

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.

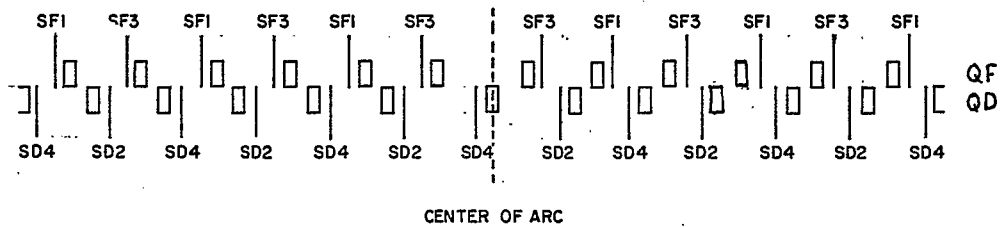
I. Introduction

In this note we are testing a sextupole scheme that has given good results in other cases^{1,2}. 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 HARMON³. Unfortunately, HARMON has shown some weakness and none run has been better than those in which sextupoles have been chosen manually.

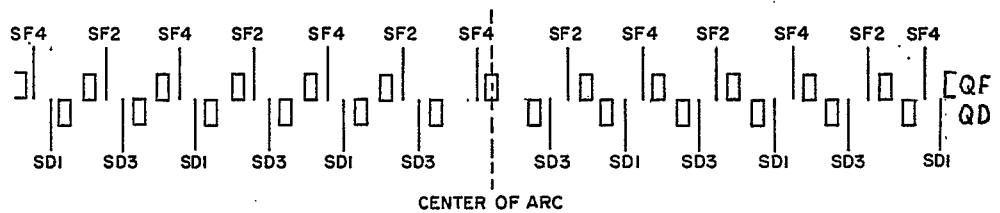
II. The Lattice

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 Servranckx⁴, 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 parameters⁵.

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

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

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

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

$$v_x / v_y = 28.851725/28.843547$$

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 β -function.

Inner Arc:

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

β_y^5 - Center of the 1st QD

β_x^{14} - Center of the 2nd QF

β_y^{19} - Center of the 2nd QD

Outer Arc:

β_x^{162} - Center of the first QF

β_y^{167} - Center of the 2nd QD

β_y^{239} - Center of the 7th QD.

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

⁵From MAD (F. CH. Iselin)

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

b. Eight families:

In order to reduce the bad behaviour of the β 's at the arcs, we decouple SF, SD into 8 families, 4 in the inner and 4 in the outer arc. The β '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

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

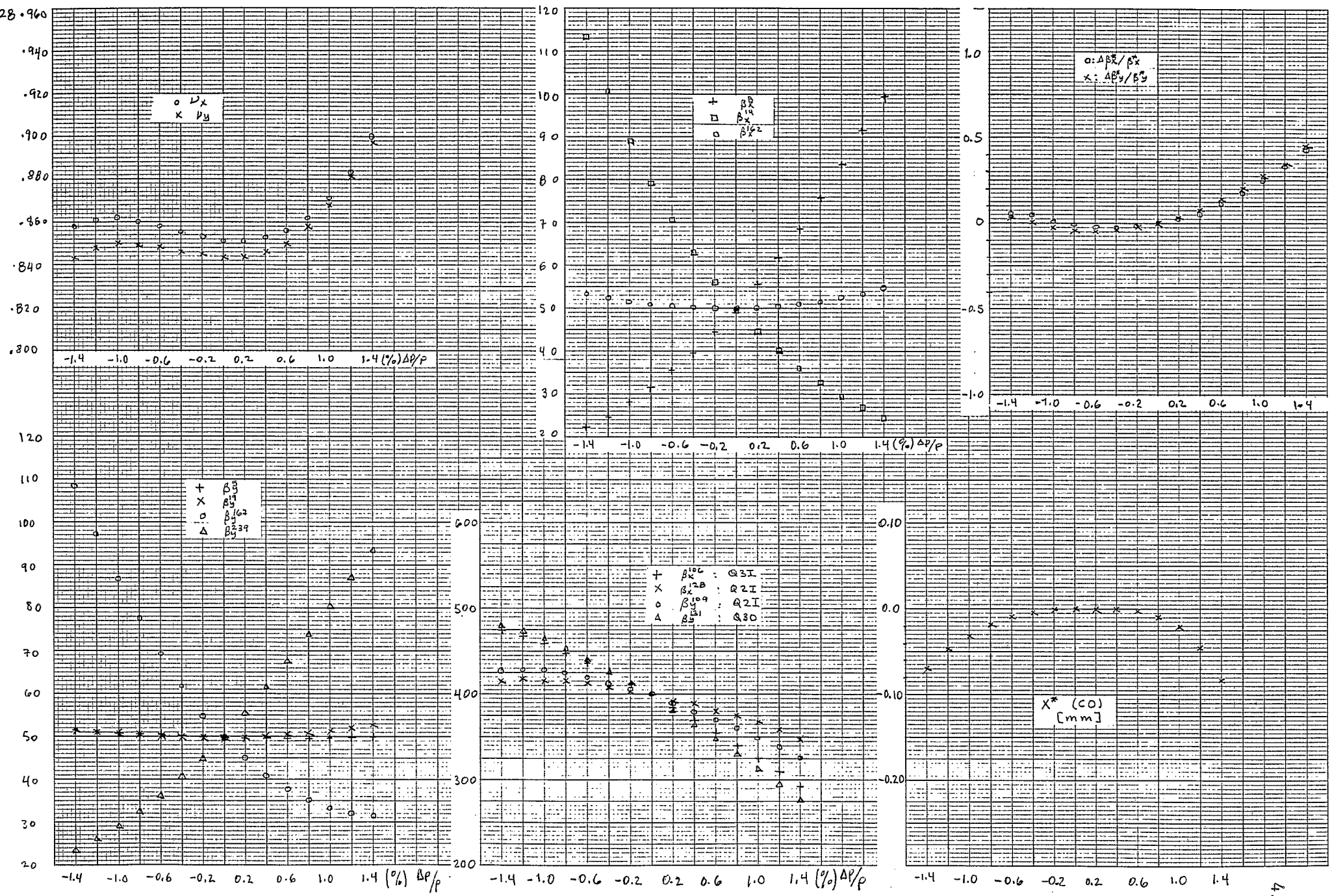


Fig. 1

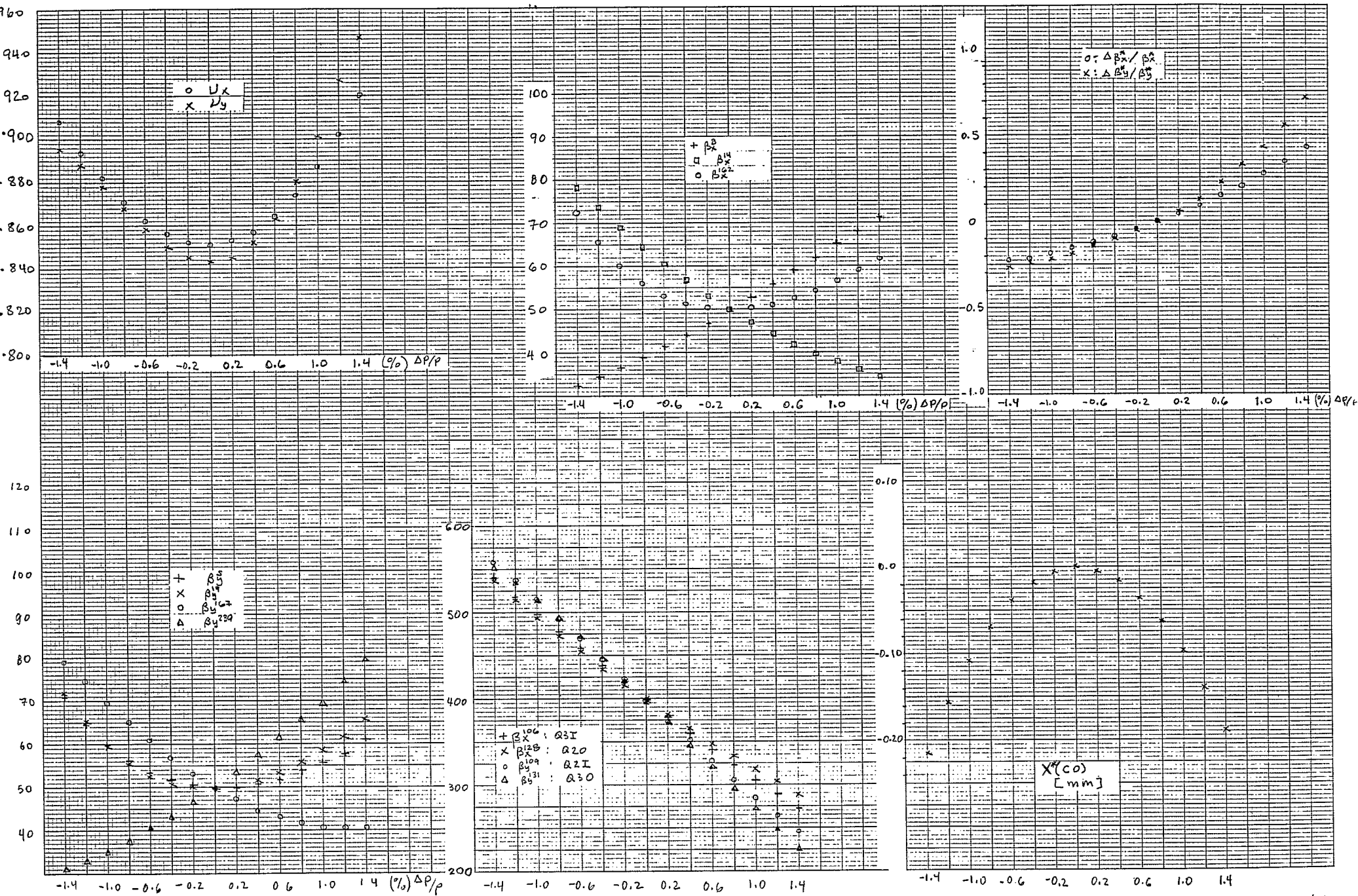


Fig. 2

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 β 's and the tune change as a function of the distance to the immediate quadrupole. In general, for $\Delta p/p < 0$ β '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 0.5π , 1π , 1.5π and 2π 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.

46 1323

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

Betas

140

120

100

80

60

40

20

0

fines

28.98

.94

.90

.86

.82

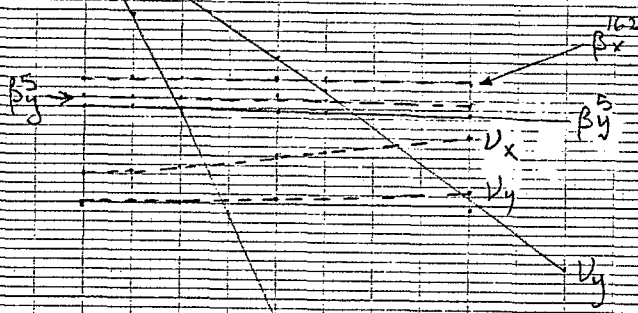
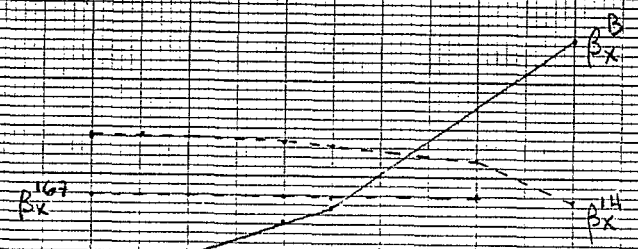
.78

.740

.70

$\Delta P/\rho = +1.4\%$

$\Delta P/\rho = -1.4\%$



U_x

Fig. 3

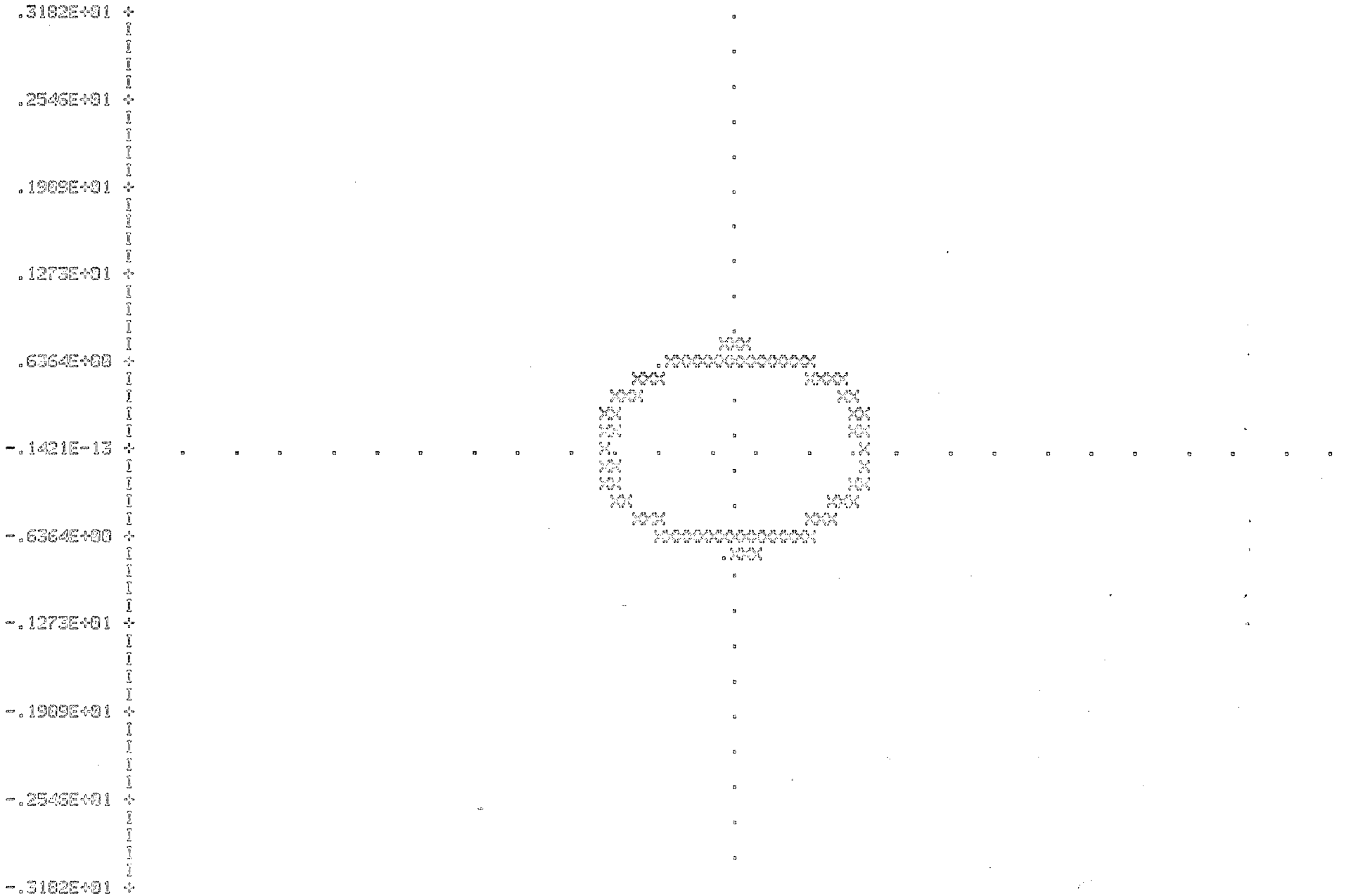
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4

distance in between [m]

INITIAL PARAMETERS OF PARTICLE #1 XA = .499E+01MM XPA = 0.
 BETATRON AMPLITUDES = IN X : .100E+02 SIGMA IN Y : .100E+02 SIGMA
 PHASE SPACE PLOT FOR 200 REVOLUTIONS

MM YA = .200E+01MM YPA = 0.
 ENERGY DEVIATION = 0.

SIGMA AT 30.00 GEV



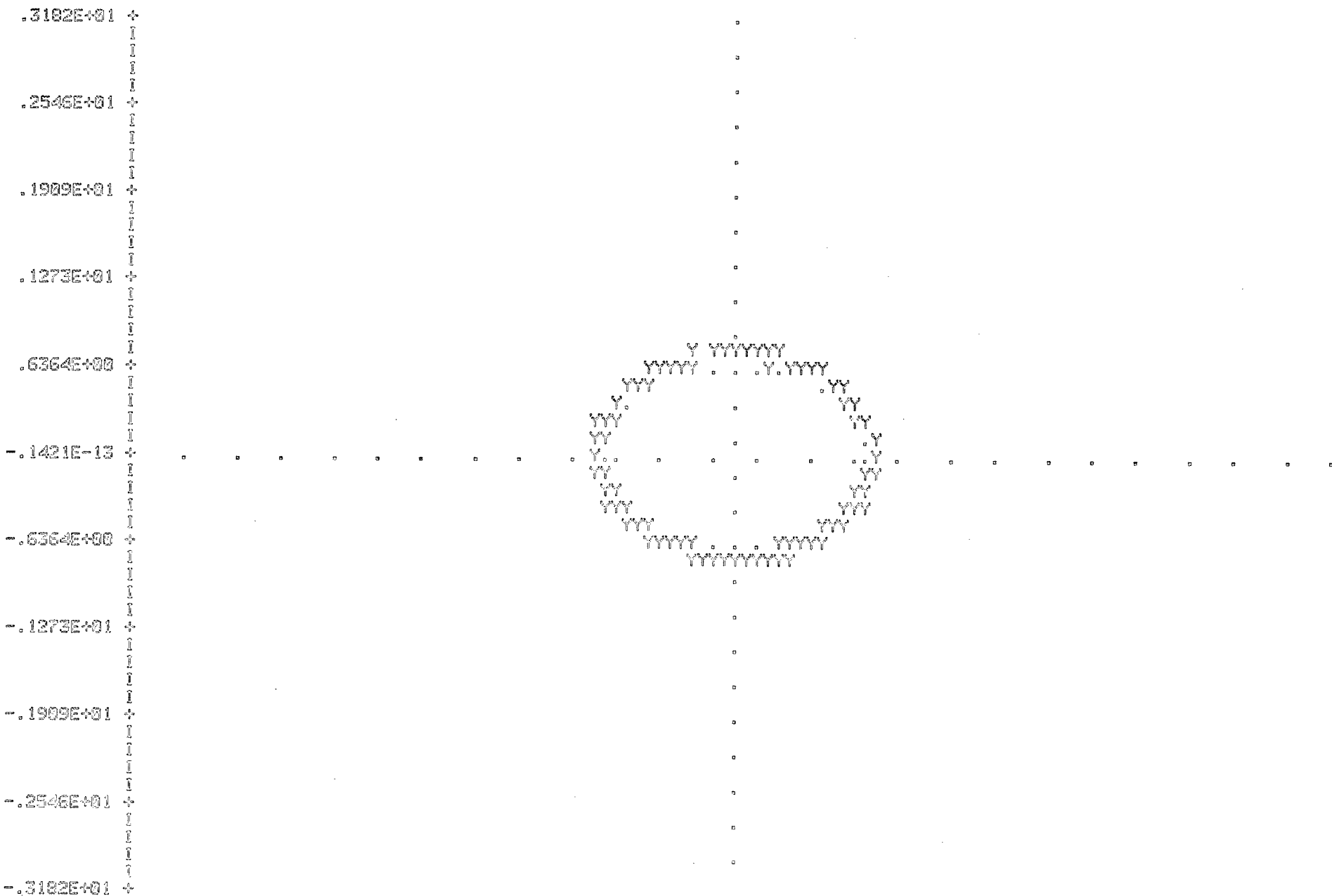
I	I	I	I	I	I	I	I
-.3182E+01	-.1909E+01	-.6364E+00	.6364E+00	.1909E+01	.3182E+01		
0	POINTS OUTSIDE DIAGRAM	MIN = -.9053E+01	MAX = .4078E+01	(N(13) = 1	SORT(BET)) =	7.8513	

Fig. 4

8

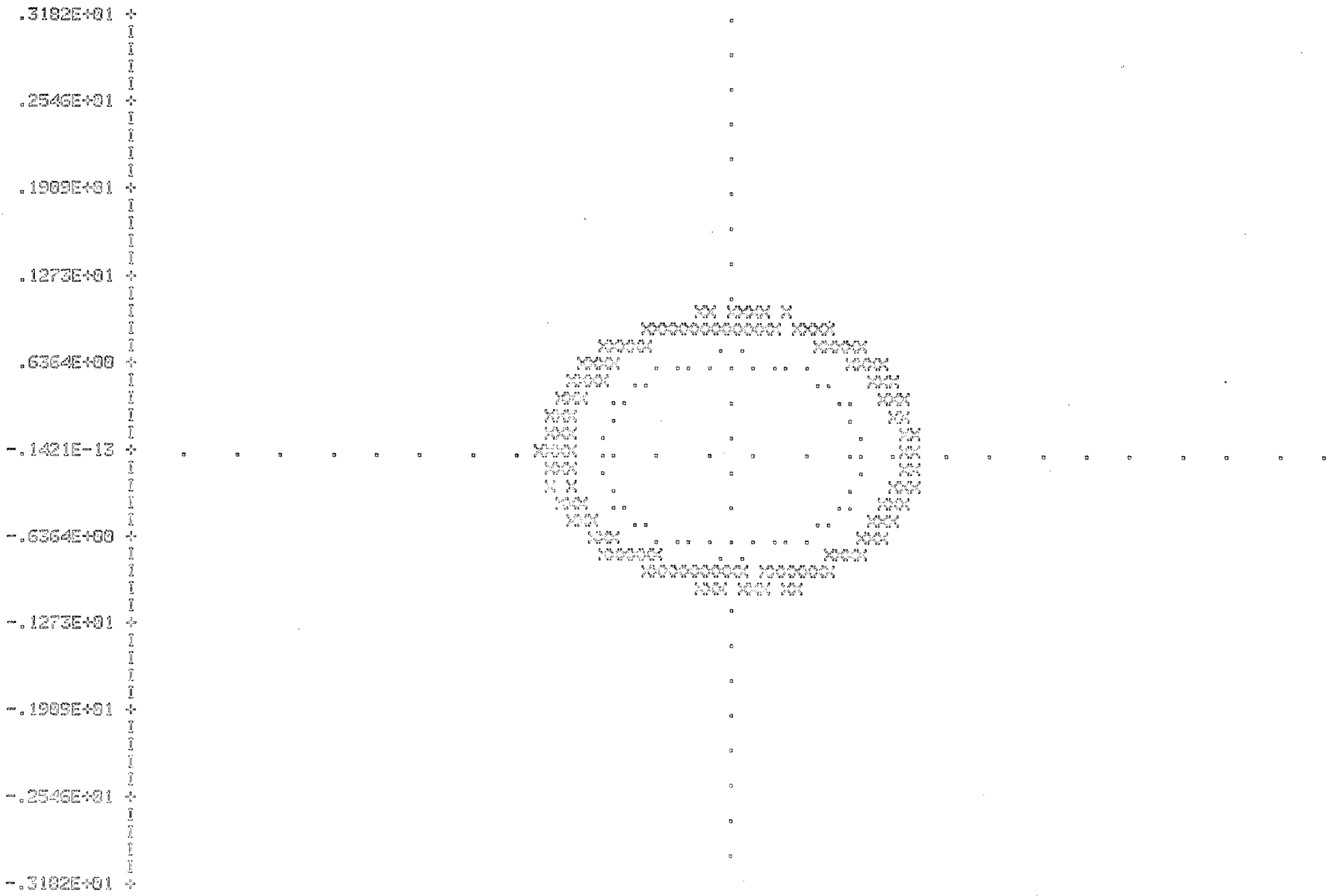
105

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



 I I I I I I I
 -.3182E+01 -.1909E+01 -.6364E+00 -.6364E+00 .1909E+01 .3182E+01
 0 POINTS OUTSIDE DIAGRAM NMIN = -.2316E+01 NMAX = .2308E+01 NW(13) = 1 SORT(BETV) = 2.9491

INITIAL PARAMETERS OF PARTICLE C2 XA = .705E+01MM XPA = 0. YA = .294E+01MM YPA = 0. NR
 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

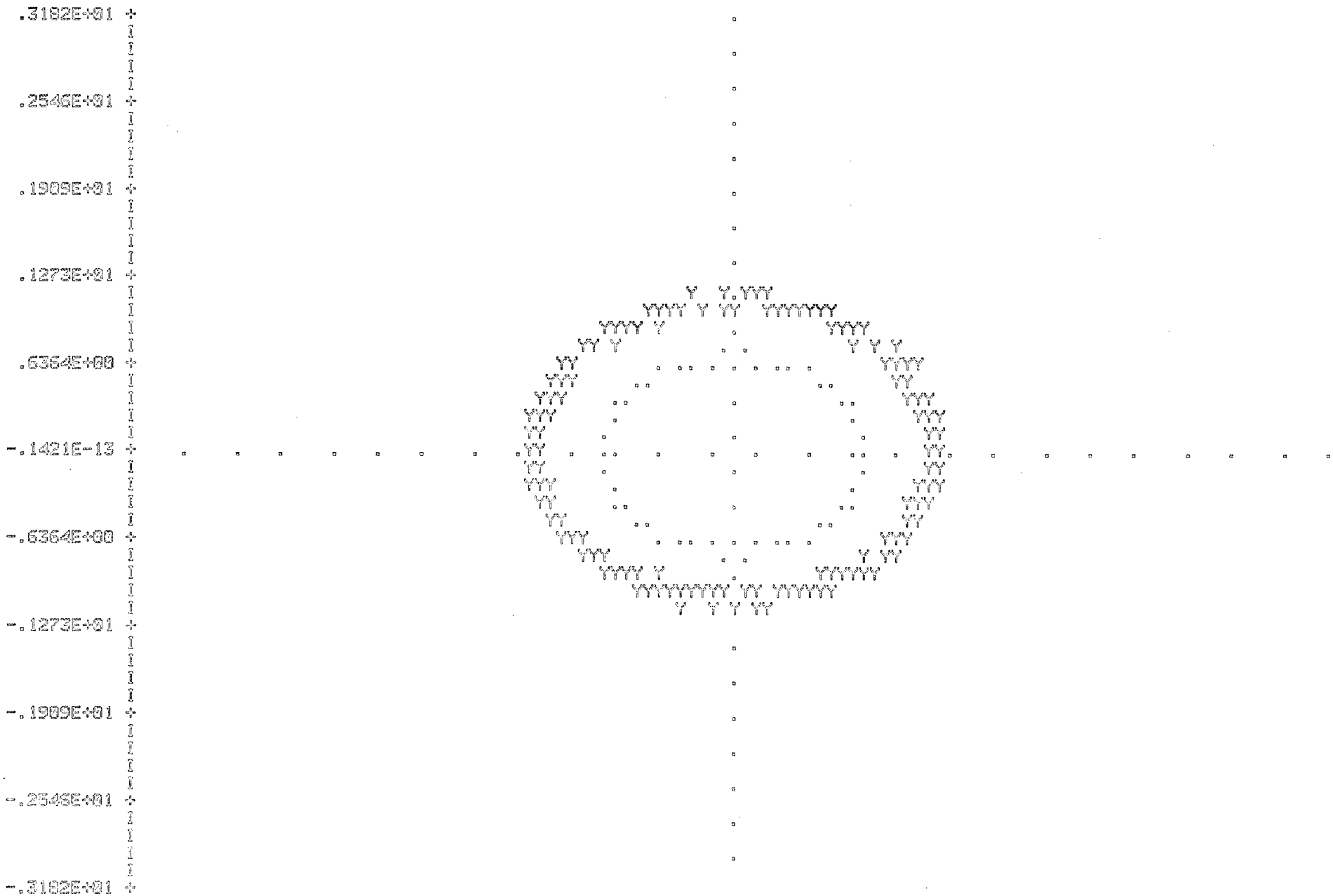


I	I	I	I	I	I	I
- .3182E+01	- .1909E+01	- .6364E+00	.6364E+00	.1909E+01	.3182E+01	
0	POINTS OUTSIDE DIAGRAM	XMIN = -.7149E+01	XMAX = .7001E+01	(MAX I) = 1	(SORT I) =	7.0513

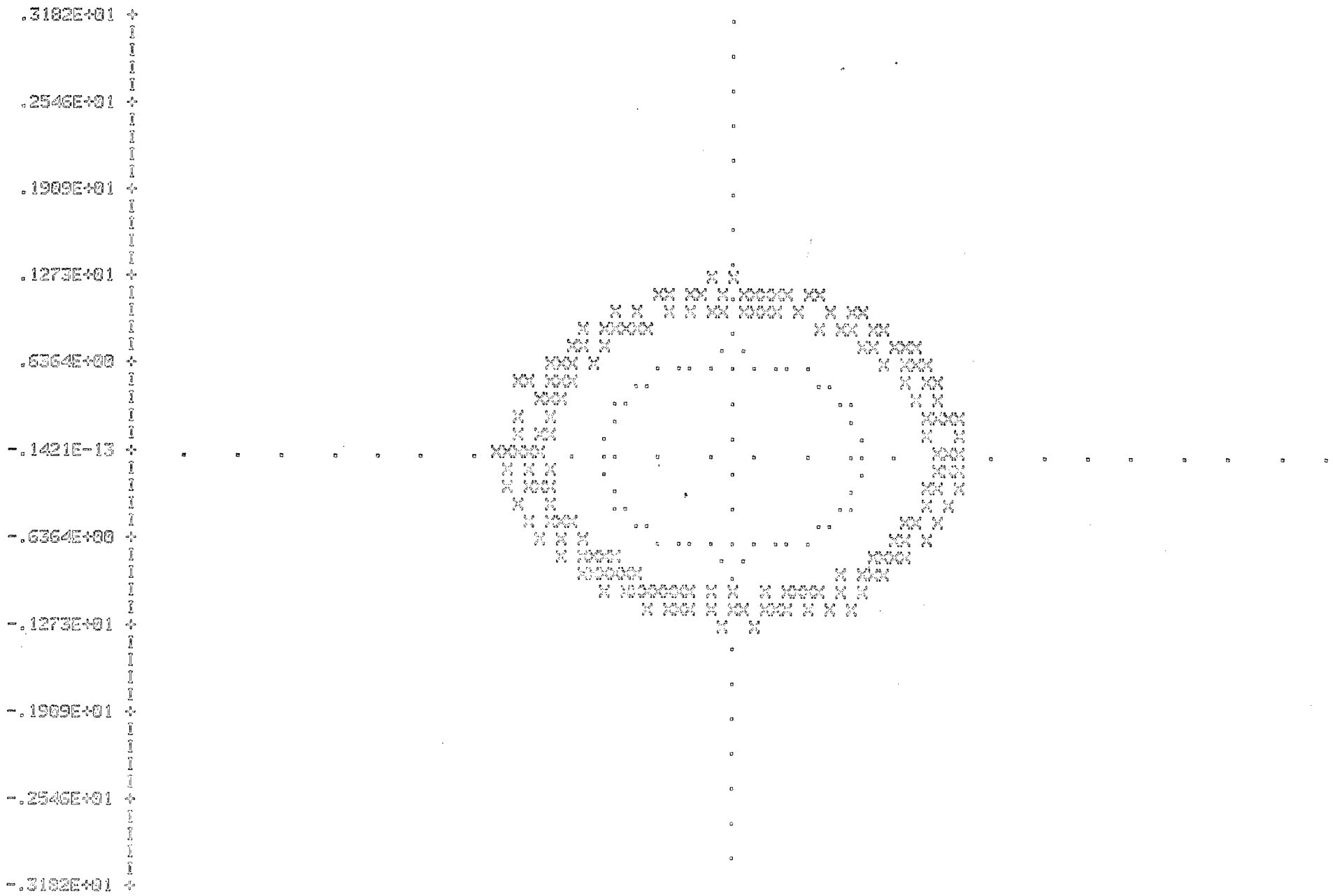
INITIAL PARAMETERS OF PARTICLE 02 XA = .705E+01MM XPA = 0.
BETATRON AMPLITUDES = IN X : .141E+02 SIGMA IN Y : .141E+02 SIGMA
PHASE SPACE PLOT FOR 200 REVOLUTIONS

MM YA = .294E+01MM YPA = 0. MR
ENERGY DEVIATION = 0. SIGMA AT 30.00 GEV

MR SIGMA AT 30.00 GEV

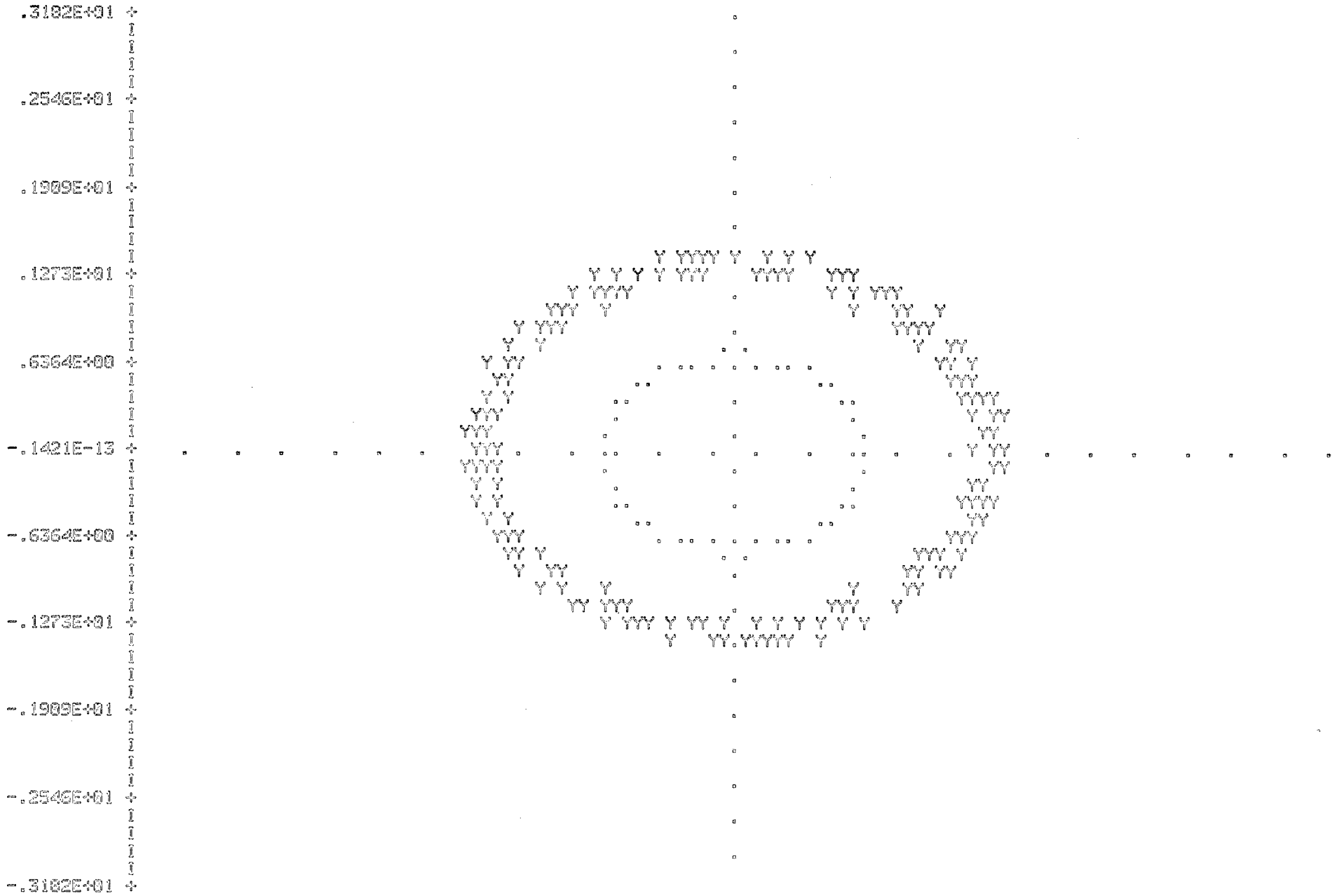


I I I I I I I
-.3182E+01 -.1909E+01 -.6364E+00 .6364E+00 .1909E+01 .3182E+01
0 POINTS OUTSIDE DIAGRAM MIN = -.5298E+01 MAX = .5278E+01 KW(13) = 1 SORT(BETV) = 2.9451



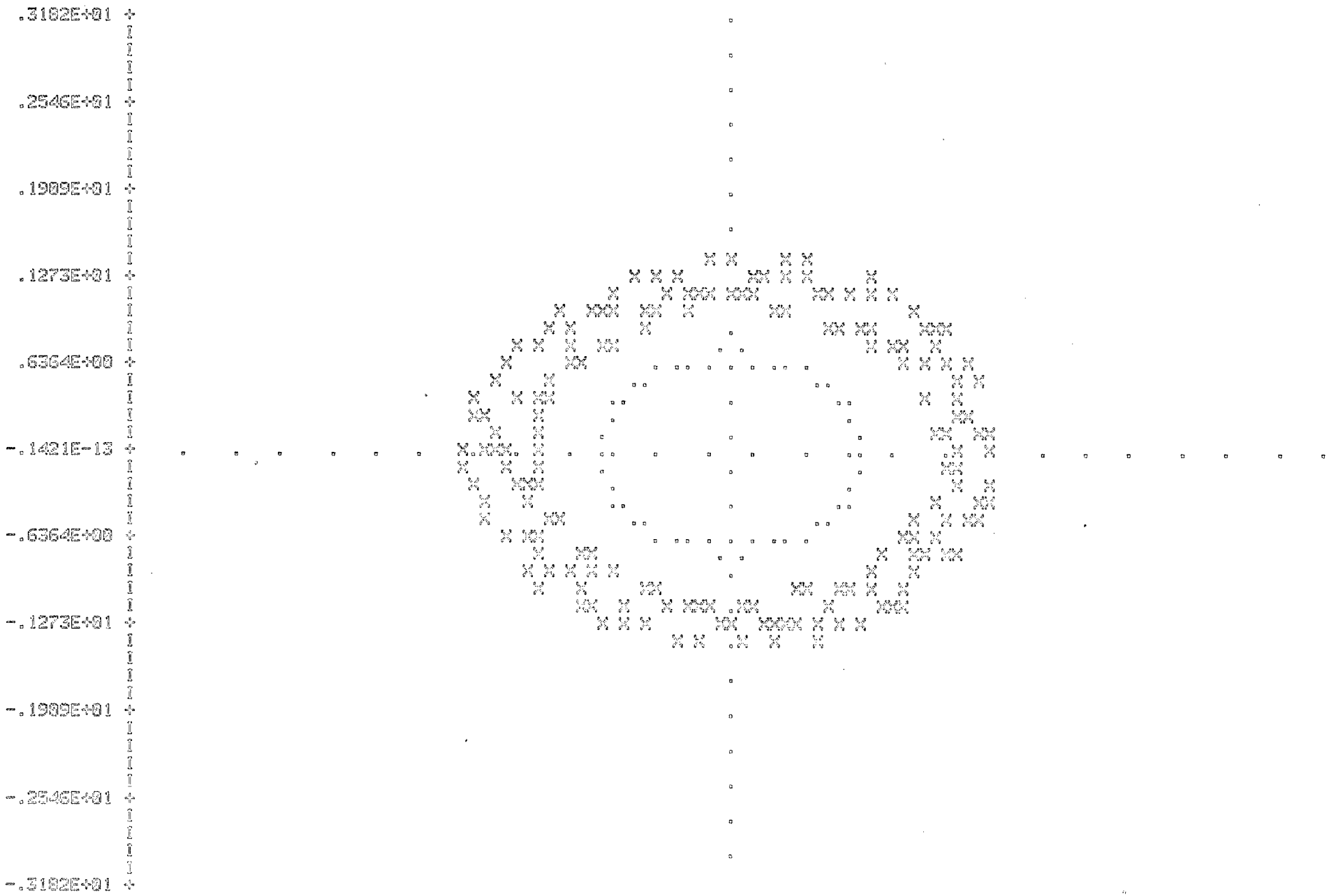
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- .3182E+01	- .1909E+01	- .6364E+00	.6364E+00	.1909E+01	.3182E+01	
0	POINTS OUTSIDE DIAGRAM	MIN = -.8781E+01	MAX = .8571E+01	KM(13) = 1	SORT(BETX) =	7.9513

INITIAL PARAMETERS OF PARTICLE #3 XA = .864E+01MM XPA = 0. MM YA = .360E+01MM YPA = 0. MR
 BETATRON AMPLITUDES = IN X : .173E+02 SIGMA IN Y : .173E+02 SIGMA ENERGY DEVIATION = 0. SIGMA AT 30.00 GEV
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



 I I I I I I I
 -0.3182E+01 -0.1909E+01 -0.6364E+00 .6364E+00 .1909E+01 0.3182E+01
 0 POINTS OUTSIDE DIARRH NMIN = -0.4227E+01 NMAX = .4321E+01 NM(13) = 1 SORT(BETW) = 2.8451

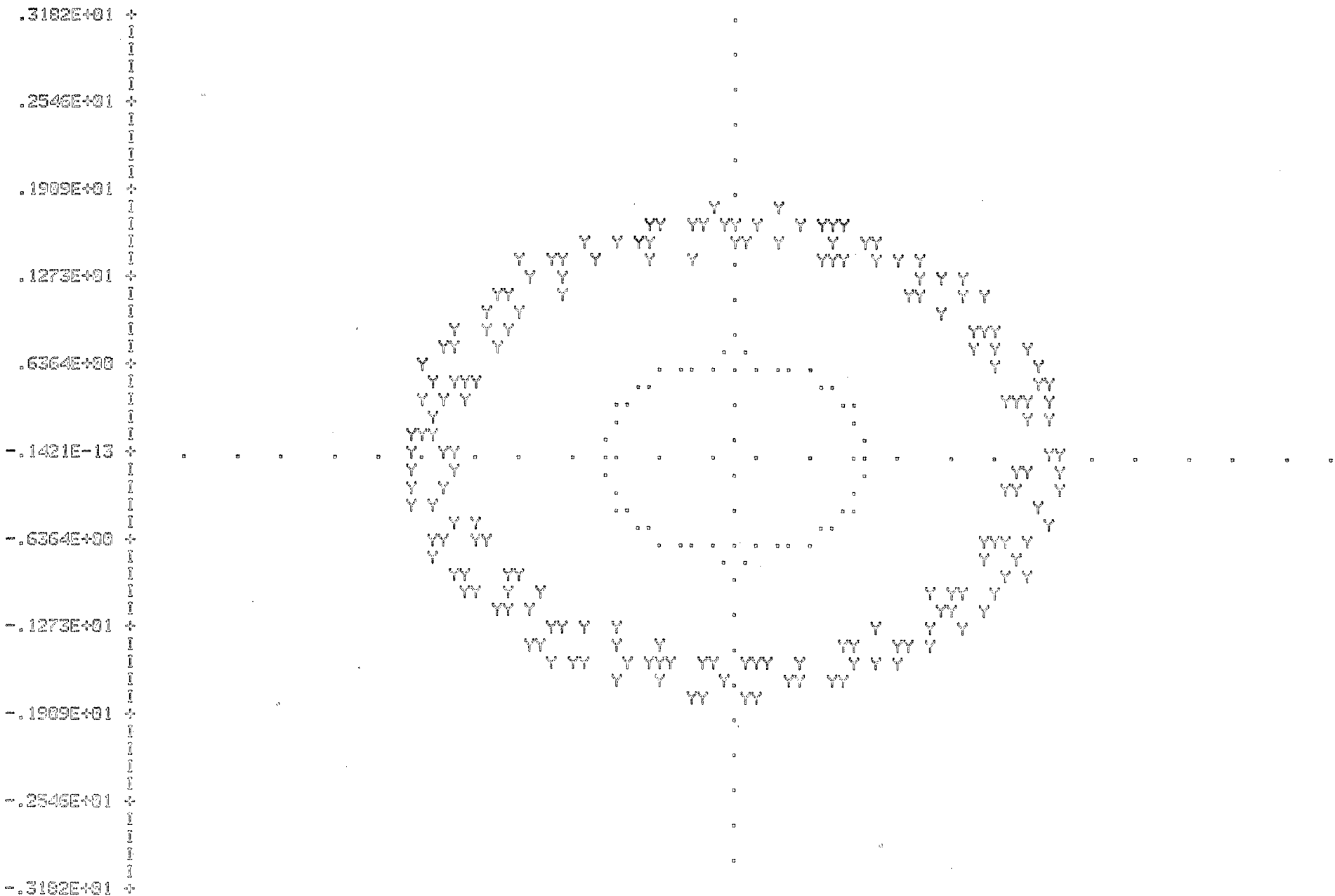
INITIAL PARAMETERS OF PARTICLE #4 XA = .997E+01MM XPA = 0. MM YA = .416E+01MM YPA = 0. MP
 BETATRON AMPLITUDES = IN X : .200E+02 SIGMA IN Y : .200E+02 SIGMA ENERGY DEVIATION = 0. SIGMA AT 30.00 GEV
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



 I I I I I I I
 -3.182E+01 -1.989E+01 -.6364E+00 .6364E+00 1.989E+01 3.182E+01
 6 POINTS OUTSIDE DIAGRAM XMIN = -.1017E+02 XMAX = .2880E+01 NUC(13) = 1 SORT(BETX) = 7.5512

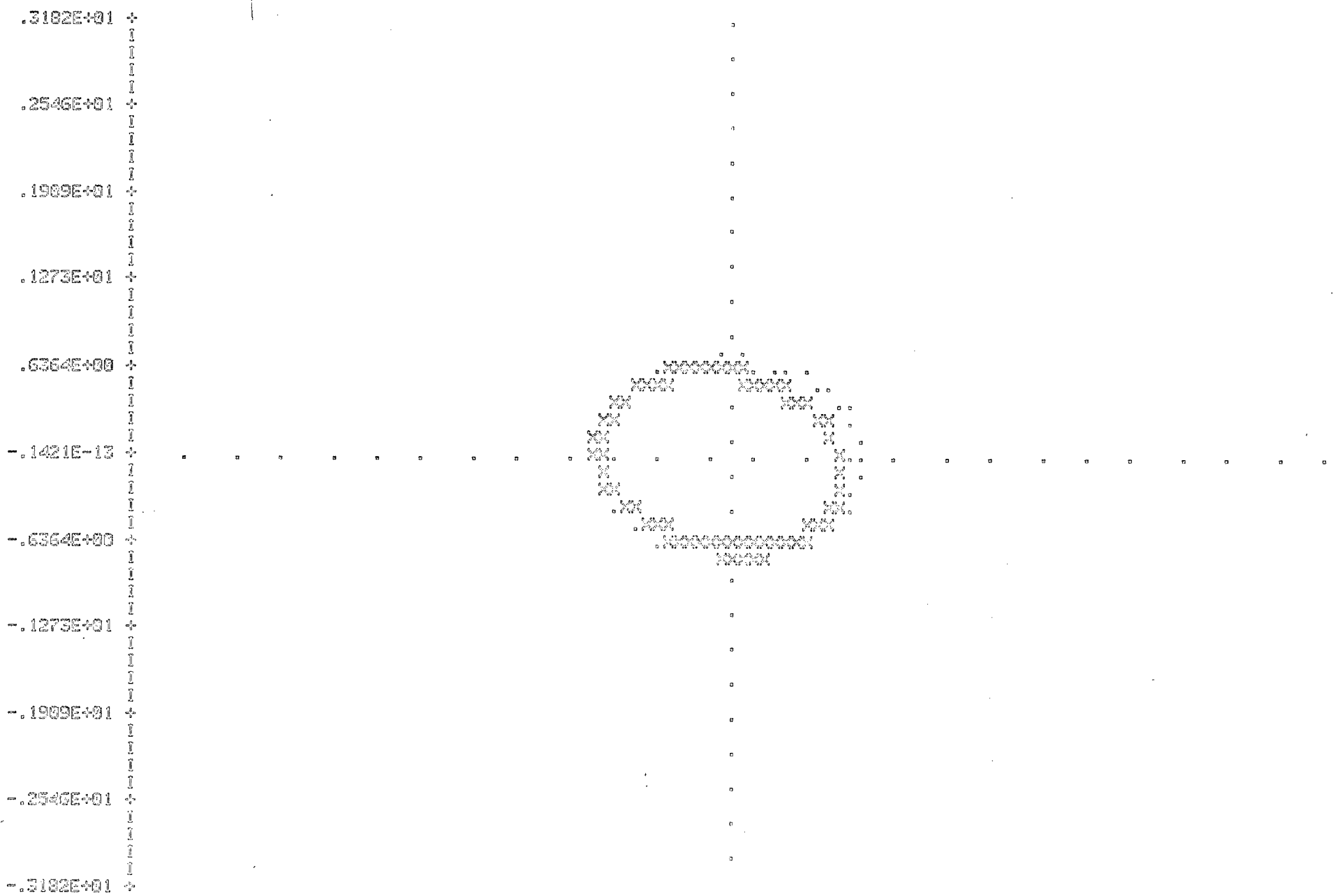
INITIAL PARAMETERS OF PARTICLE #4 XA = .997E+01MM XPA = 0.
 BETATRON AMPLITUDES = IN X : .200E+02 SIGMA IN Y : .200E+02 SIGMA
 PHASE SPACE PLOT FOR 200 REVOLUTIONS

MM YA = .416E+01MM YPA = 0. MR
 ENERGY DEVIATION = 0. SIGMA AT 30.00 BEV



 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 = -0.5126E+01 XMAX = 0.5112E+01 KUK(15) = 1 SORT(BETY) = 2.9021

INITIAL PARAMETERS OF PARTICLE #1 XA = .211E+02MM XPA = -.402E-02MM YA = .266E+01MM YPA = 0. MA
 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

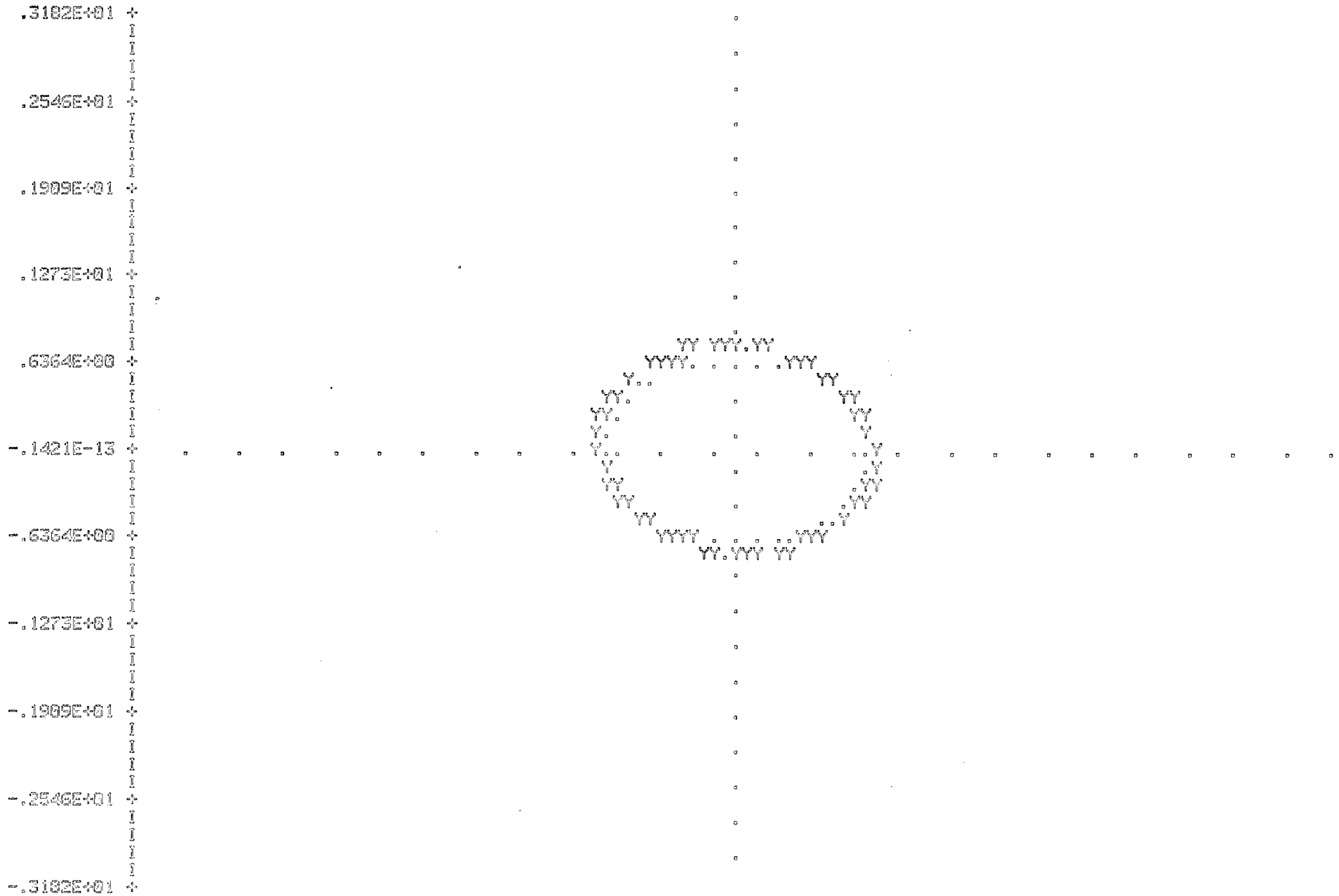


-0.1331E+01	-0.5033E-01	0.1214E+01	0.2437E+01	0.2760E+01	0.5033E+01
N	POINTS OUTSIDE DIAGRAM	MIN = 0.	MAX = .1900E+02	NR(13) = 1	SRRT(BETX) = 8.1532

Fig. 5

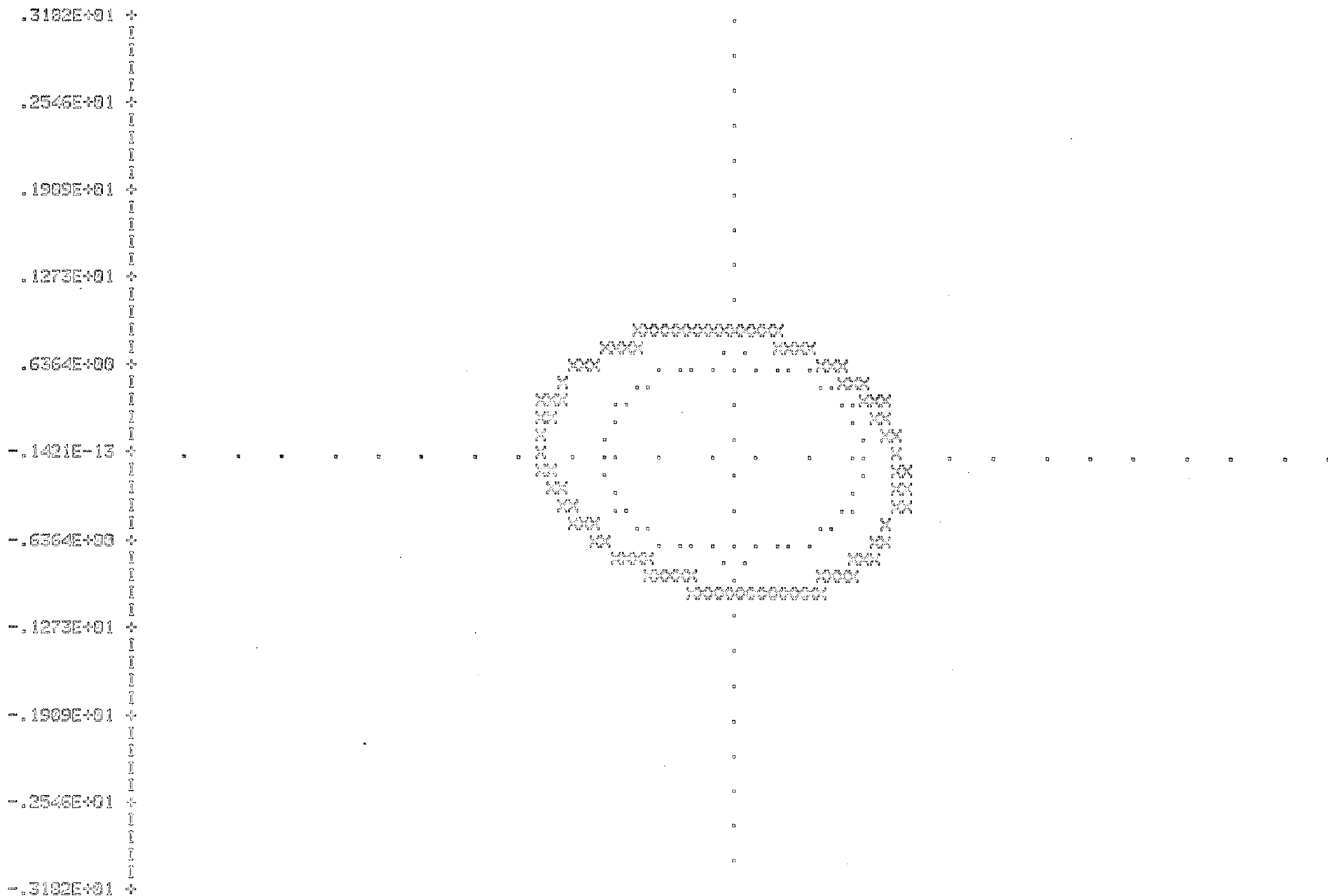
001

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



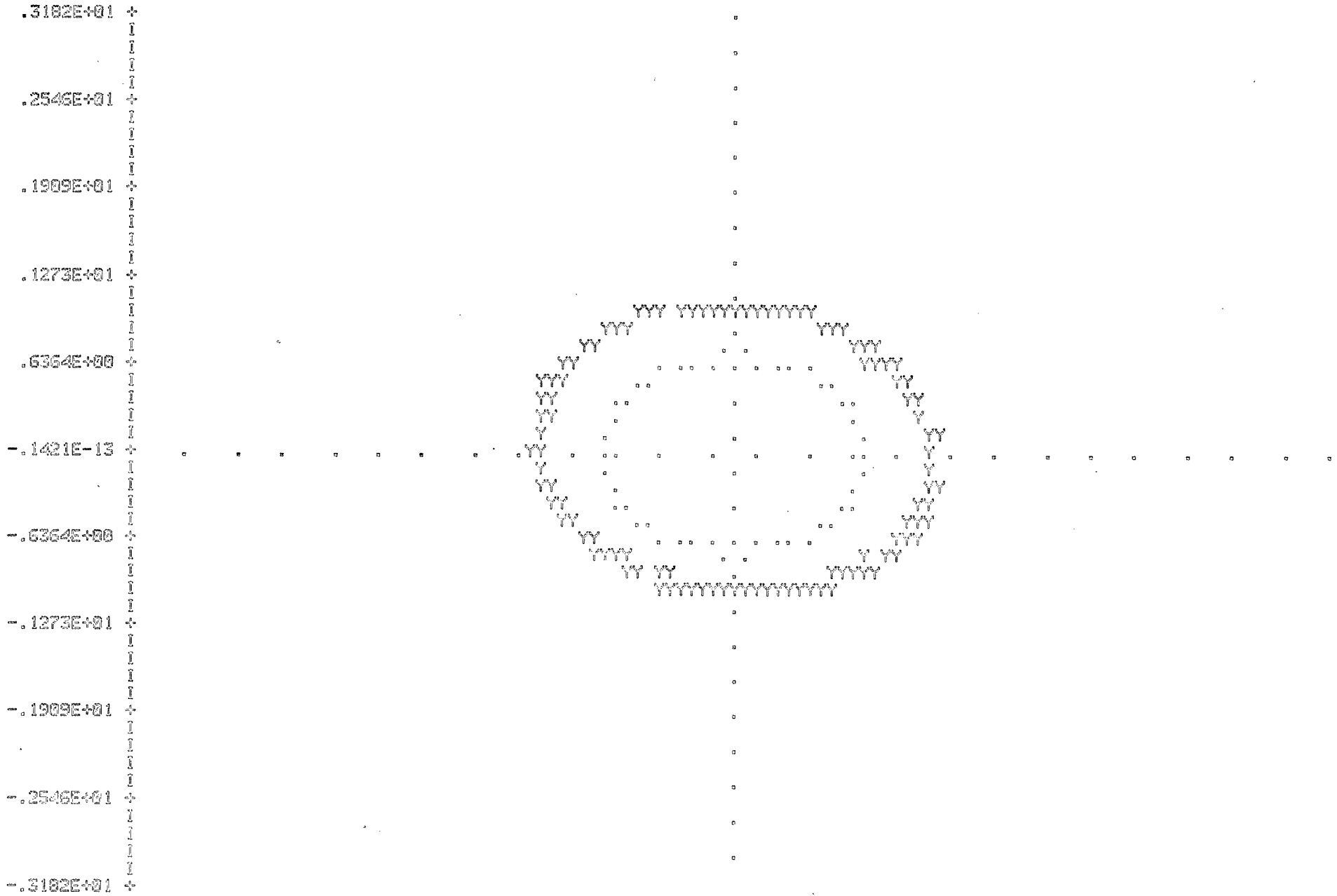
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0	POINTS OUTSIDE DIAGRAM	MIN = -0.2720E+01	MAX = 0.2713E+01	KW(15) = 1	SOPT(BETY) = 3.6551	

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



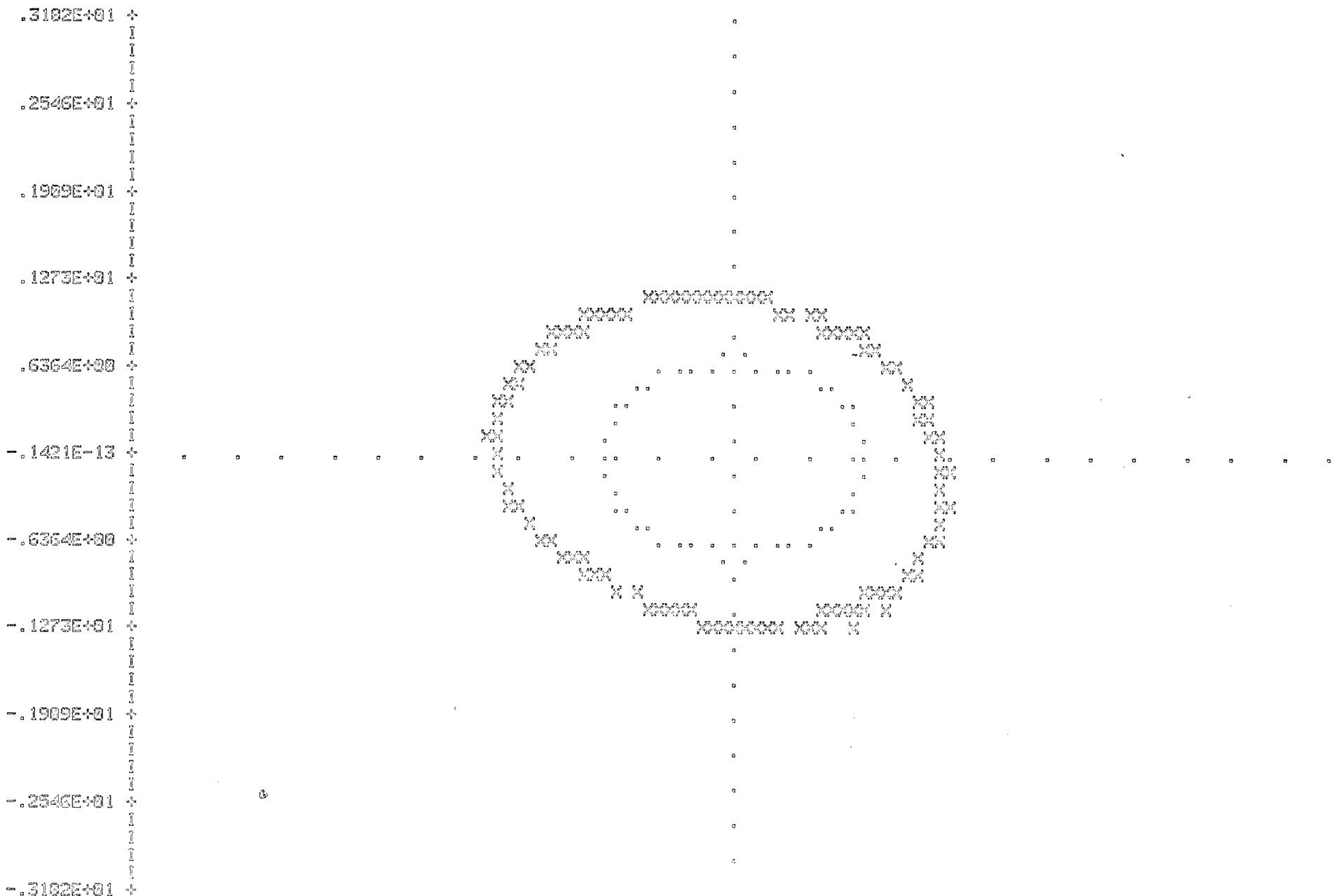
 I I I I I I
 -.1331E+01 -.5066E-01 .1214E+01 .2497E+01 .3700E+01 .5033E+01
 0 POINTS OUTSIDE DIAGRAM NMIN = 0. NMAX = .2208E+02 KNU(13) = 1 SORT(BET) = 8.1532

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 30.00 BEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS



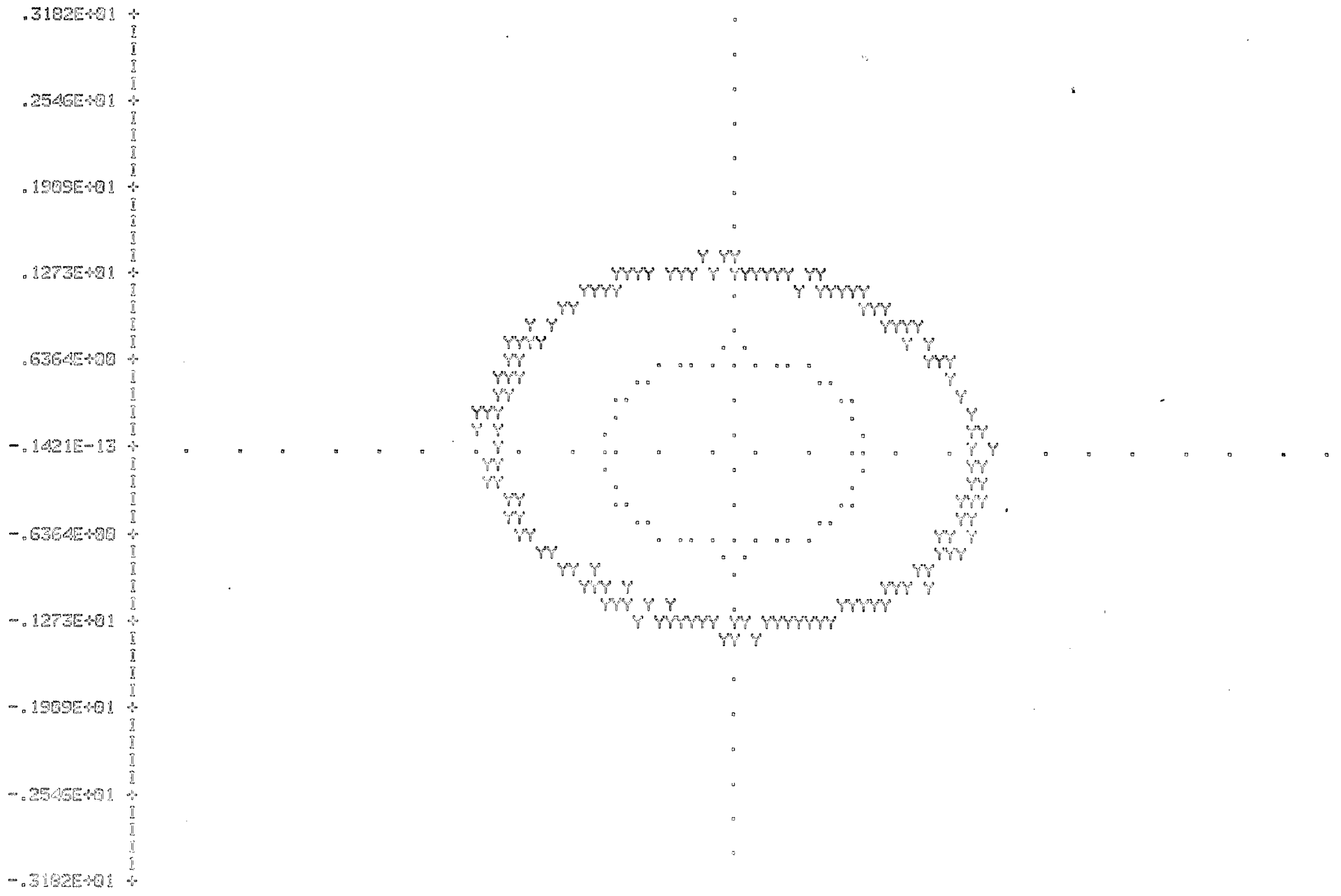
I I I I I I I
-3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 .1909E+01 3.182E+01
0 POINTS OUTSIDE DIAGRAM NMIN = -.3930E+01 NMAX = .3930E+01 NM(13) = 1 SORT(BETY) = 3.6551

INITIAL PARAMETERS OF PARTICLE 63 X0 = .253E+02MM XPA = -.402E-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



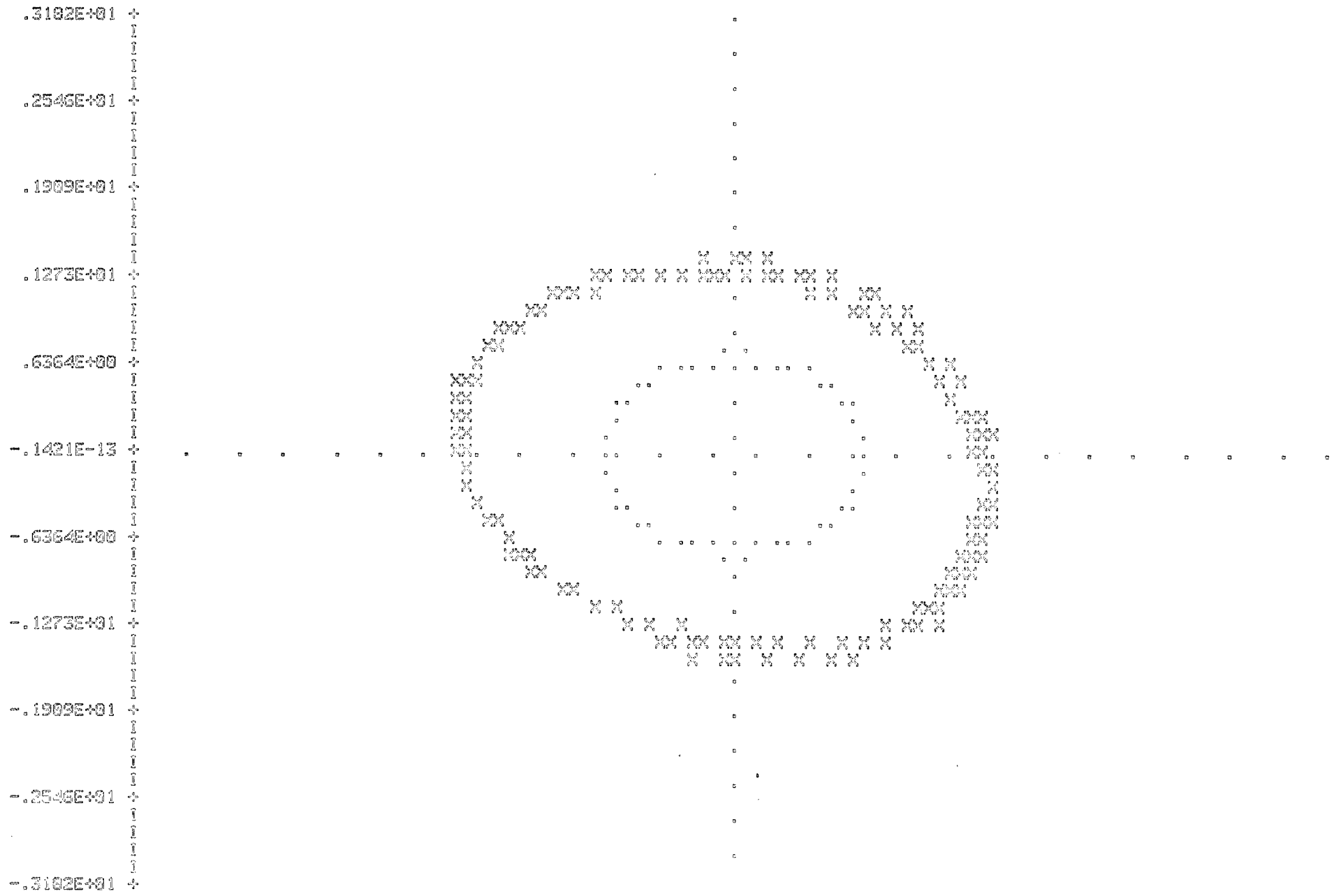
 I I I I I I I
 -0.1331E+01 -0.5966E-01 0.1214E+01 0.2487E+01 0.3760E+01 0.5053E+01
 0 POINTS OUTSIDE DIAGRAM XMIN = 0. XMAX = 0.2487E+02 KX(12) = 1 SQR(BETX) = 0.1533

INITIAL PARAMETERS OF PARTICLE 63 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



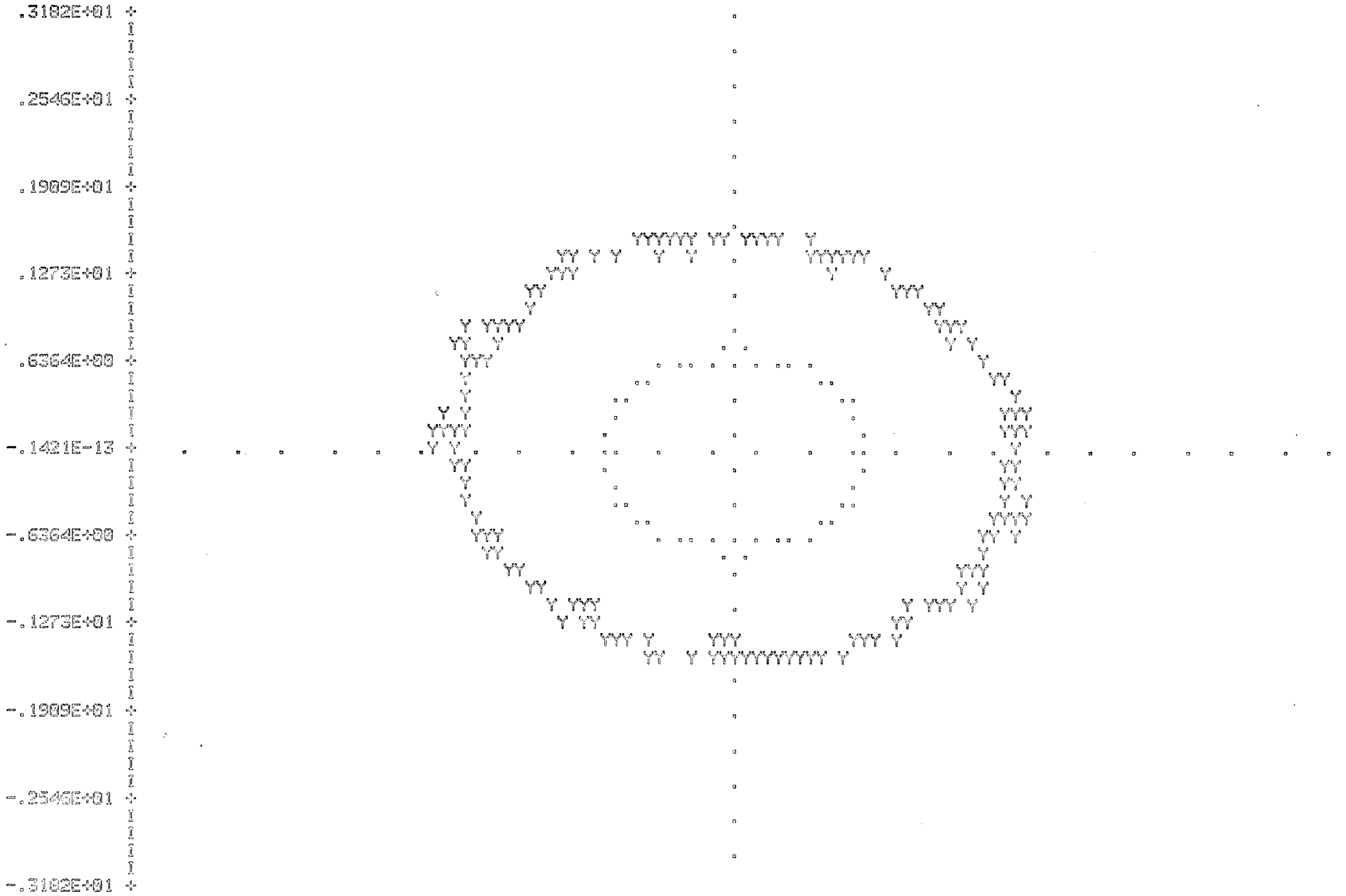
I I I I I I I
 -0.3102E+01 -0.1909E+01 -0.6364E+00 -0.6364E+00 0.1909E+01 0.3102E+01
 0 POINTS OUTSIDE DIAGRAM XMIN = -.4895E+01 XMAX = .4874E+01 NM(13) = 1 SORT(BETX) = 3.6551

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



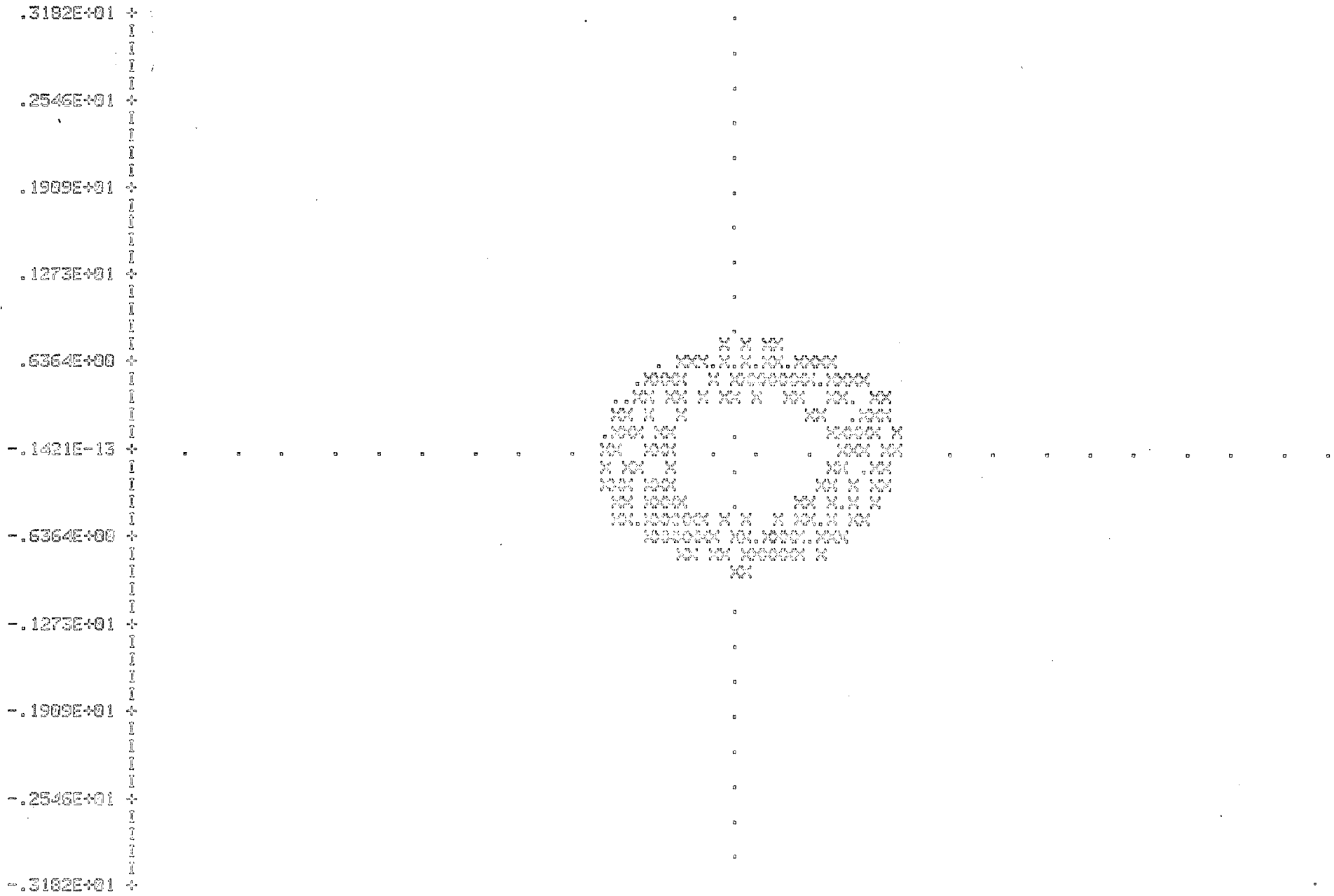
 I I I I I I I
 -.1331E+01 -.5966E-01 .1214E+01 .2497E+01 .3760E+01 .5033E+01
 0 POINTS OUTSIDE DIAGRAM MIN = 0. MAX = .2636E+02 KKK(13) = 1 SORT(OBTR) = 0.1532

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



 I I I I I I
 -0.3182E+01 -0.1909E+01 -0.6364E+00 -0.6364E+00 0.1909E+01 0.3182E+01
 O POINTS OUTSIDE DIAGRAM NMIN = -0.88-0E+01 NMAX = 0.5786E+01 NUN(13) = 1 SORT(BETY) = 3.6551

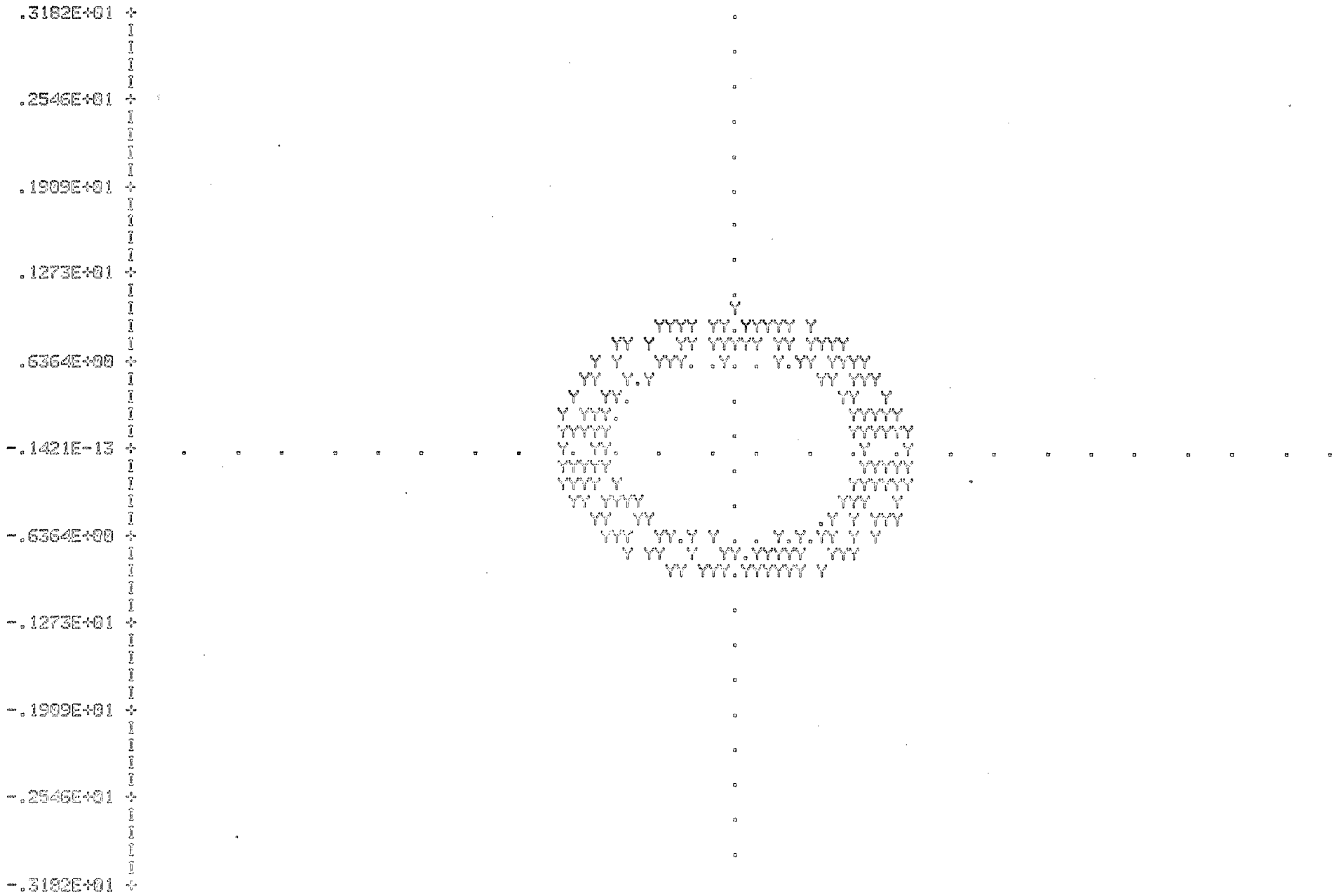
INITIAL PARAMETERS OF PARTICLE 01 MA = -.991E+01MM XPA = .996E-02MM YA = .156E+01MM YPA = 0. MR
 BETATRON AMPLITUDES = IN X: .100E+02 SIGMA IN Y: .100E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV
 PHASE SPACE PLOT FOR 200 REVOLUTIONS



 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. NUC(15) = 1 SORT(BETA) = 5.9311

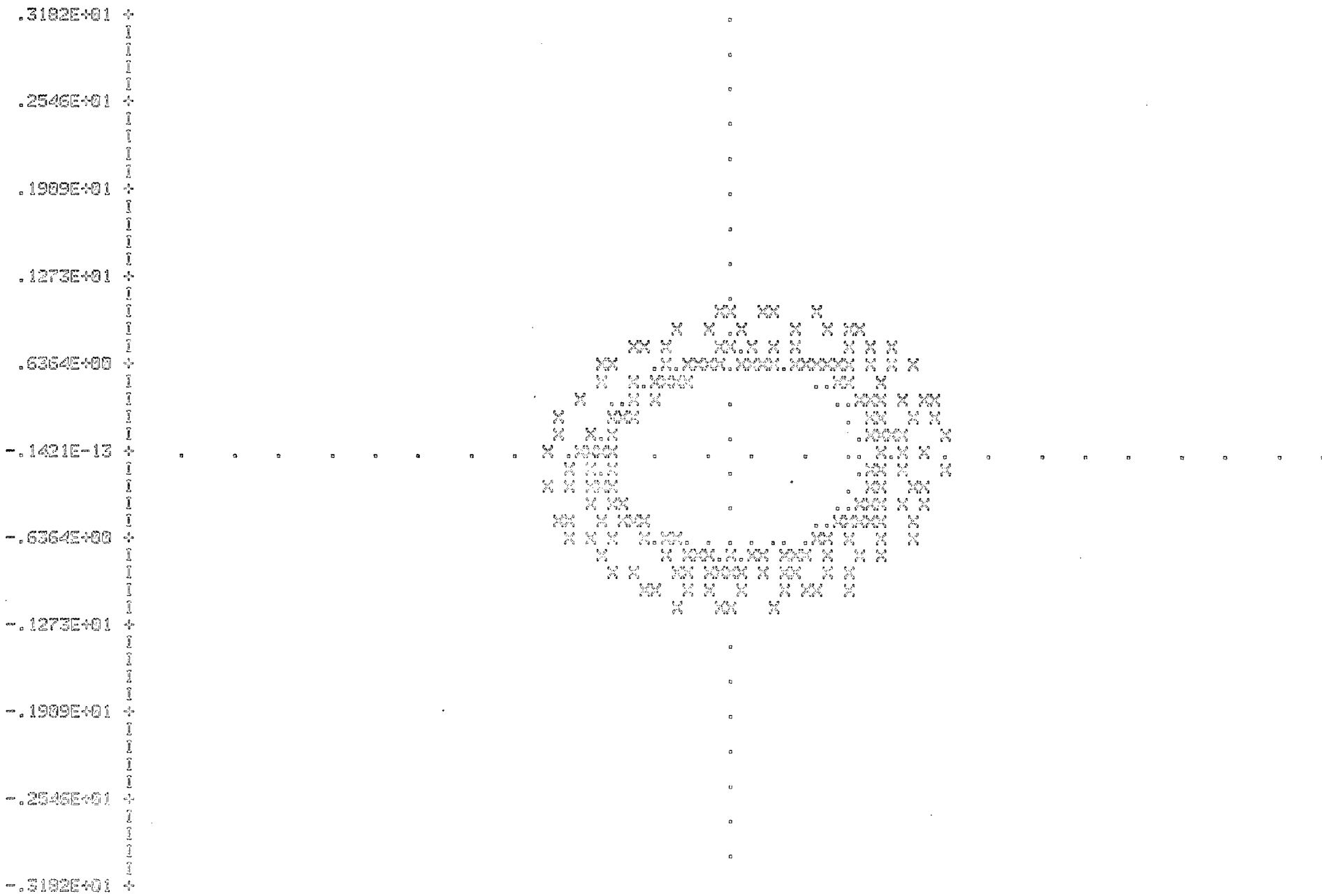
Fig. 6

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



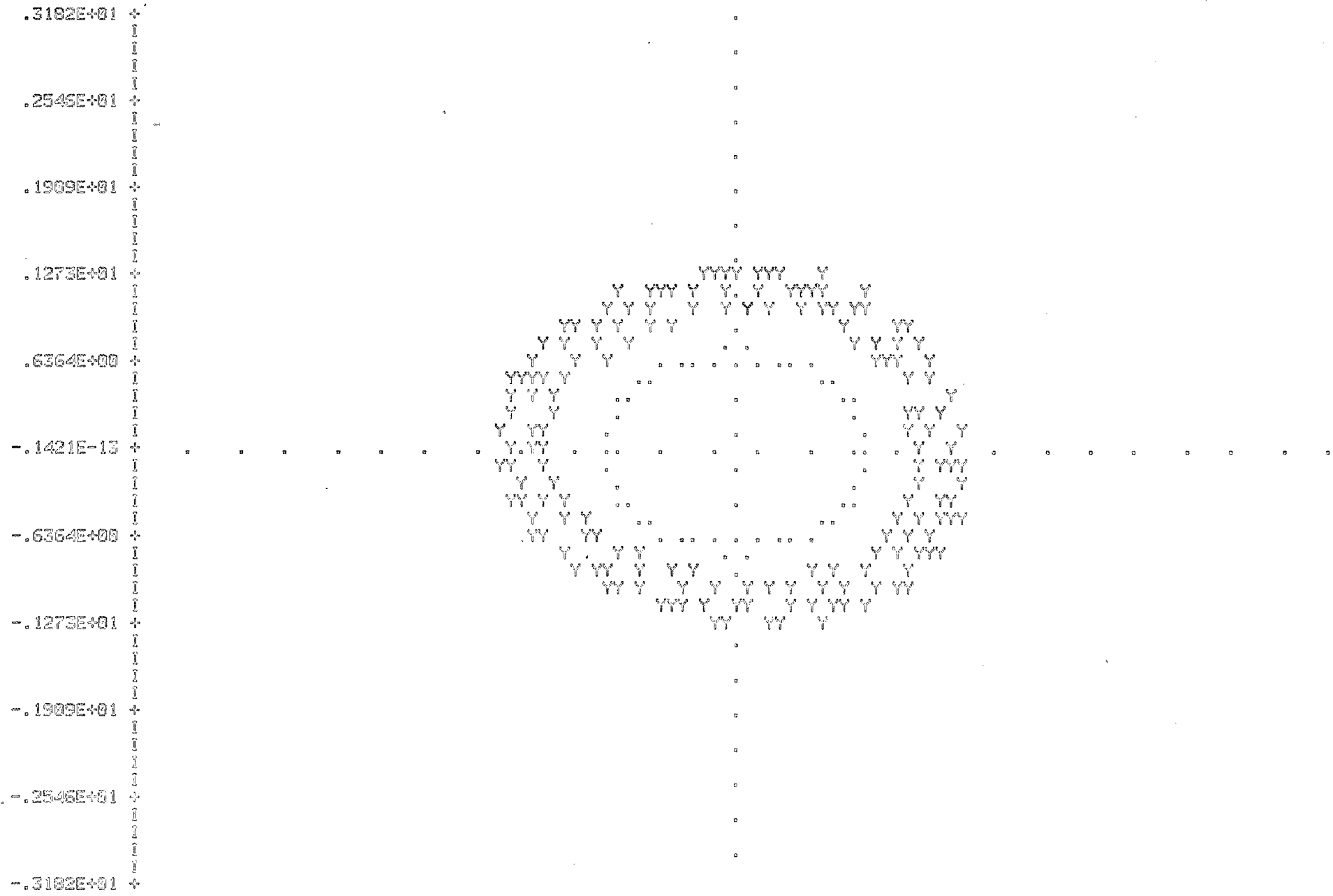
 I I I I I I I
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 .1909E+01 3.182E+01
 0 POINTS OUTSIDE DIBERAN XMIN = -3.156E+01 XMAX = .210E+01 KMC(13) = 1 SORT(BETY) = 2.2787

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



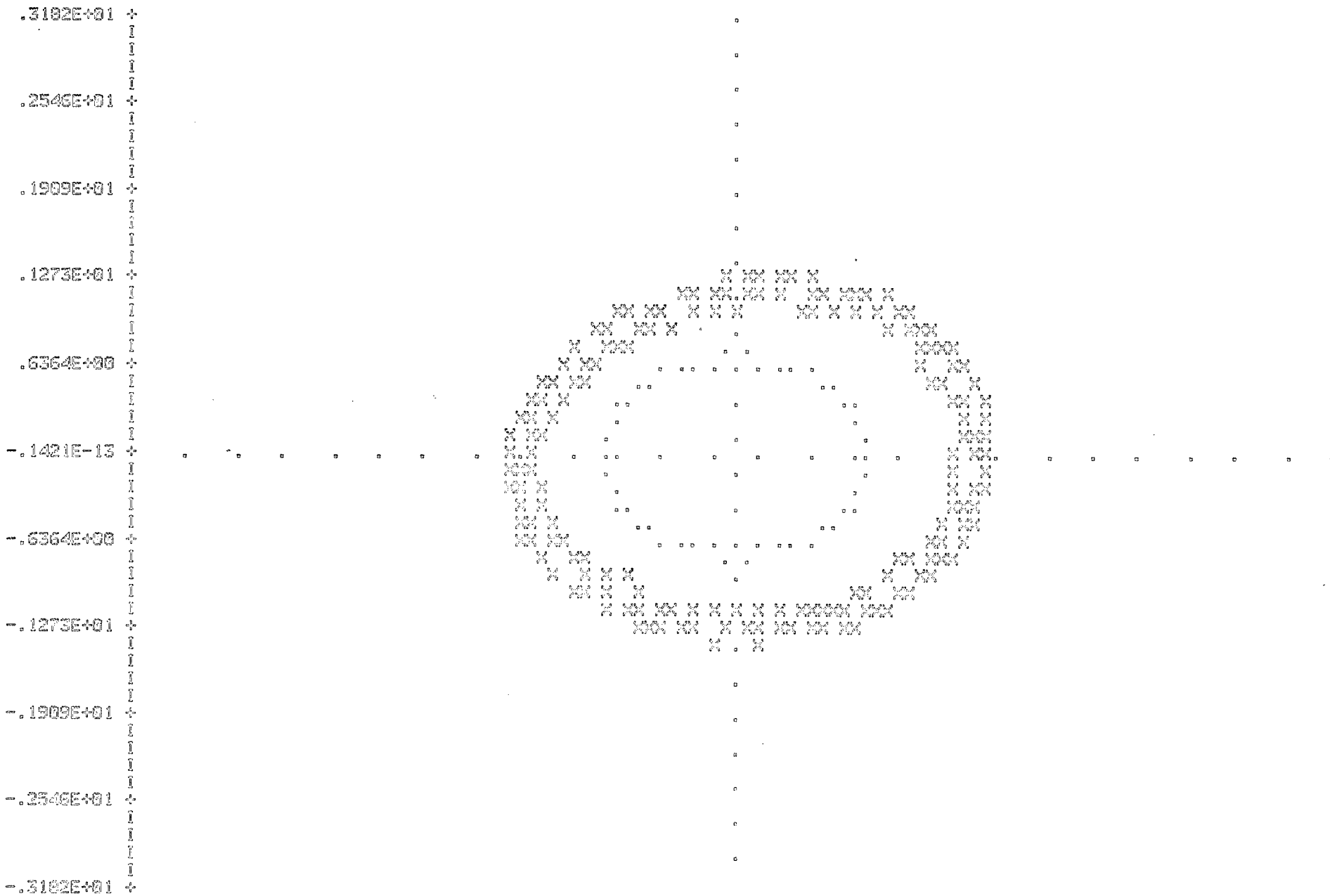
 I I I I I I I
 -.5992E+01 -.4710E+01 .2457E+01 -.2164E+01 -.8913E+00 .3815E+00
 0 POINTS OUTSIDE DIAGRAM MIN = -.2357E+02 MAX = 0. NUC(15) = 1 PART(BET0) = 5.9311

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



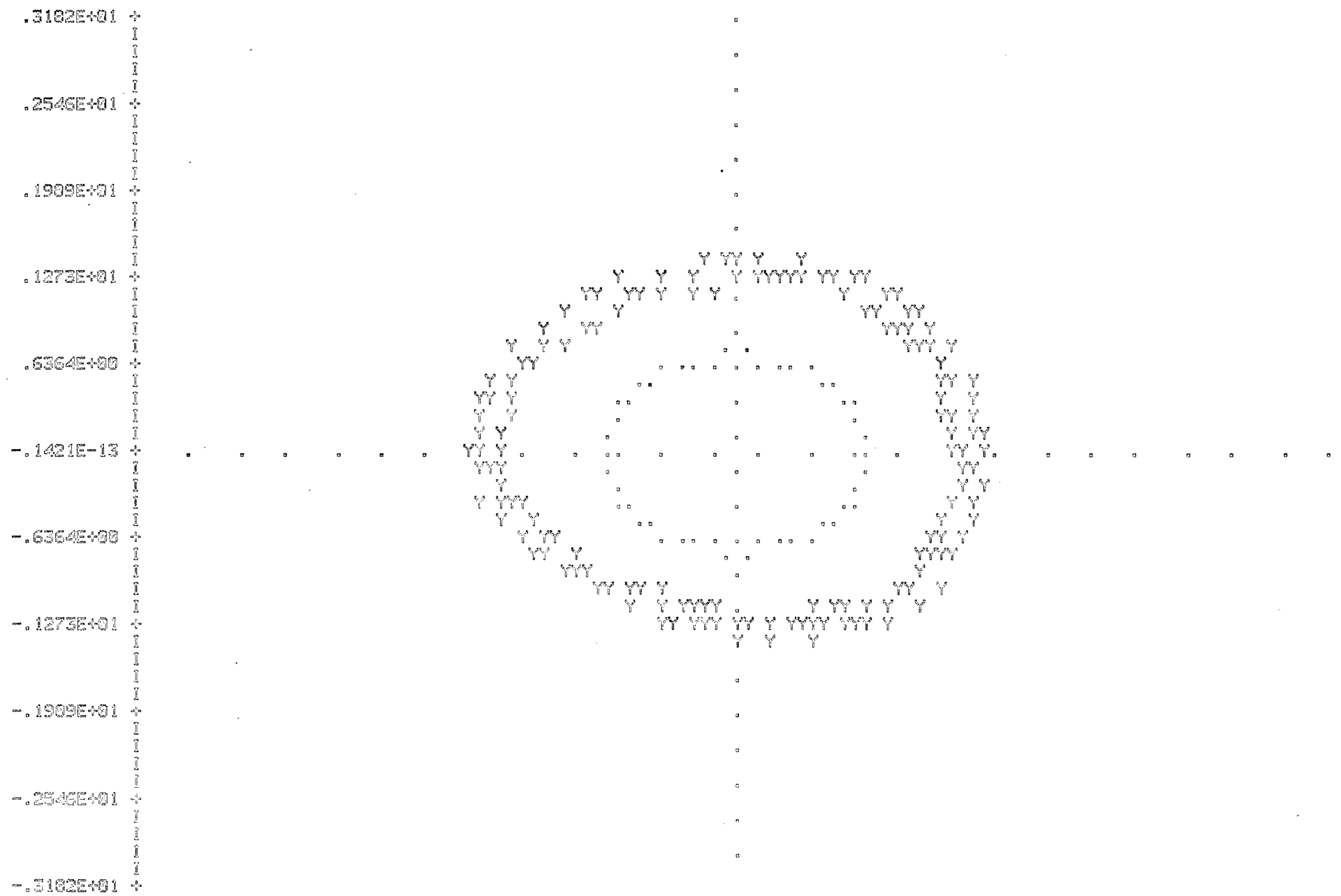
 I I I I I I I
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 1.909E+01 3.182E+01
 0 POINTS OUTSIDE DIAGRAM XMIN = -.2952E+01 XMAX = .3927E+01 KLV(13) = 1 SORT(BETY) = 2.2787

INITIAL PARAMETERS OF PARTICLE 03 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



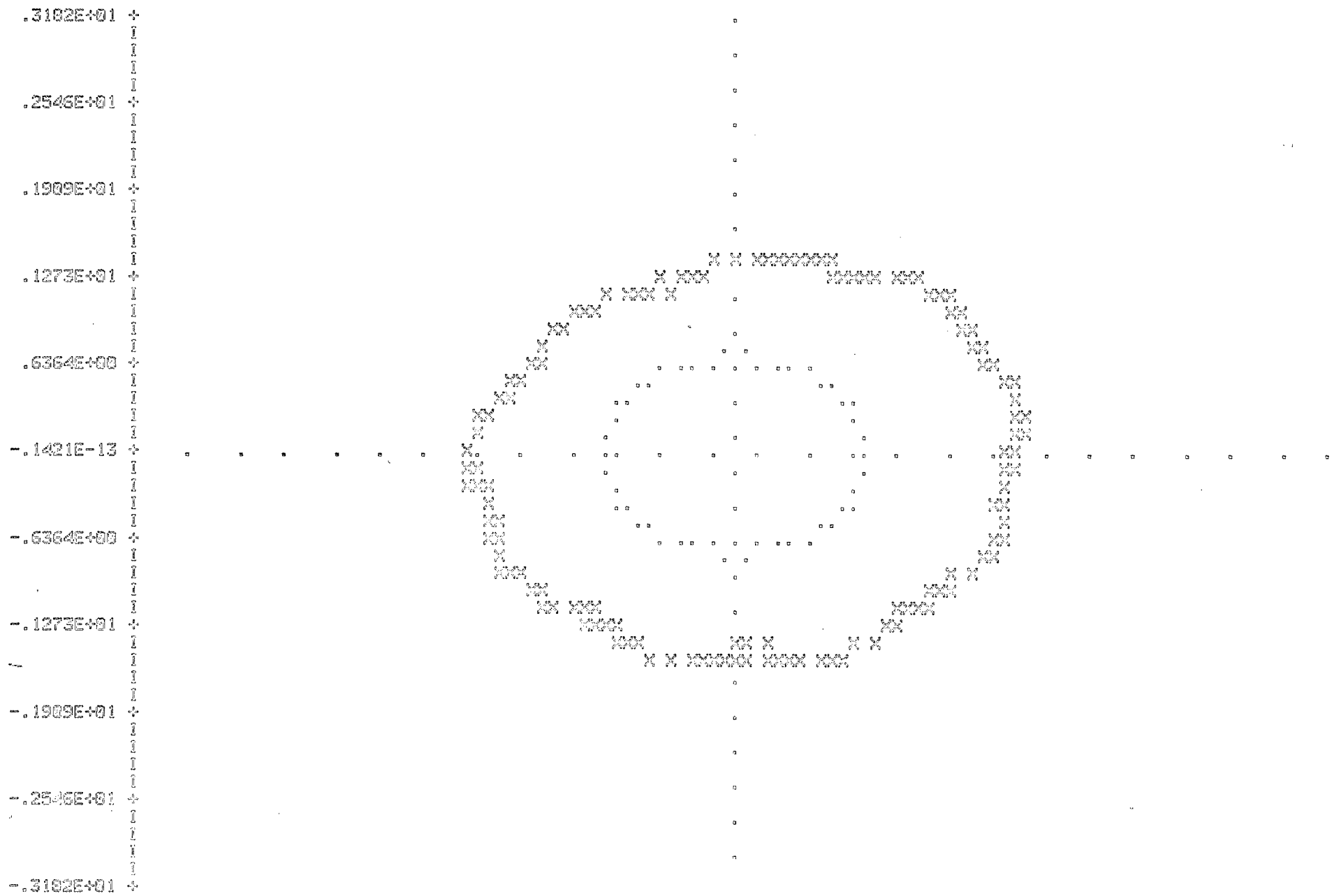
 I I I I I I I
 -.5982E+01 -.4710E+01 -.3457E+01 -.2164E+01 -.0915E+00 .5915E+01
 0 POINTS OUTSIDE DIAGRAM NMIN = -.2334E+02 NMAX = 0. NUX(1) = 1 SORT(BETD) = 5.9311

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



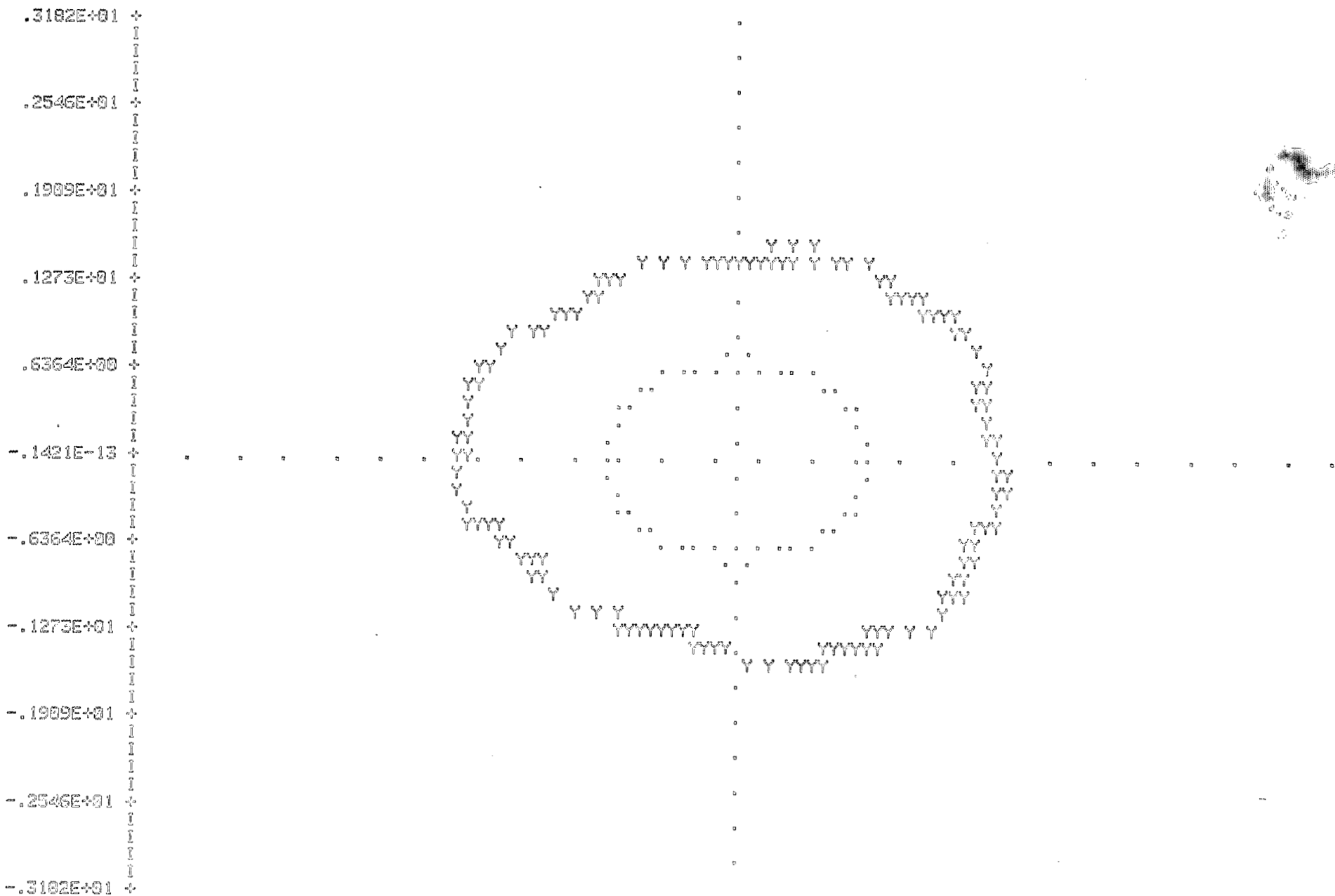
 I I I I I
 -3.182E+01 -1.909E+01 -.6364E+00 .6364E+00 1.909E+01 3.182E+01
 0 POINTS OUTSIDE DIAGRAM XMIN = -.3238E+01 XMAX = .3049E+01 NUC(13) = 1 SORT(25TV) = 3.2787

INITIAL PARAMETERS OF PARTICLE #4 XA = -.570E+01MM XPA = .996E-02MM YA = .312E+01MM YPA = 0. NR
 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



 I I I I I I I
 -0.5982E+01 -0.4710E+01 -0.3437E+01 -0.2164E+01 -0.0912E+00 0.3815E+00
 0 POINTS OUTSIDE DIAGRAM NMIN = 0.2815E+02 NMAX = 0. KM(13) = 1 SQR(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



 I I I I I I I
 -3.182E+01 -1.909E+01 -0.6364E+00 0.6364E+00 1.909E+01 3.182E+01
 0 POINTS OUTSIDE DIAGRAM NMIN = -3.432E+01 NMAX = .3256E+01 NW(12) = 1 SORT(BETV) = 2.2787