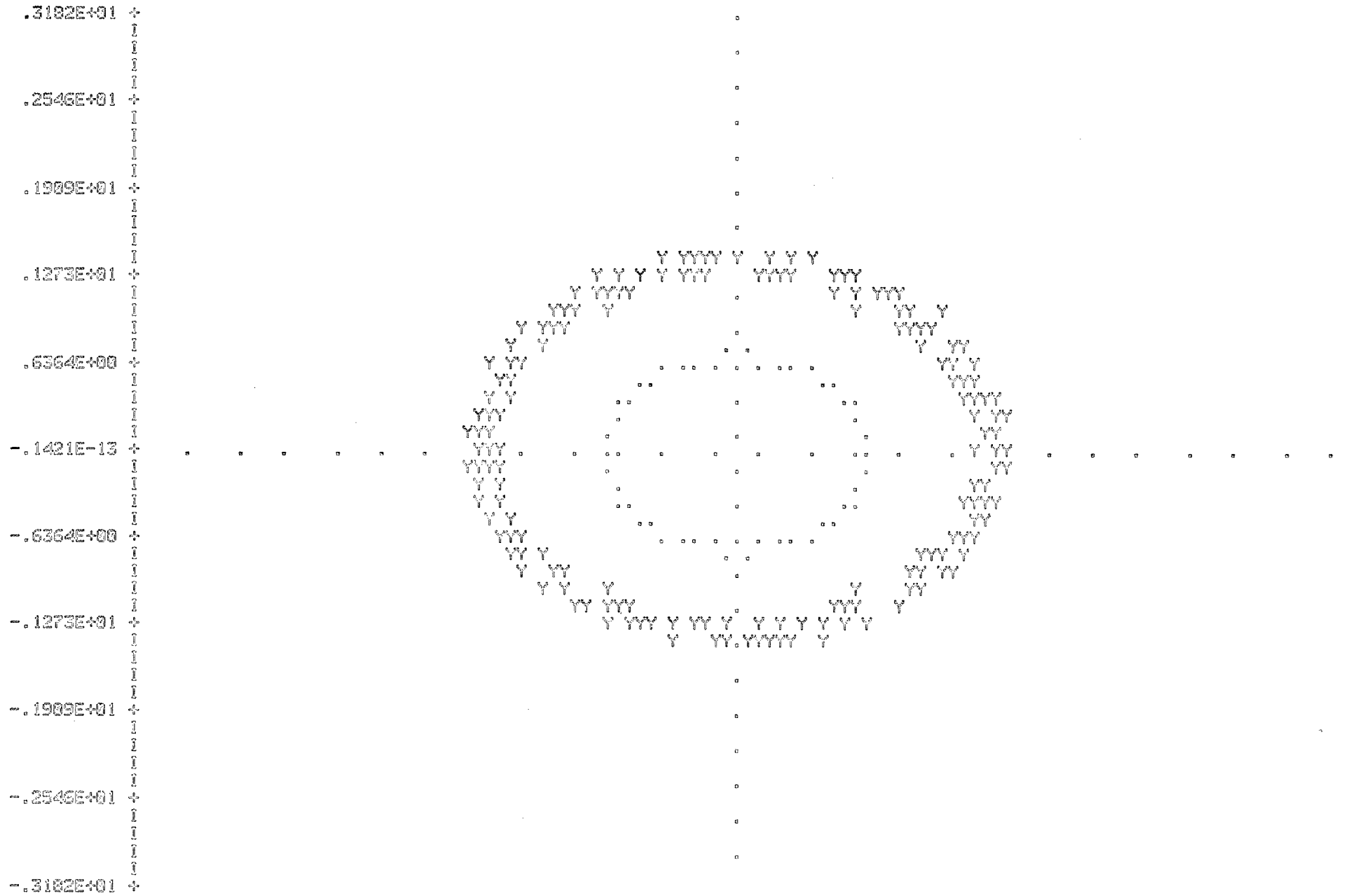
INITIAL PARAMETERS OF PARTICLE 03 MA = .864E+01MM XPA = 0.  
 BETATRON AMPLITUDES = IN X: .173E+02 SIGMA IN Y: .173E+02 SIGMA  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS

MM YA = .360E+01MM YPA = 0. MR  
 ENERGY DEVIATION = 0. SIGMA AT 30.00 GEV




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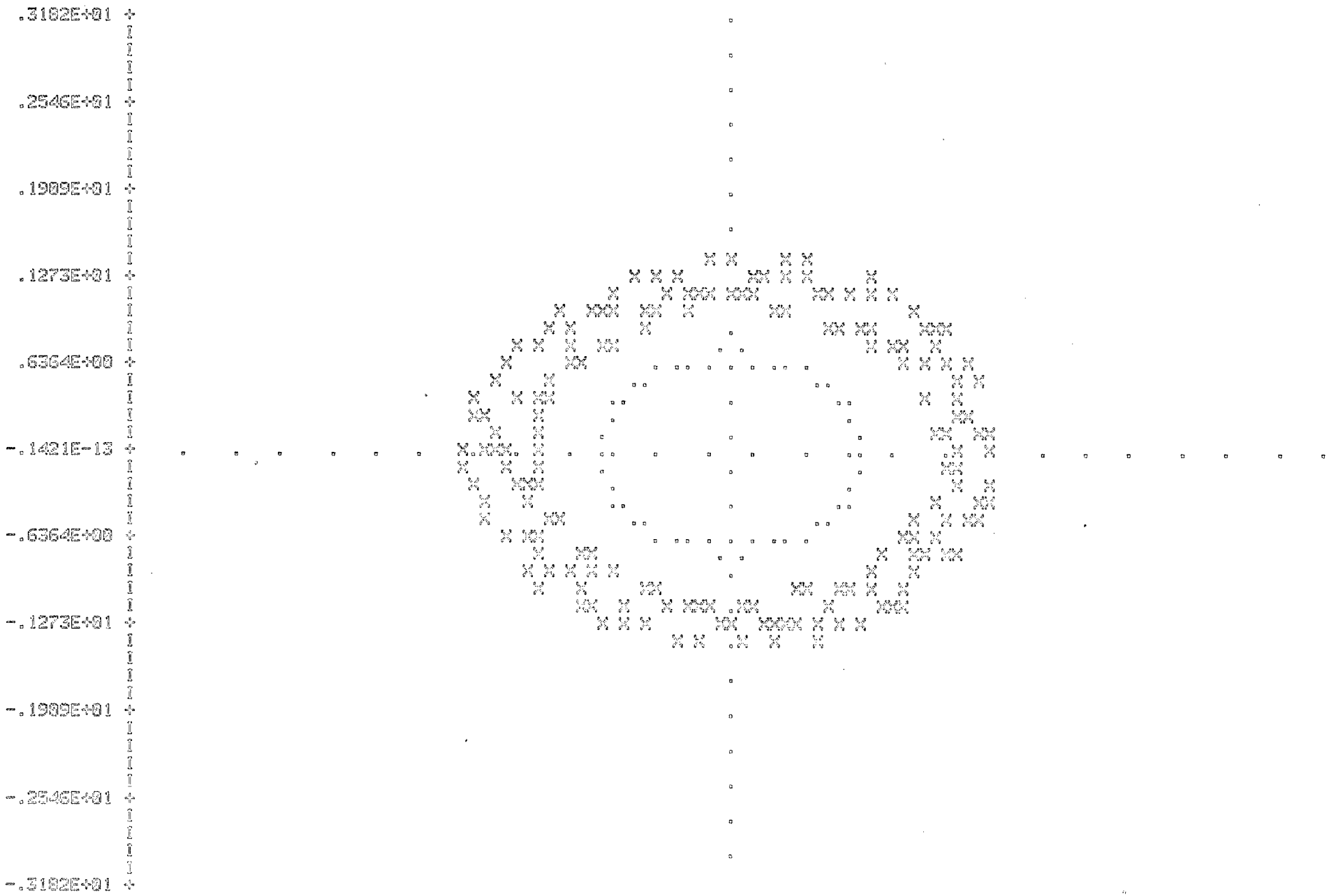
I	I	I	I	I	I	I
- .3182E+01	- .1909E+01	- .6364E+00	.6364E+00	.1909E+01	.3182E+01	
0	POINTS OUTSIDE DIAGRAM	MIN = -.8781E+01	MAX = .8571E+01	KM(13) = 1	80RT(BETX) = 7.0513	



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 I                            I                            I                            I                            I                            I  
 -0.3182E+01    -0.1909E+01    -0.6364E+00    0.6364E+00    0.1909E+01    0.3182E+01  
 0 POINTS OUTSIDE DIARRH    NMIN = -0.4227E+01    NMAX = 0.4221E+01    NM(13) = 1    SORT(BETV) = 2.8451



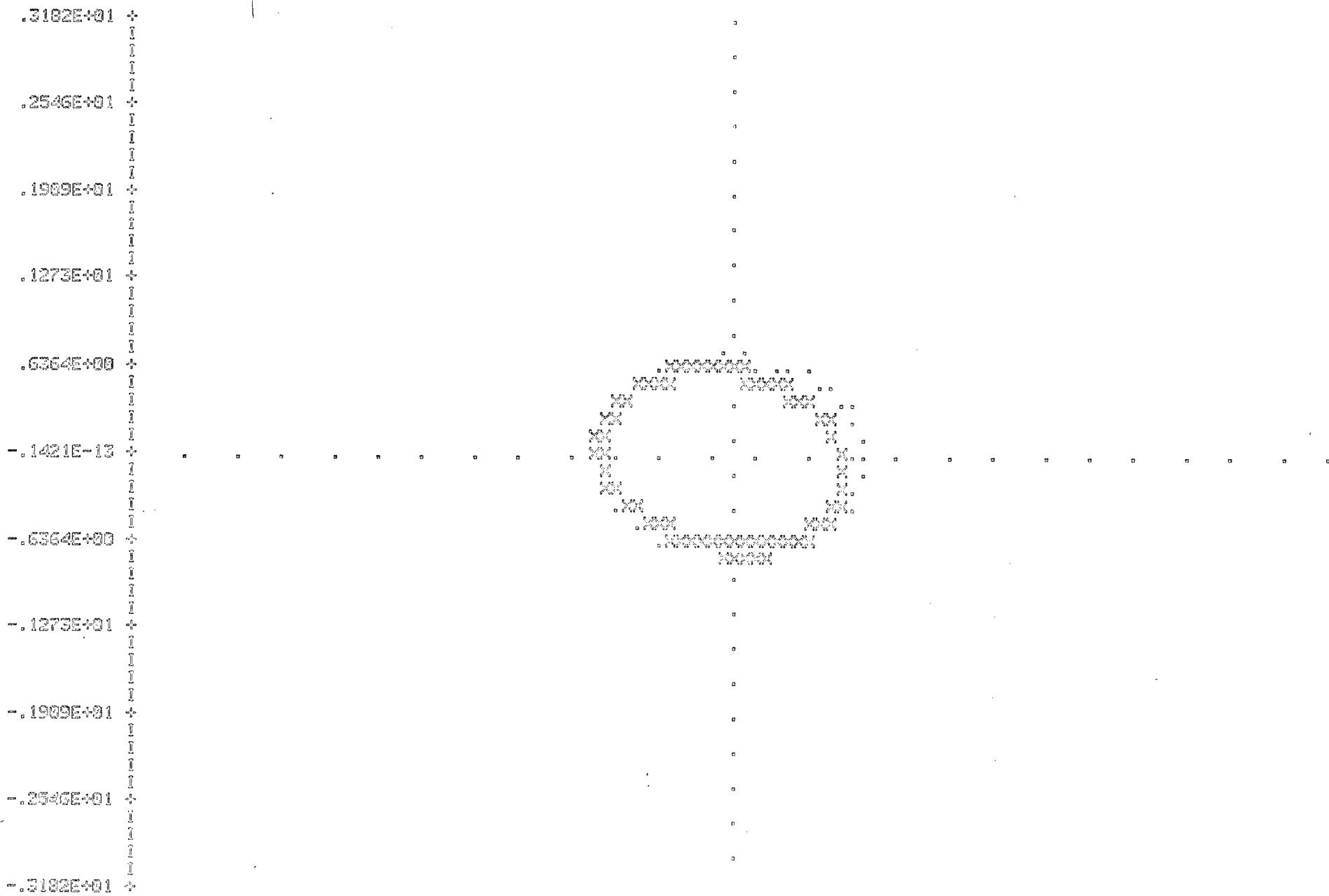
INITIAL PARAMETERS OF PARTICLE #4    XA = .997E+01MM    XPA = 0.    MM    YA = .416E+01MM    YPA = 0.    MR  
 BETATRON AMPLITUDES = IN X : .200E+02 SIGMA    IN Y : .200E+02 SIGMA    ENERGY DEVIATION = 0.    SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 -0.3182E+01                    -0.1909E+01                    -0.6364E+00                    0.6364E+00                    0.1909E+01                    0.3182E+01  
 6 POINTS OUTSIDE DIAGRAM    XMIN = -0.1017E+02    XMAX = 0.2880E+01    NUC(13) = 1    SORT(BET7) = 7.5512



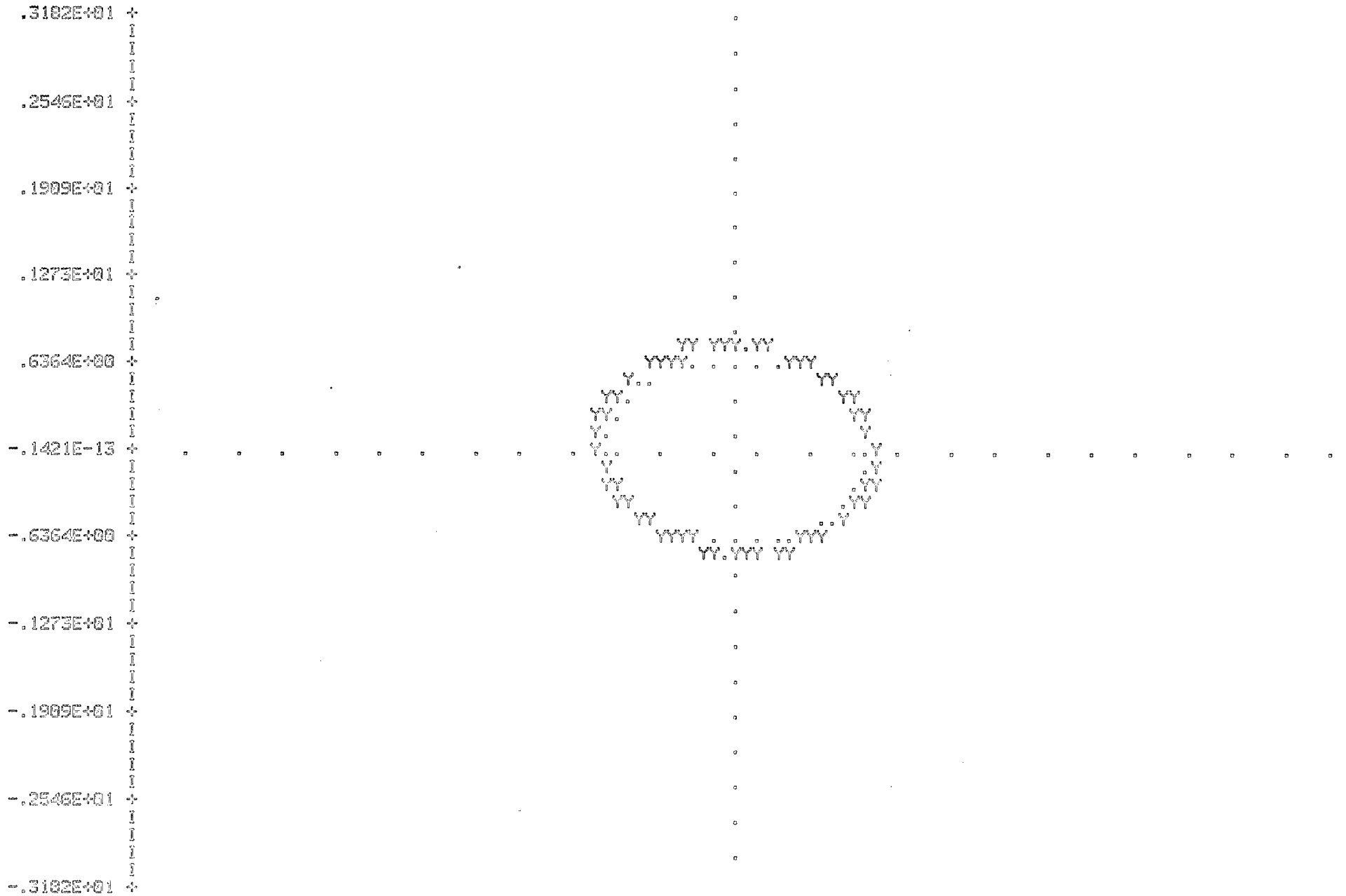
INITIAL PARAMETERS OF PARTICLE #1 XA = .211E+02MM XPA = -.402E-02MM YA = .266E+01MM YPA = 0. NR  
 BETATRON AMPLITUDES = IN X : .100E+02 SIGMA IN Y : .100E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



I I I I I I  
 -0.1331E+01 -0.5966E-01 0.1214E+01 0.2487E+01 0.3760E+01 0.5033E+01  
 N POINTS OUTSIDE DIAGRAM NMIN = 0. NMAX = .1908E+02 NW(13) = 1 SORT(BETN) = 8.1532

Fig. 5

INITIAL PARAMETERS OF PARTICLE #1    XA = .211E+02MM    XPA = -.492E-02MM    YA = .266E+01MM    YPA = 0.    MR  
 BETATRON AMPLITUDES = IN X : .100E+02 SIGMA    IN Y : .100E+02 SIGMA    ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS

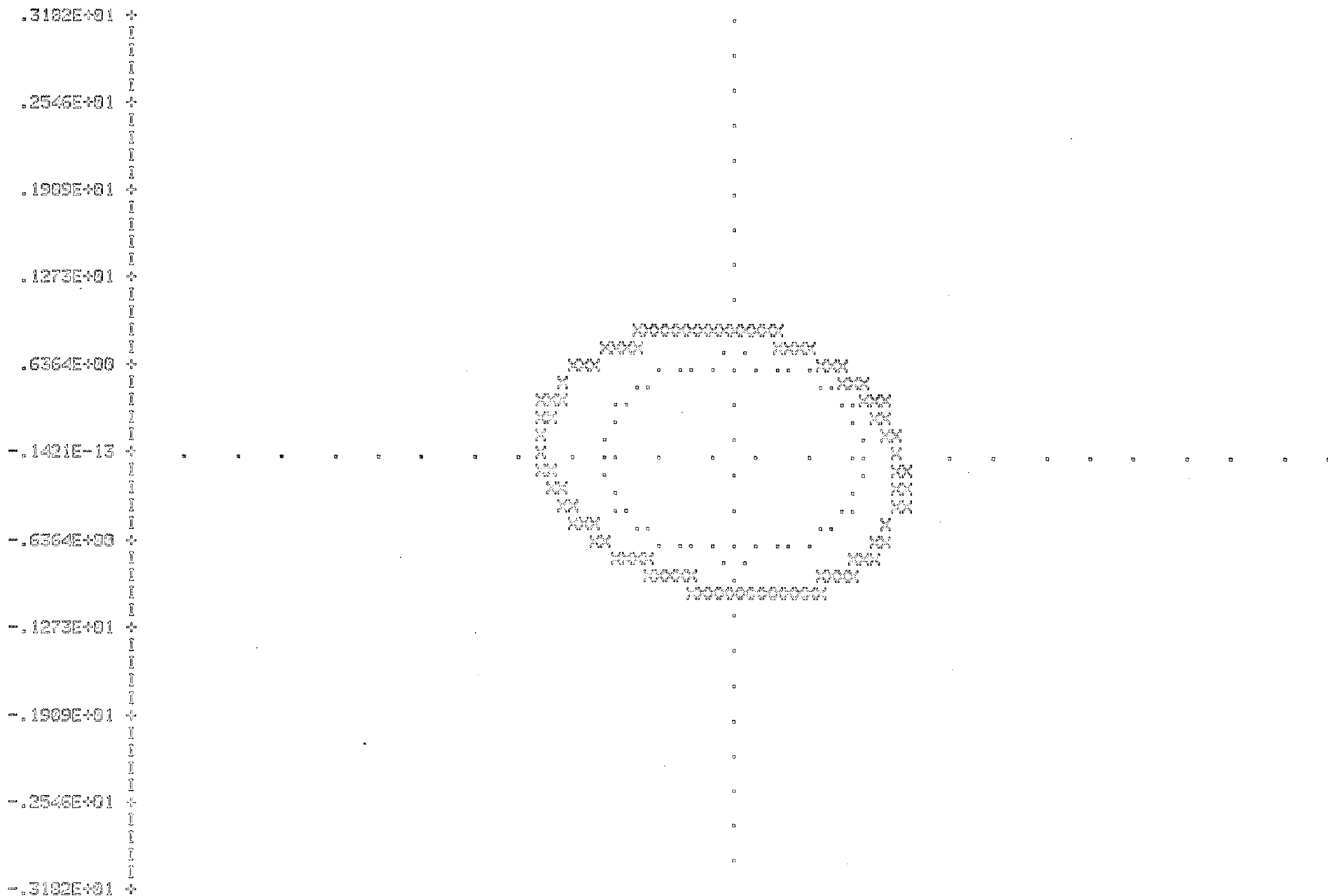



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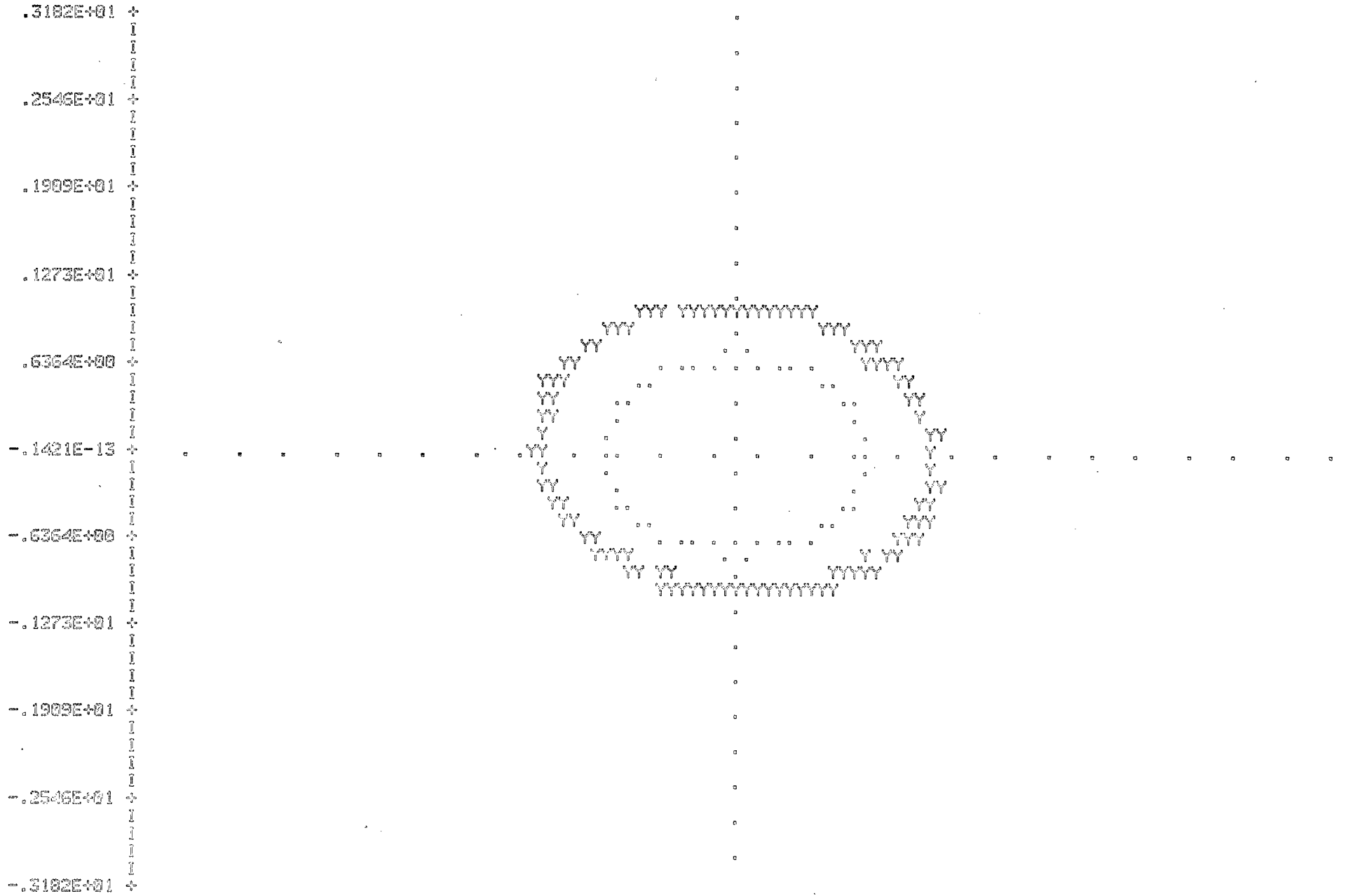
-0.3182E+01	-0.1909E+01	-0.6364E+00	0.6364E+00	0.1909E+01	0.3182E+01
0 POINTS OUTSIDE DIAGRAM	MIN = -0.2730E+01	MAX = 0.2713E+01	KW(15) = 1	SOPT(BETY) =	3.6551

INITIAL PARAMETERS OF PARTICLE #2    XA = .235E+02MM    XPA = -.492E-02MM    YA = .376E+01MM    YPA = 0.    MR  
 BETATRON AMPLITUDES = IN X : .141E+02 SIGMA    IN Y : .141E+02 SIGMA    ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



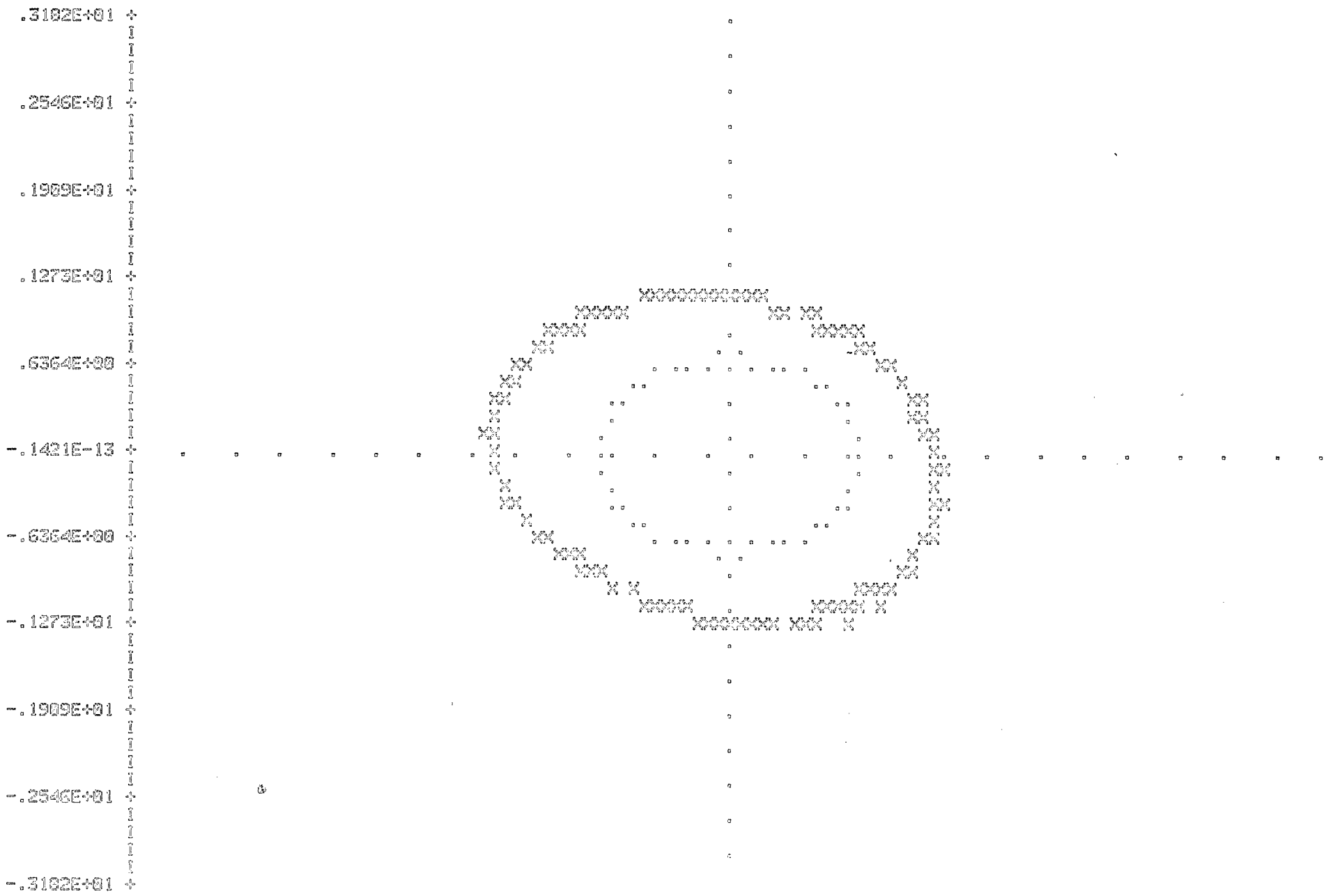
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 I                                    I                                    I                                    I                                    I                                    I  
 -.1331E+01                                    -.5066E-01                                    .1214E+01                                    .2497E+01                                    .3700E+01                                    .5033E+01  
 0 POINTS OUTSIDE DIAGRAM    NMIN = 0.    NMAX = .2208E+02    KNU(13) = 1    SORT(BET) = 8.1532

INITIAL PARAMETERS OF PARTICLE #2    XA = .235E+02MM    XPA = -.402E-02MM    YA = .376E+01MM    YPA = 0.    MR  
 BETATRON AMPLITUDES = IN X : .141E+02 SIGMA    IN Y : .141E+02 SIGMA    ENERGY DEVIATION = .100E+01 SIGMA AT 39.00 BEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



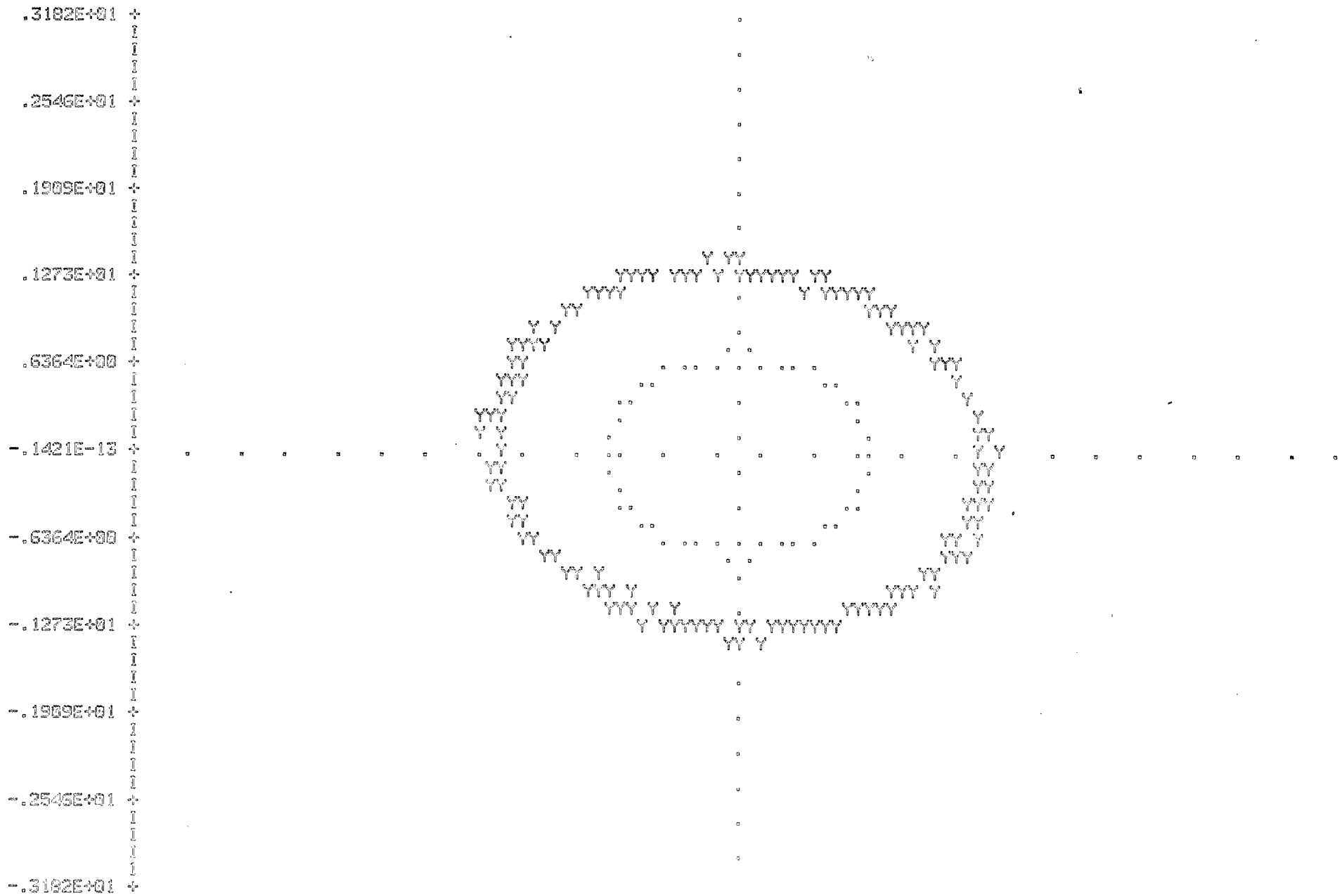
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 - .3182E+01                    - .1909E+01                    - .6364E+00                    .6364E+00                    .1909E+01                    .3182E+01  
 0    POINTS OUTSIDE DIAGRAM    NMIN = -.3930E+01                    NMAX = .3930E+01                    NM(12) = 1                    SORT(BETY) = 5.6551

INITIAL PARAMETERS OF PARTICLE 63    XA = .253E+02MM    XPA = -.482E-02MM    YA = .460E+01MM    YPA = 0.    MR  
 BETATRON AMPLITUDES = IN X : .173E+02 SIGMA    IN Y : .173E+02 SIGMA    ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I                            I                            I                            I                            I                            I  
 -0.1831E+01                    -0.5866E-01                    0.1214E+01                    0.2487E+01                    0.3760E+01                    0.5853E+01  
 0    POINTS OUTSIDE DIAGRAM    XMIN = 0.                    XMAX = 0.2486E+02                    MAX(Z) = 1                    SQR(BETX) = 0.1533

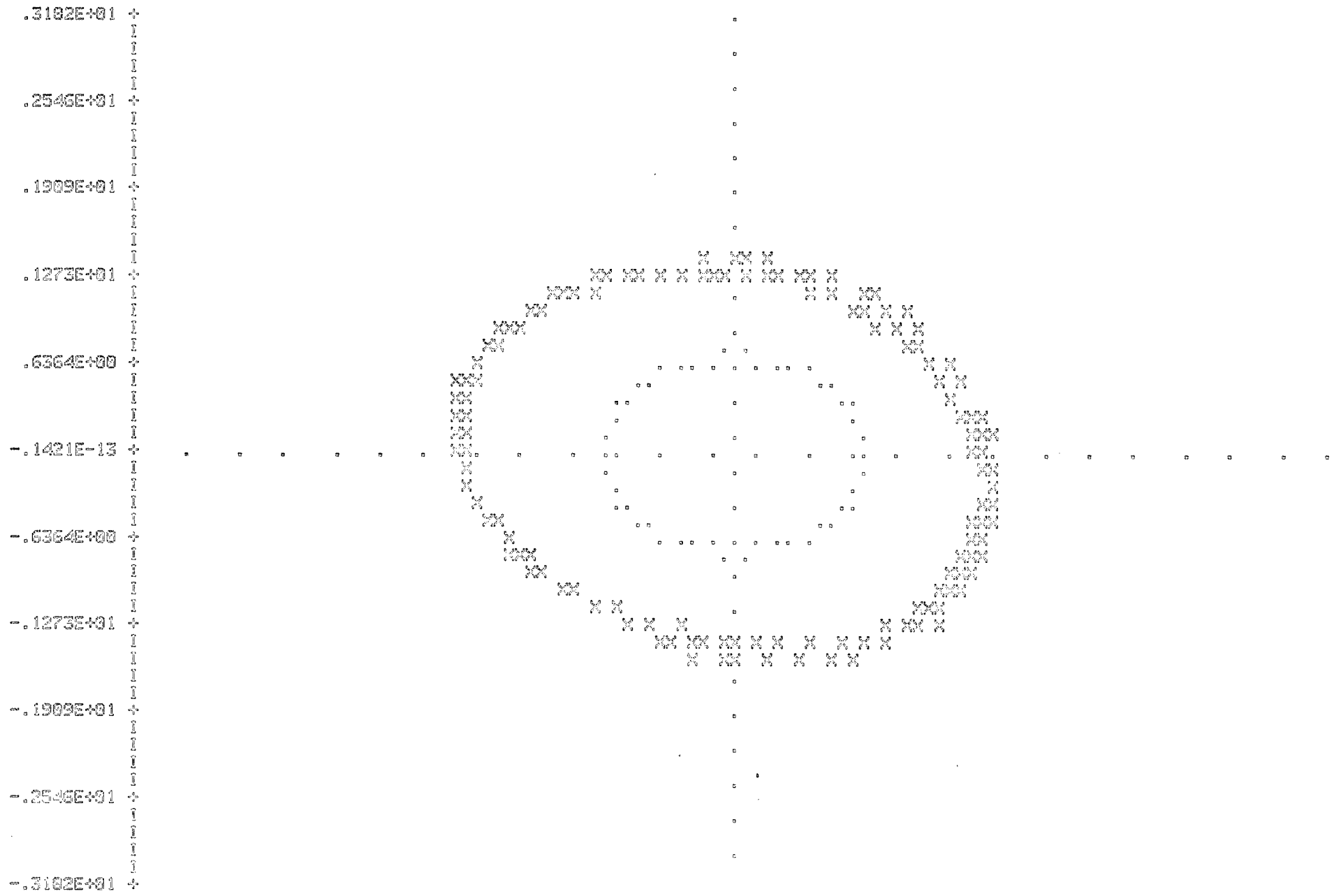
INITIAL PARAMETERS OF PARTICLE #3    XA = .253E+02MM    XPA = -.482E-02MM    YA = .460E+01MM    YPA = 0.    NR  
 BETATRON AMPLITUDES = IN X : .173E+02 SIGMA    IN Y : .173E+02 SIGMA    ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I                                    I                                    I                                    I                                    I  
 -0.3182E+01                    -0.1909E+01                    -0.6364E+00                    -0.6364E+00                    0.1909E+01                    0.3182E+01  
 0 POINTS OUTSIDE DIAGRAM    XMIN = -.4895E+01    XMAX = .4874E+01    NW(13) = 1    SORT(BETY) = 3.6551

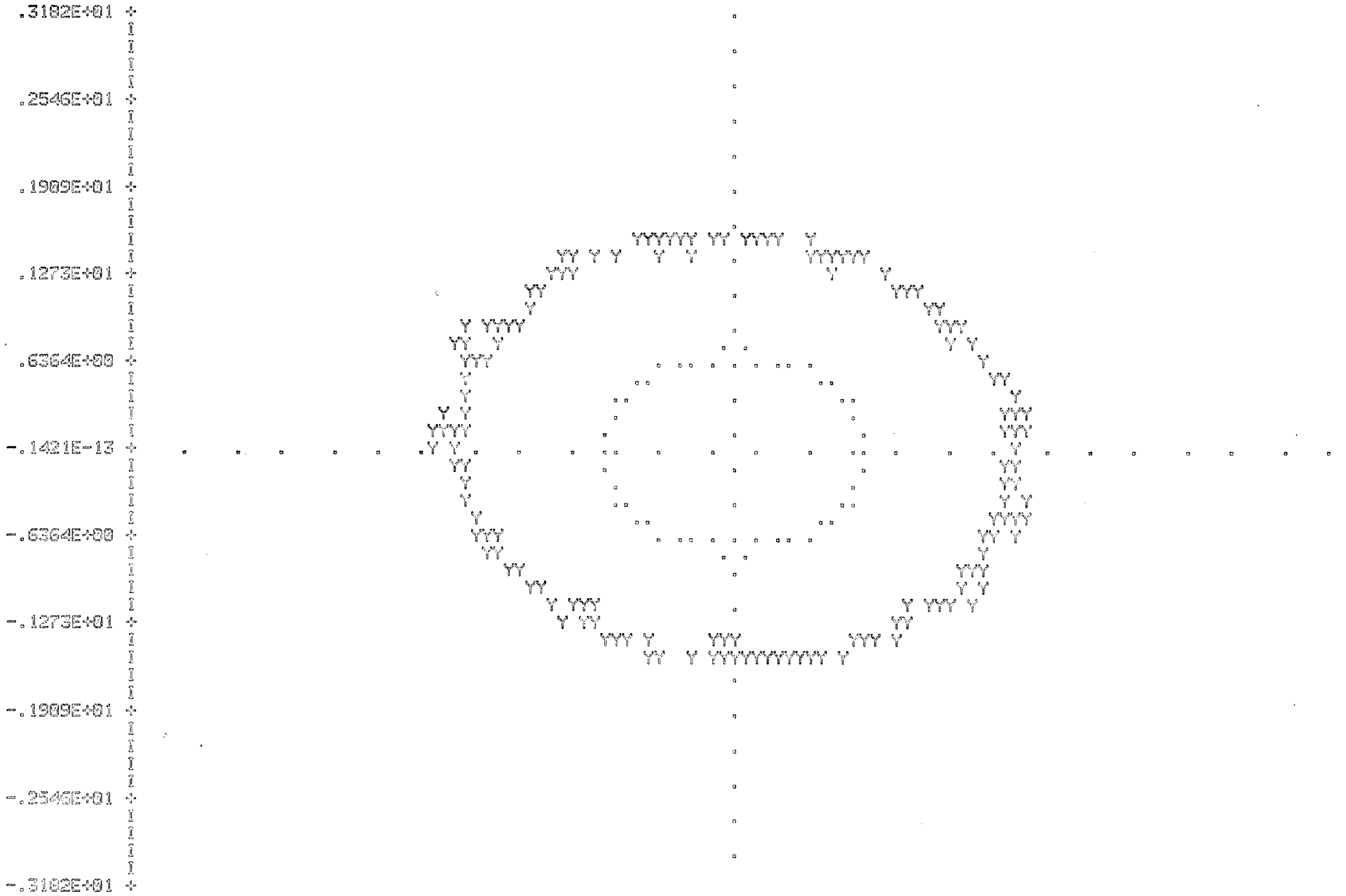


INITIAL PARAMETERS OF PARTICLE #4 XA = .268E+02MM XPA = -.482E-02MM YA = .531E+01MM YPA = 0. PR  
 BETATRON AMPLITUDES = IN X : .200E+02 SIGMA IN Y : .200E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



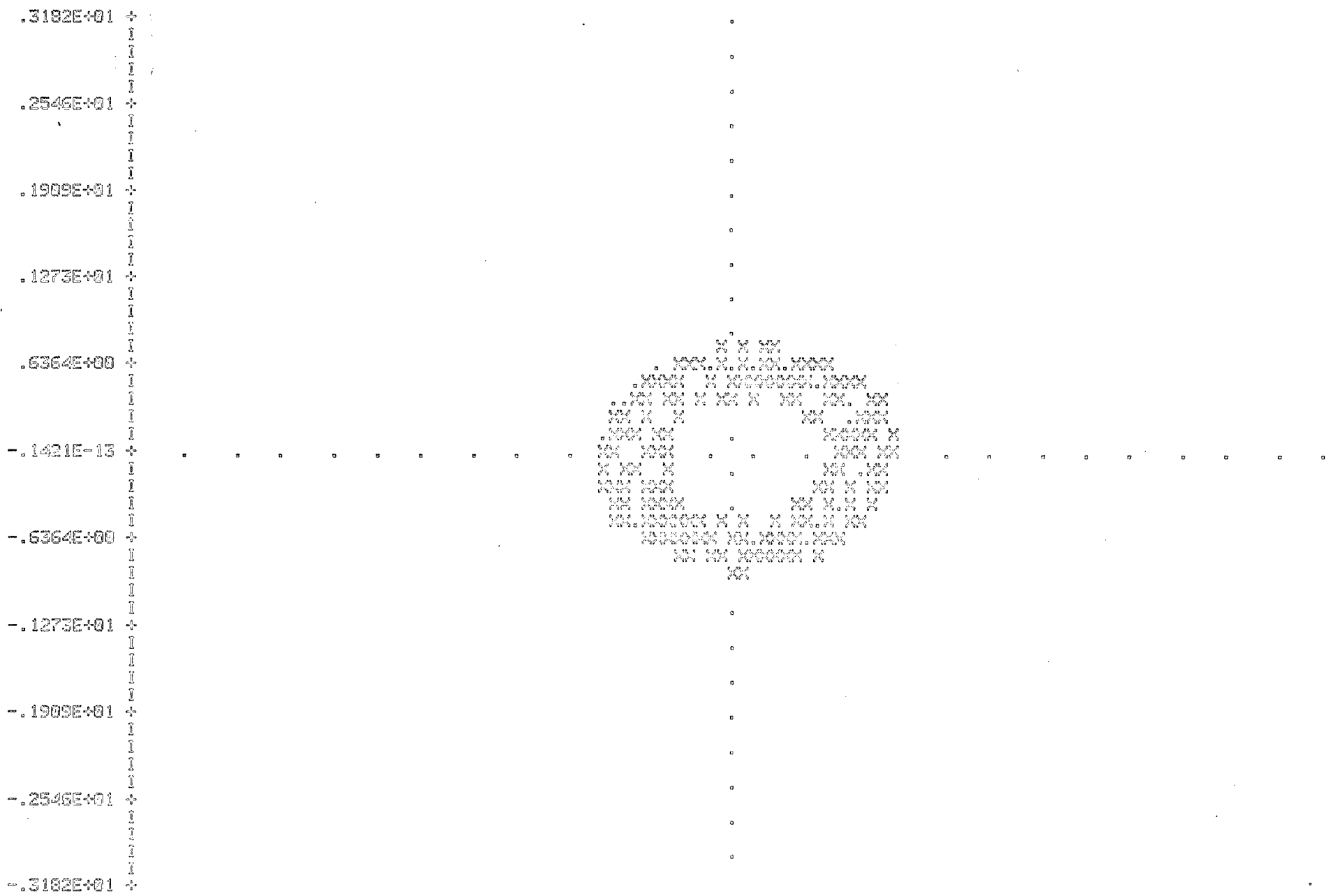
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 I I I I I I I  
 -.1331E+01      -.5966E-01      .1214E+01      .2497E+01      .3760E+01      .5033E+01  
 0 POINTS OUTSIDE DIAGRAM      MIN = 0.      MAX = .2636E+02      NK(13) = 1      SORT(OBTR) = 0.1532

INITIAL PARAMETERS OF PARTICLE #4 MA = .269E+02MM XPA = -.402E-02MM YA = .531E+01MM YPA = 0. MR  
 BETATRON AMPLITUDES = IN X : .200E+02 SIGMA IN Y : .200E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I I I I I I I  
 -.3182E+01 -.1909E+01 -.6364E+00 -.6364E+00 .1909E+01 .3182E+01  
 O POINTS OUTSIDE DIAGRAM NMIN = -.98-9E+01 NMAX = .5796E+01 NUN(13) = 1 SORT(BETY) = 3.6551

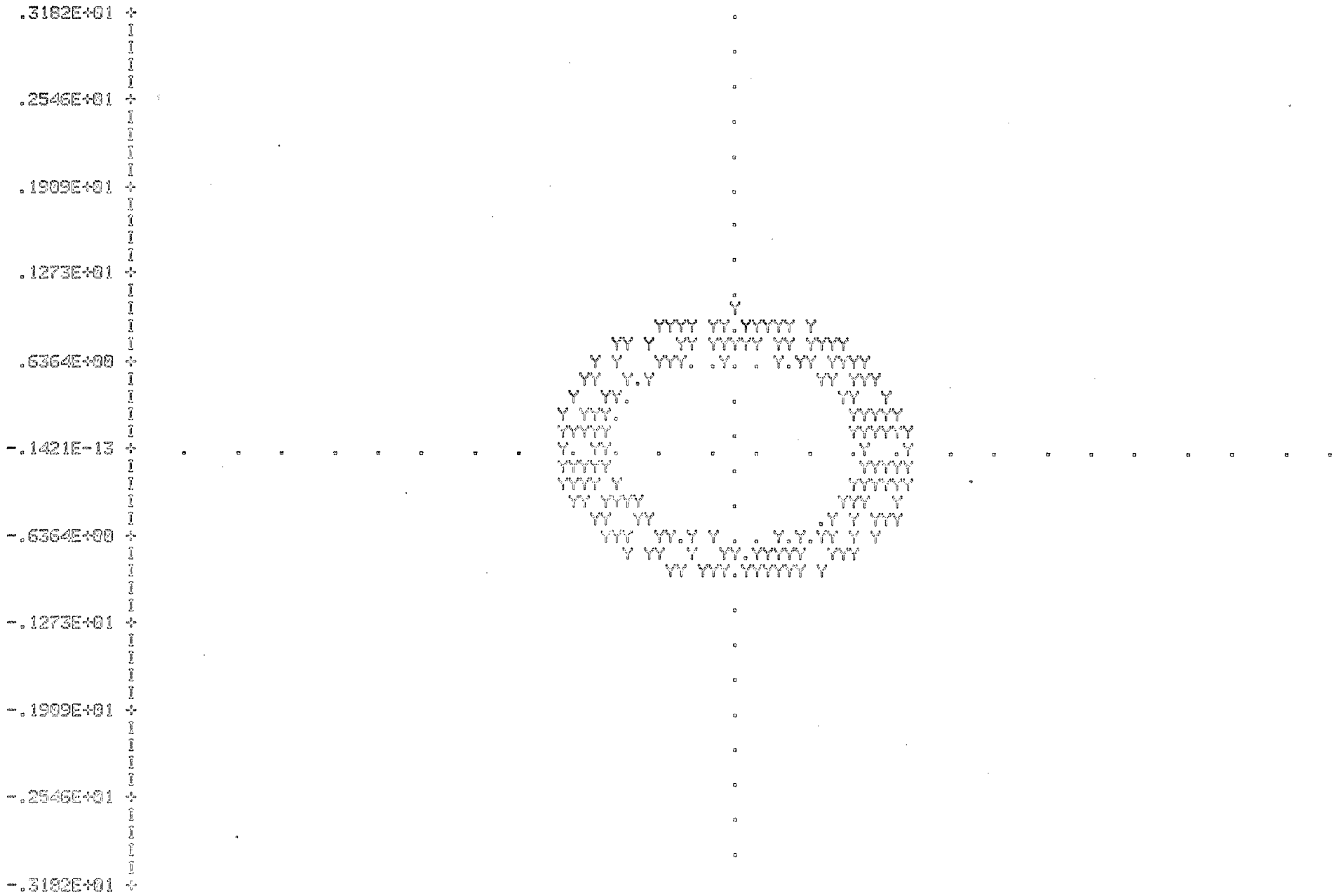
INITIAL PARAMETERS OF PARTICLE 01 MA = -.991E+01MM XPA = .996E-02MM YA = .156E+01MM YPA = 0. MR  
 BETATRON AMPLITUDES = IN X: .100E+02 SIGMA IN Y: .100E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I I I I I I I  
 -0.5982E+01 -0.4710E+01 -0.3437E+01 -0.2164E+01 -0.0913E+00 .3819E+02  
 0 POINTS OUTSIDE DIAGRAM XMIN = -0.2981E+02 XMAX = 0. NUM(15) = 1 SORT(BETA) = 5.9311

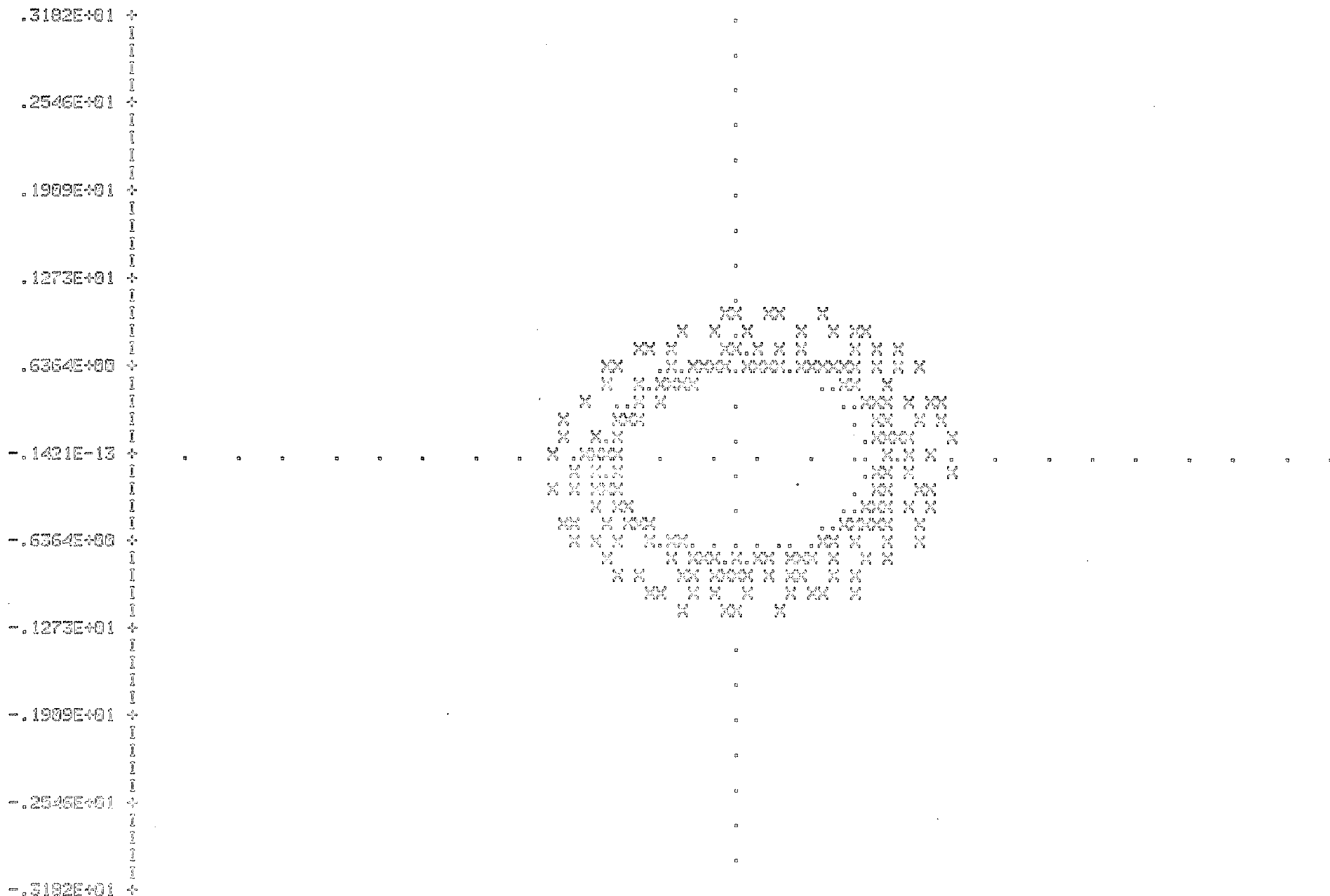
Fig. 6

INITIAL PARAMETERS OF PARTICLE #1 XA = -.991E+01MM XPA = .996E-02MM YA = .156E+01MM YPA = 0. MR  
 BETATRON AMPLITUDES = IN X : .100E+02 SIGMA IN Y : .100E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



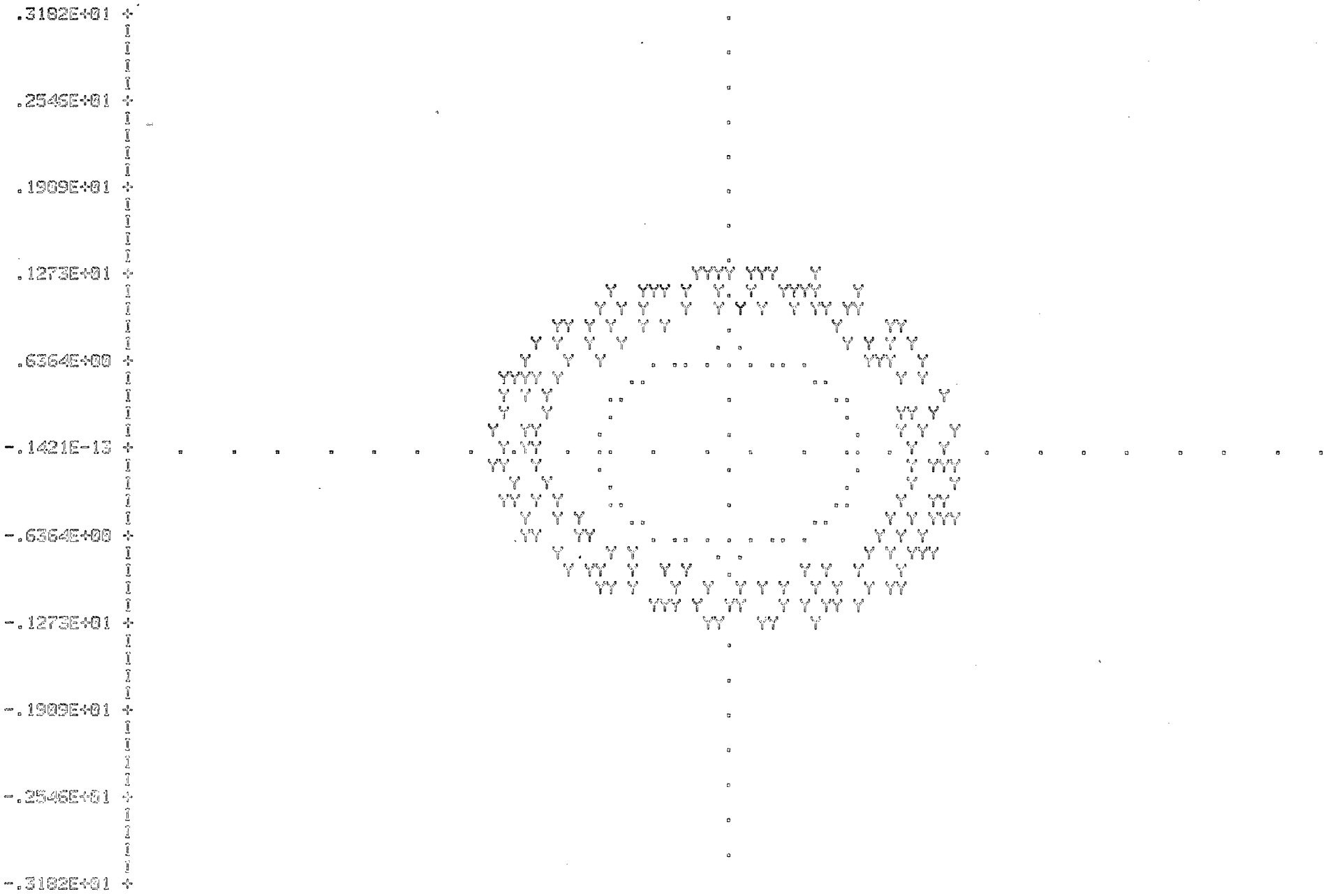
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 I I I I I I I  
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 .1909E+01 3.182E+01  
 0 POINTS OUTSIDE DIBERAN XMIN = -.2156E+01 XMAX = .2164E+01 KMC(13) = 1 SORT(BETY) = 2.2787

INITIAL PARAMETERS OF PARTICLE #2 XA = -.917E+01MM XPA = .996E-02MM YA = .220E+01MM YPA = 0. NR  
 BETATRON AMPLITUDES = IN X : .141E+02 SIGMA IN Y : .141E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



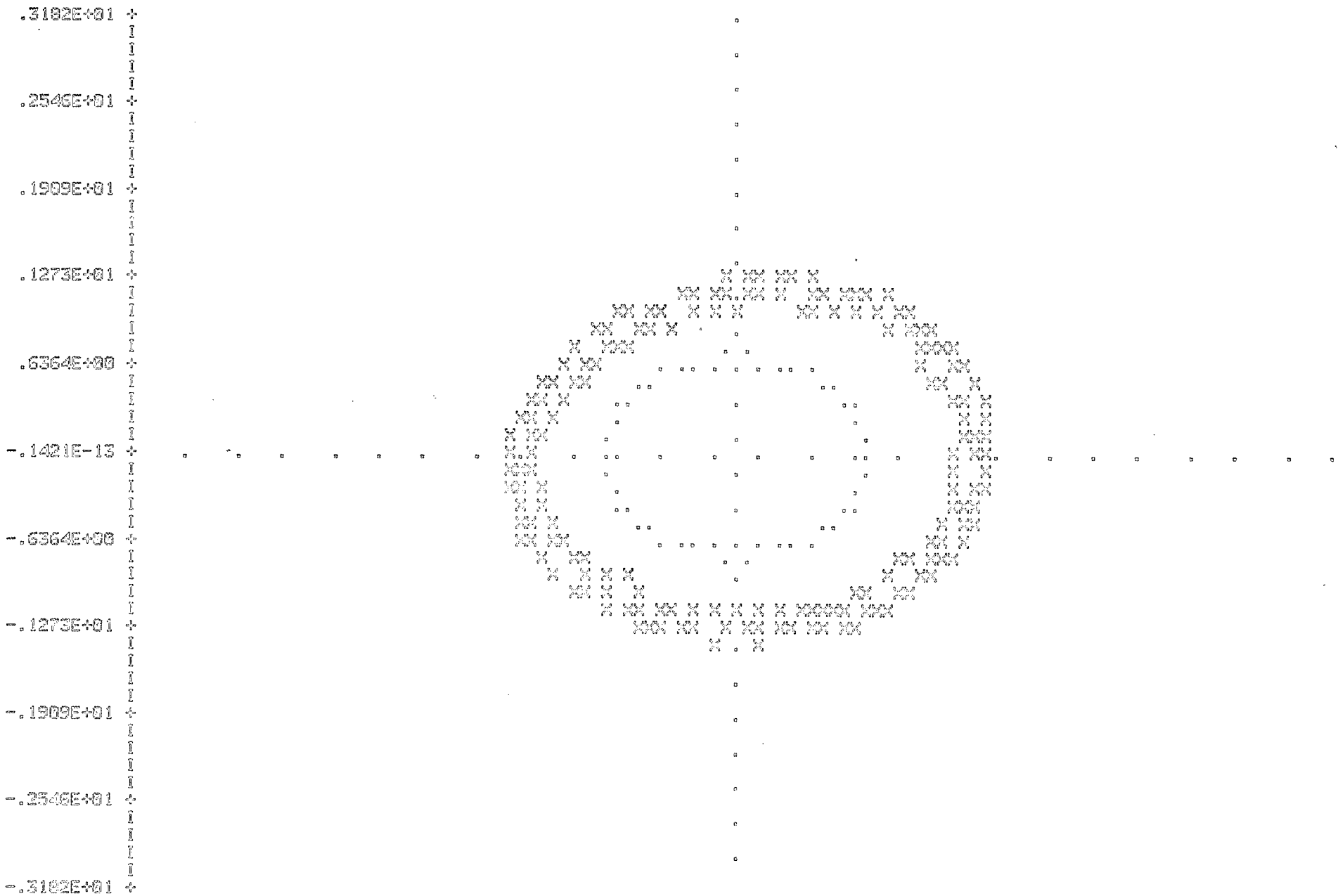
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 I I I I I I I  
 -.5992E+01 -.4710E+01 .2457E+01 -.2164E+01 -.8913E+00 .3815E+00  
 0 POINTS OUTSIDE DIAGRAM MIN = -.2357E+02 MAX = 0. NUM(15) = 1 PART(BET0) = 5.9311

INITIAL PARAMETERS OF PARTICLE #2 XA = -.817E+01MM XPA = .996E-02MM YA = .220E+01MM YPA = 0. MR  
 BETATRON AMPLITUDES = IN X : .141E+02 SIGMA IN Y : .141E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



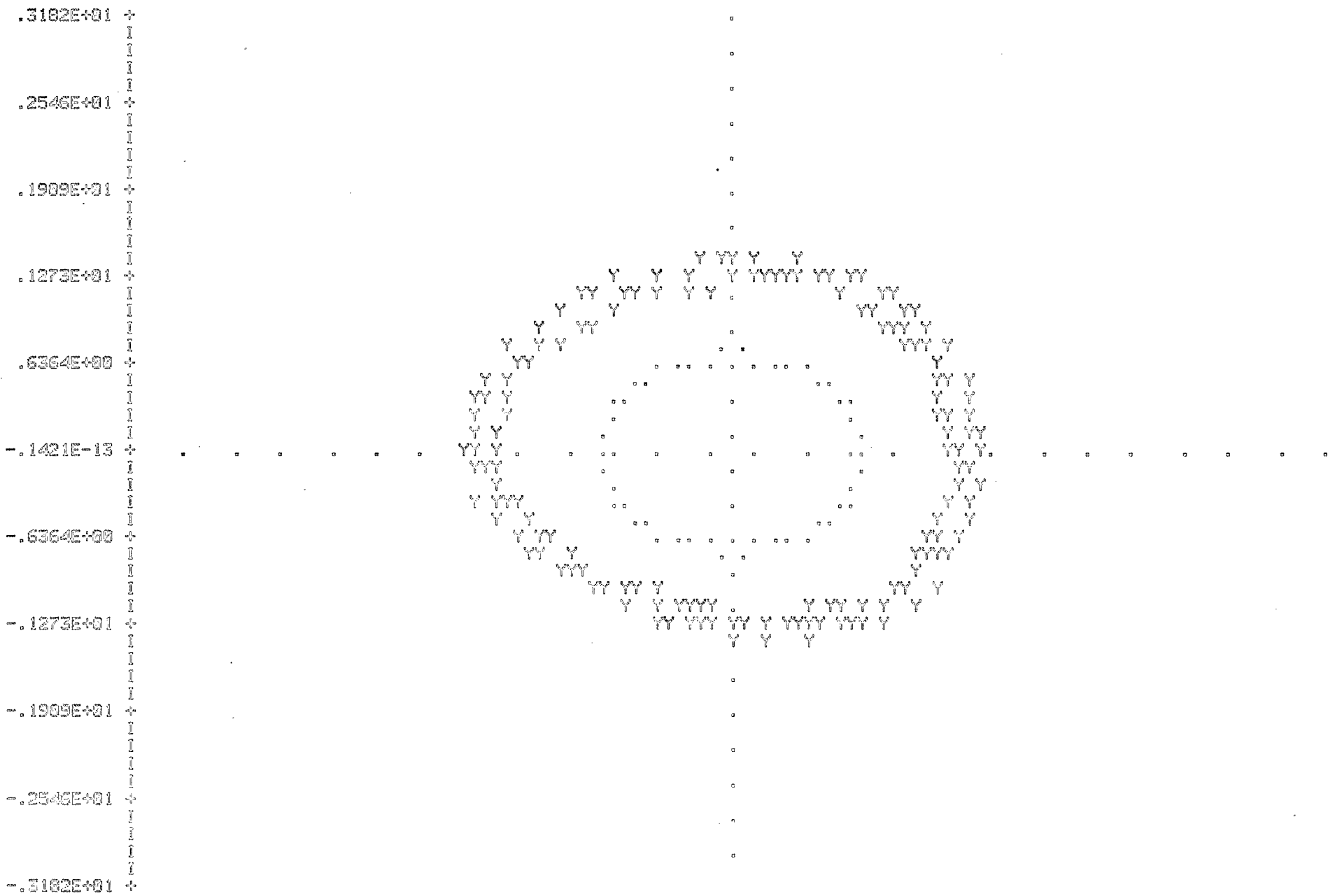
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 I I I I I I I  
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 1.909E+01 3.182E+01  
 0 POINTS OUTSIDE DIAGRAM XMIN = -.2952E+01 XMAX = .3227E+01 KLV(13) = 1 SORT(BETY) = 2.2787

INITIAL PARAMETERS OF PARTICLE 63    XA = -.683E+01MM    XPA = .996E-02MM    YA = .270E+01MM    YPA = 0.    MR  
 BETATRON AMPLITUDES - IN X : .173E+02 SIGMA    IN Y : .173E+02 SIGMA    ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



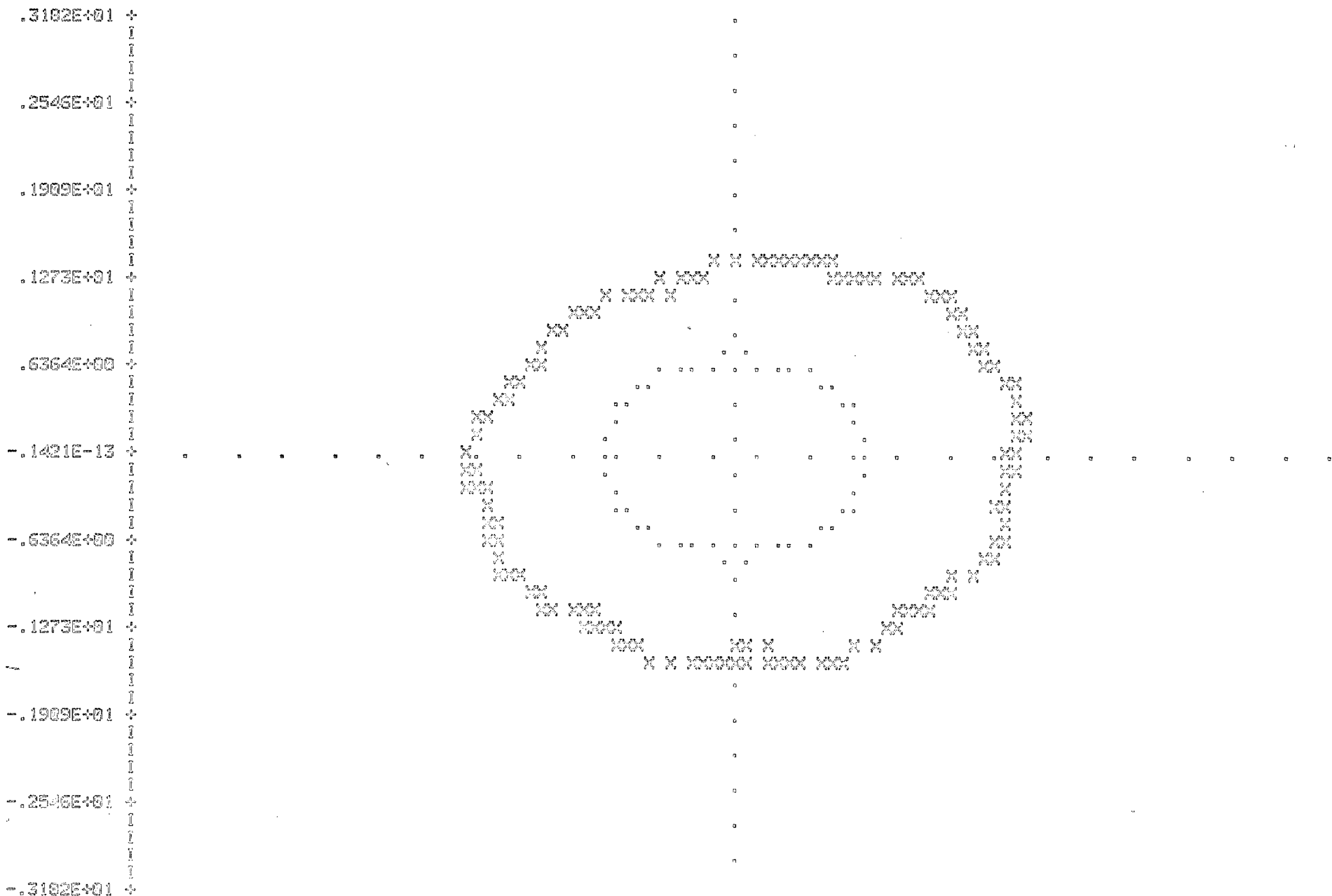
I	I	I	I	I	I
-.5992E+01	-.4710E+01	-.3437E+01	-.2164E+01	-.8913E+00	.3815E+00
0	POINTS OUTSIDE DIAGRAM	XMIN = -.2334E+02	XMAX = 0.	NUM(I) = 1	SORT(BETD) = 5.9311

INITIAL PARAMETERS OF PARTICLE #3 X0 = -.683E+01MM XPA = .996E-02MM YA = .270E+01MM YPA = 0. NR  
 BETATRON AMPLITUDES = IN X : .173E+02 SIGMA IN Y : .173E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



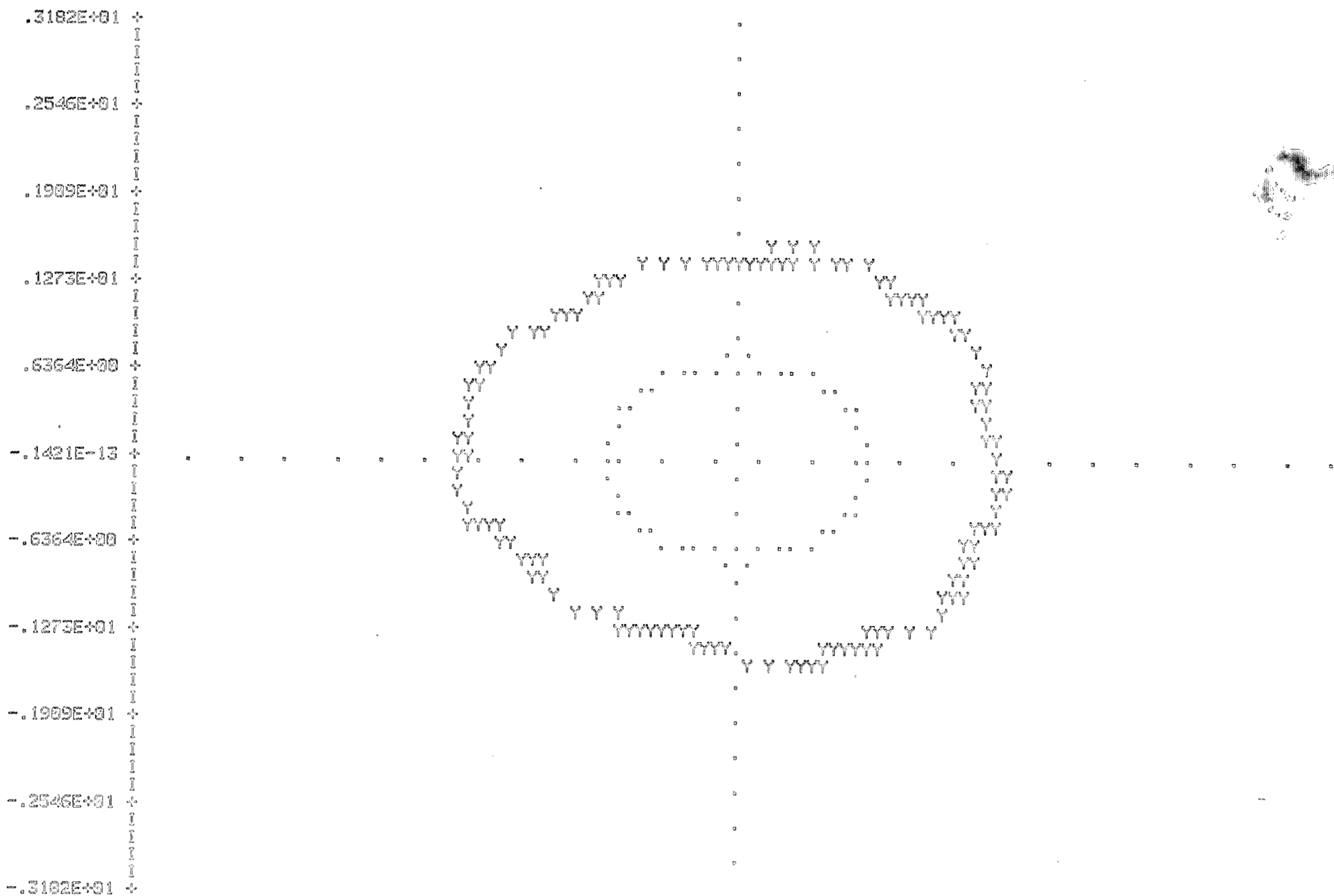
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 I I I I I  
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 1.909E+01 3.182E+01  
 0 POINTS OUTSIDE DIAGRAM XMIN = -.3238E+01 XMAX = .3049E+01 NU(13) = 1 SORT(25TV) = 3.2787





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 I I I I I I I  
 $-5.982E+01$   $-4.710E+01$   $-3.437E+01$   $-2.164E+01$   $-9.812E+00$   $0.3815E+00$   
 0 POINTS OUTSIDE DIAGRAM XMIN =  $-0.2515E+02$  XMAX = 0. KM(13) = 1 QRT(BETA) = 8.9311

INITIAL PARAMETERS OF PARTICLE #4 XA = -.570E+01MM XPA = .996E-02MM YA = .312E+01MM YPA = 0.  
 BETATRON AMPLITUDES = IN X : .200E+02 SIGMA IN Y : .200E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV  
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



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 I I I I I I I  
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 1.909E+01 3.182E+01  
 0 POINTS OUTSIDE DIAGRAM NMIN = -.3432E+01 NMAX = .3256E+01 NW(12) = 1 SORT(BETV) = 2.2787