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Some Results for the Chromatic Correction of the Antisymmetric RHIC Lattice

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DISCLAIMER

RHIC-AP-27

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Armando Antillón

February 24, 1986

ABSTRACT

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

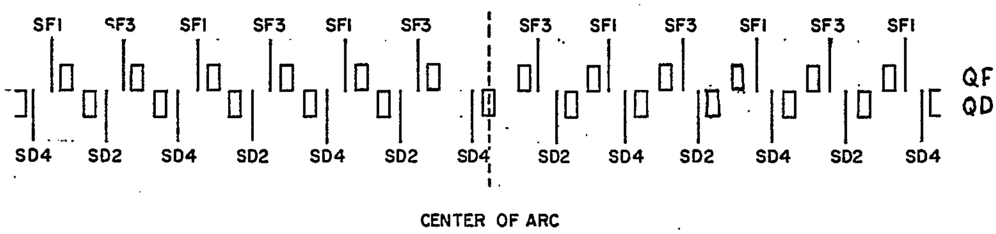
I. Introduction

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 HARMON[3]. Unfortunately, HARMON has shown some weakness and none run has been better than those in which sextupoles have been chosen manually.

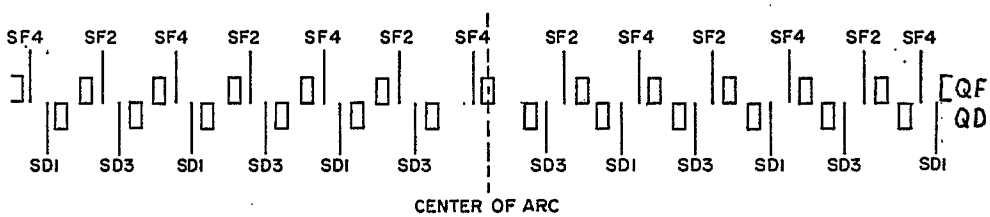
II. The Lattice

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[4], 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.

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[5].

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

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

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

$\varepsilon_x/\varepsilon_y = -57.5/-57.4$

$\nu_x/\nu_y = 28.851725/28.843547$

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.

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[5]From 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

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

Inner arc:

SF2 = 1.148
SF4 = 1.738
SD1 = -4.0
SD3 = -2.5135

Outer arc:

SF1 = 1.426
SF3 = 2.474
SD2 = -2.6541
SD4 = -4.0 (Fig. 2).

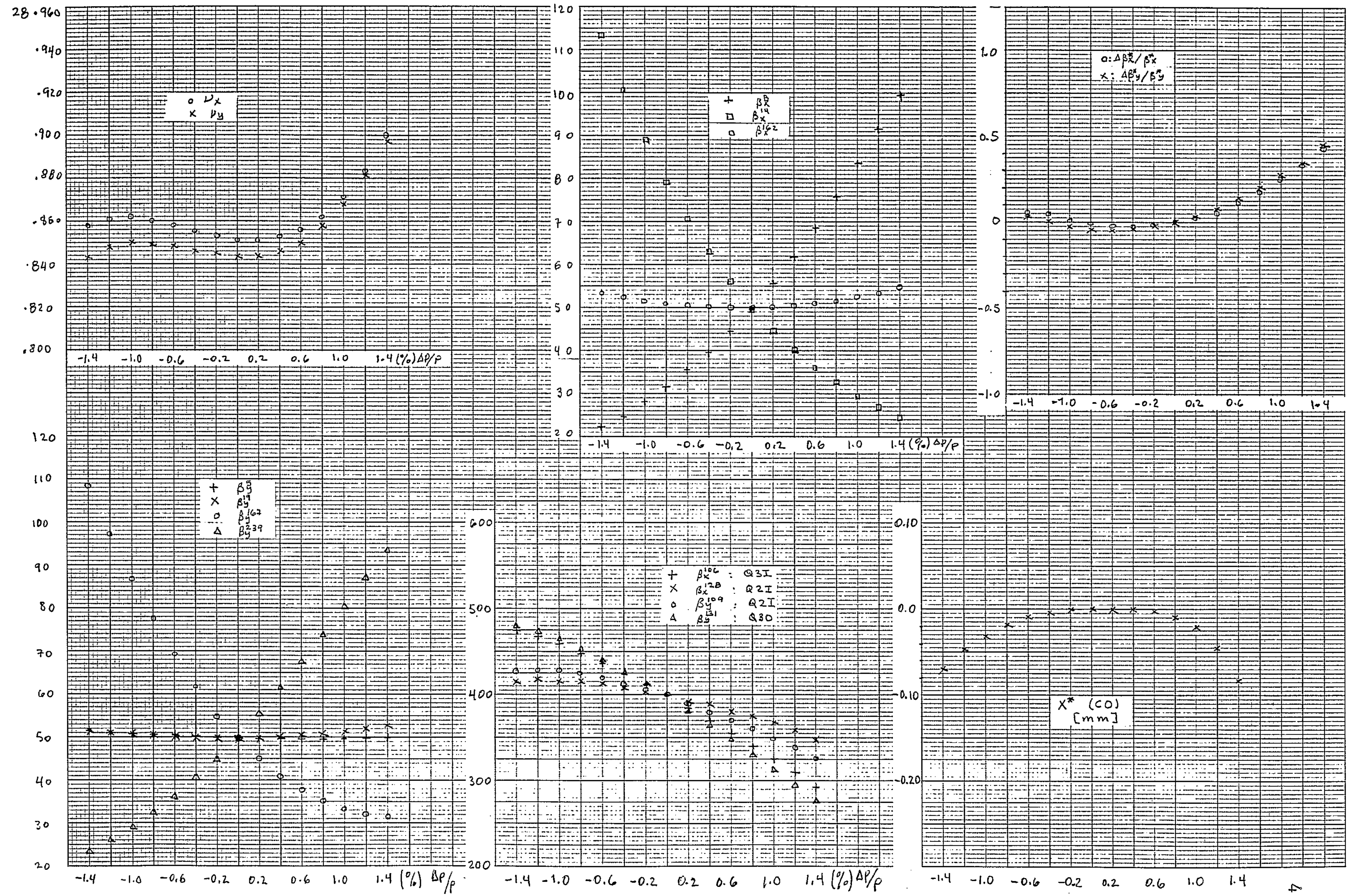
IV. Tune versus Amplitude

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

$\Delta Q_x / \Delta \varepsilon_x = -145$

$\Delta Q_y / \Delta \varepsilon_y = 579$

$\Delta Q_y / \Delta \varepsilon_x = -960.$



o νx
x νy
+ βx
□ βx 14
o βx 162
o: Δβx*/βx*
x: Δβy*/βy*
+ βy
x βy
o βy 167
Δ βy 239
+ βx 106 : Q3I
x βx 128 : Q2I
o βy 109 : Q2I
Δ βy 131 : Q3O
X* (CO) [mm]
(%) Δp/p

Fig. 1

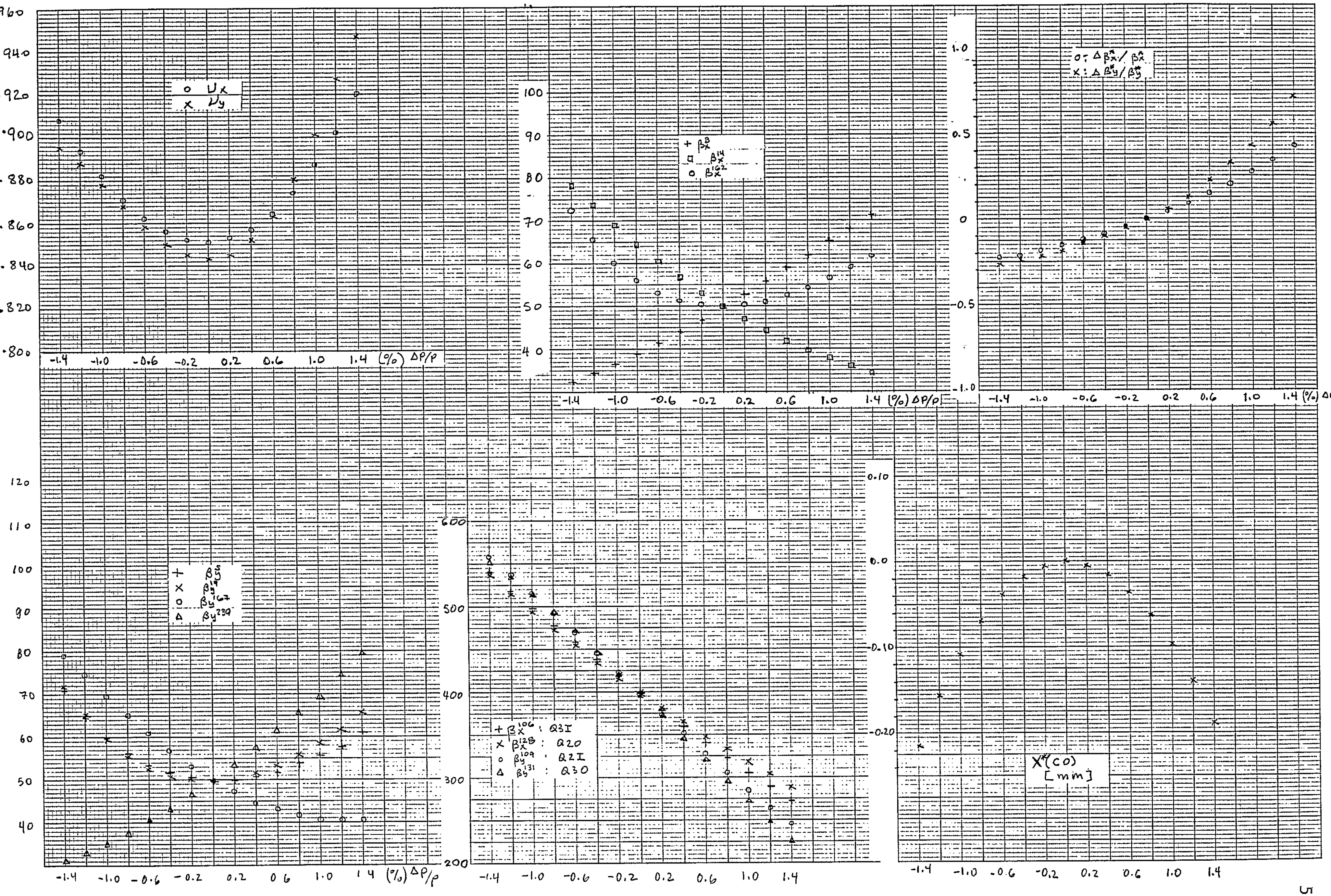

o ν_x
x ν_y
(%) $\Delta P/P$
+ β_x^{8}
□ β_x^{14}
o β_x^{162}
o : $\Delta\beta_x^*/\beta_x^*$
x : $\Delta\beta_y^*/\beta_y^*$
+ β_y^{5}
x β_y^{19}
o β_y^{167}
Δ β_y^{239}
+ β_x^{106} : Q3I
x β_x^{128} : Q2O
o β_y^{109} : Q2I
Δ β_y^{131} : Q3O
X^*(CO)
[mm]

Fig. 2

So, for an emittance of 0.3 mm-mrad

$$\Delta\nu_x \sim 3.3\times10^{-4}$$

$$\Delta\nu_y \sim 1.14\times10^{-4}$$

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

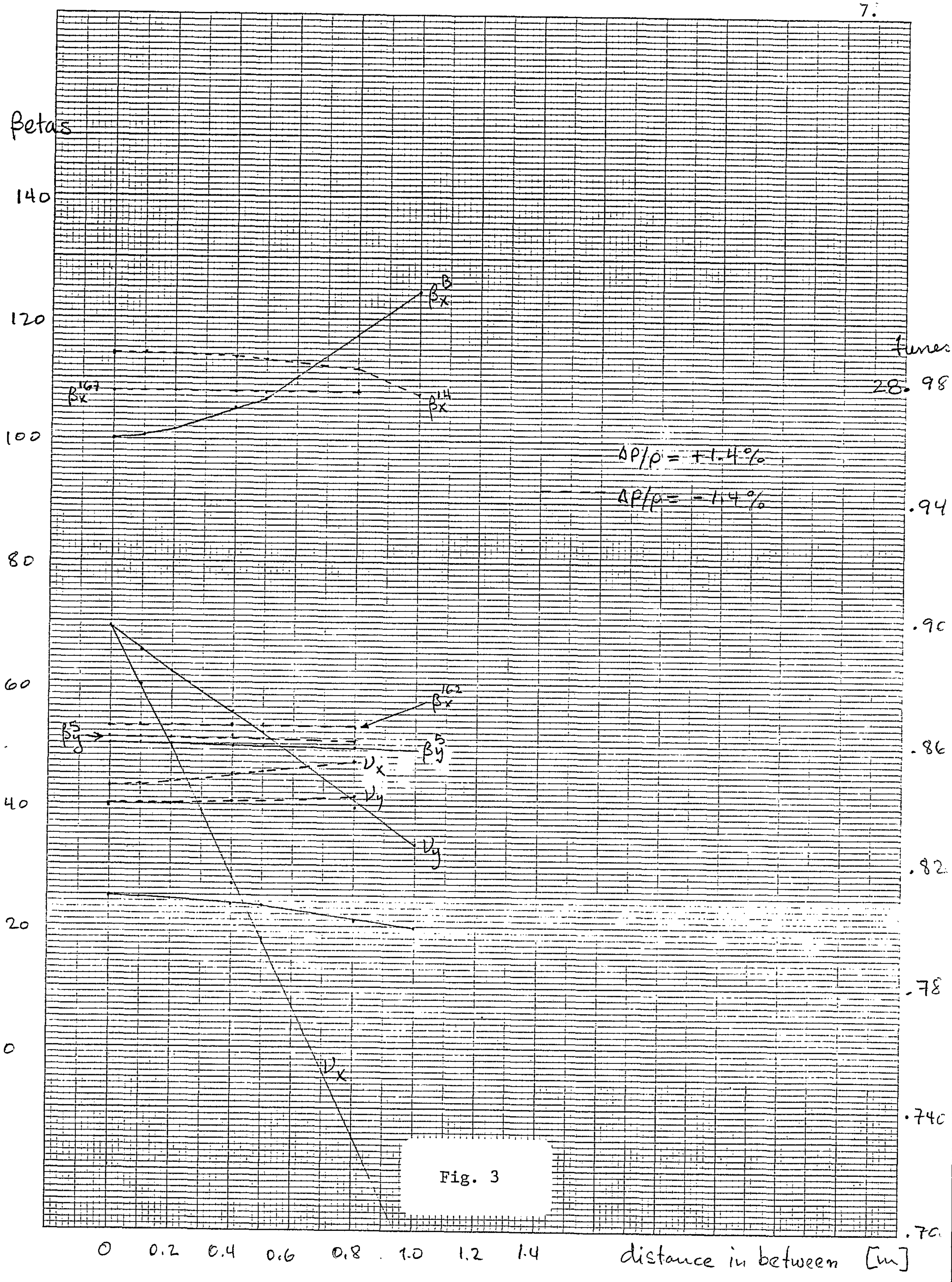
Finally we are going to show tracking results for the case of 8 families. We are using PATRICIA with 4 particles with emittances 0.5π, 1π, 1.5π and 2π mm-mrad.

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:

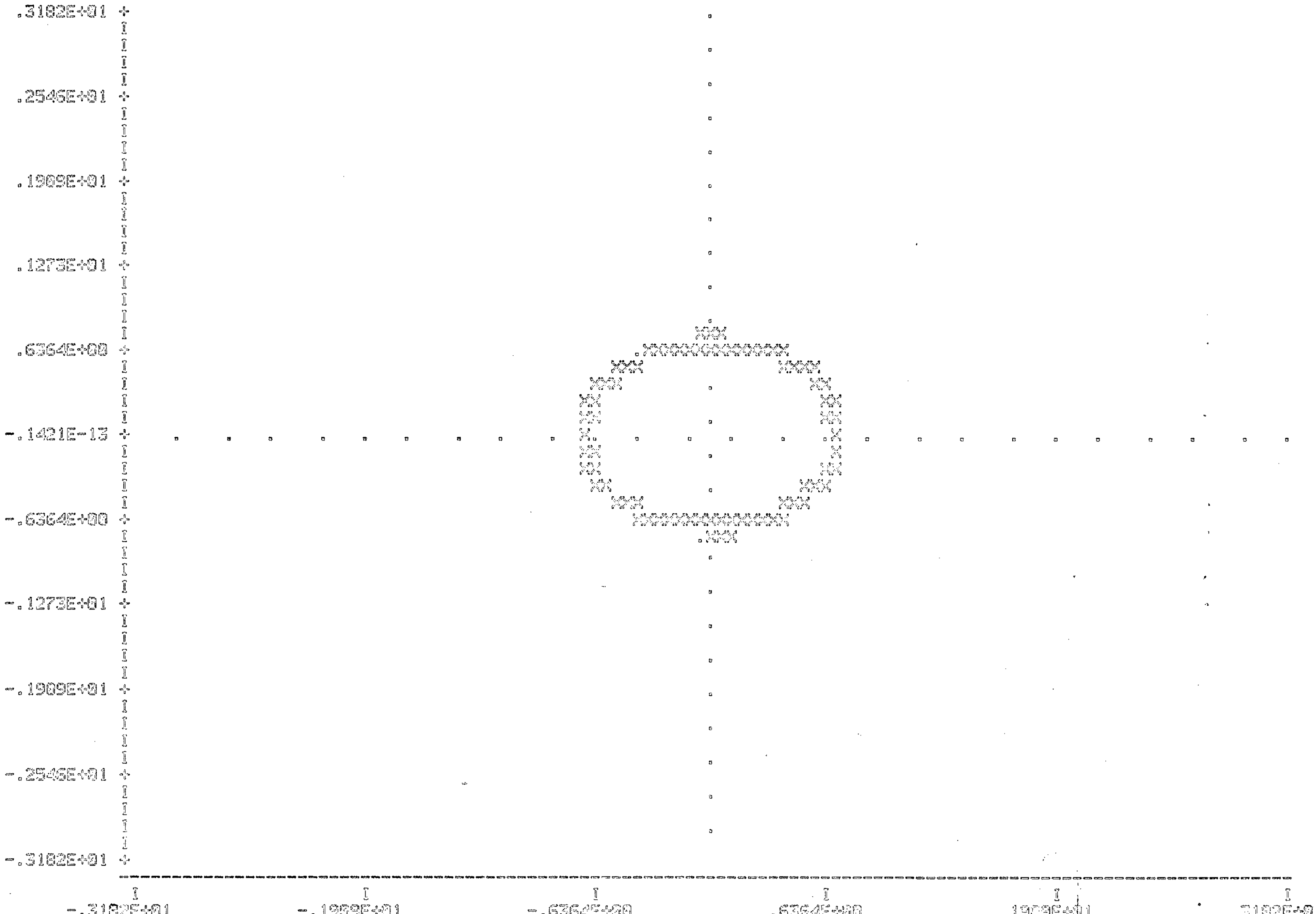
I am very grateful to Dr. Martin H. Donald from SLAC for his help and suggestions for the program HARMON, and to R. Gupta, S. Y. Lee and Z. Parsa for their help with the first version of MAD/HARMON.



Betas
140
120
100
80
60
40
20
0
tunes
28. 98
.94
.90
.86
.82
.78
.740
.70
β_x^B
β_x^{167}
β_x^{14}
$\Delta P/P = +1.4\%$
$\Delta P/P = -1.4\%$
β_x^{162}
β_y^5
β_y^5
ν_x
ν_y
ν_y
ν_x
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
distance in between [m]

Fig. 3

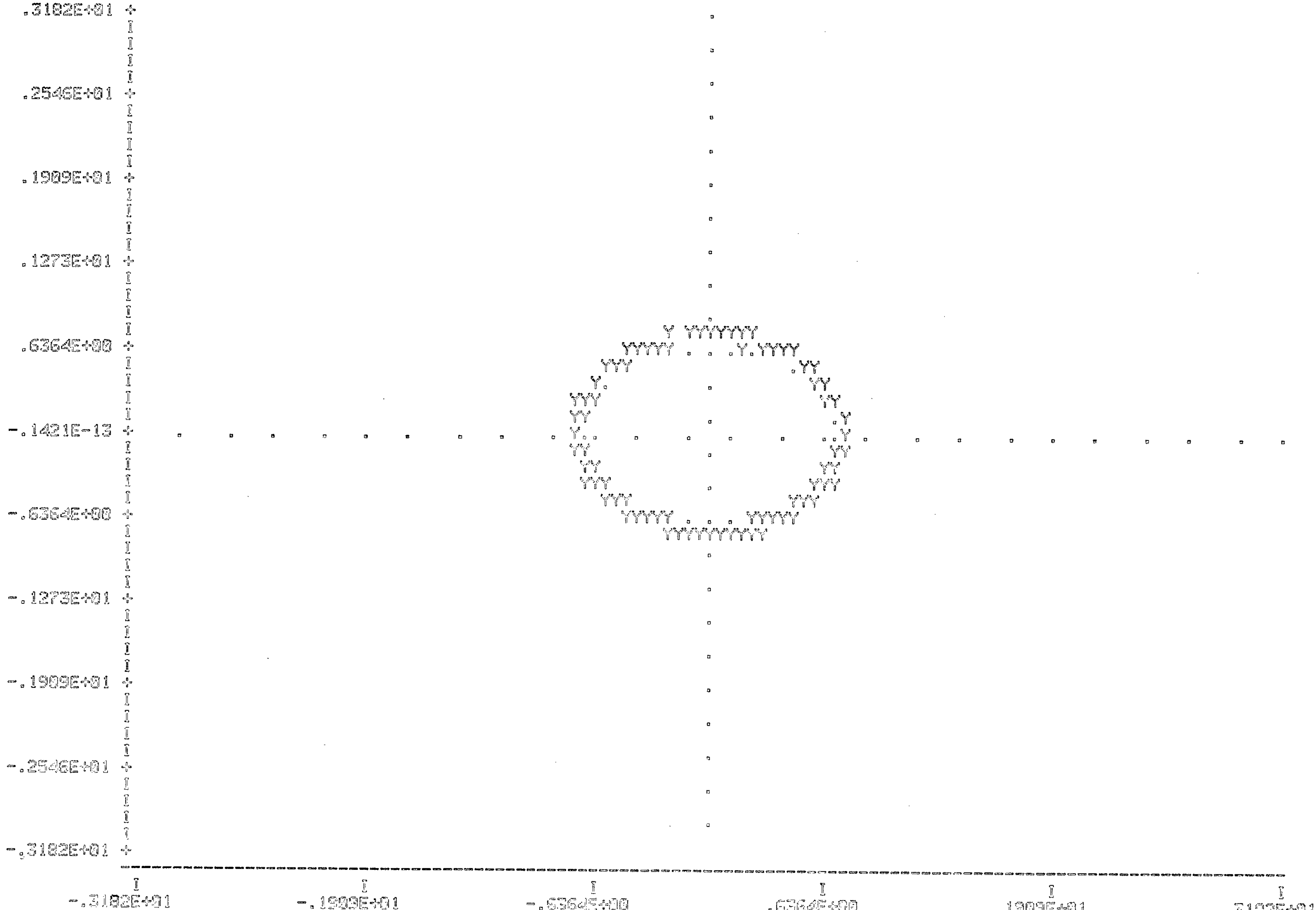
INITIAL PARAMETERS OF PARTICLE #1   XA = .499E+01MM   XPA = 0.   MM   YA = .208E+01MM   YPA = 0.   MR
BETATRON AMPLITUDES = IN X : .100E+02 SIGMA   IN Y : .100E+02 SIGMA   ENERGY DEVIATION = 0.   SIGMA AT 30.00 GEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS



0 POINTS OUTSIDE DIAGRAM   XMIN = -.5053E+01   XMAX = .4076E+01   KW(13) = 1   SQRT(BETX) = 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

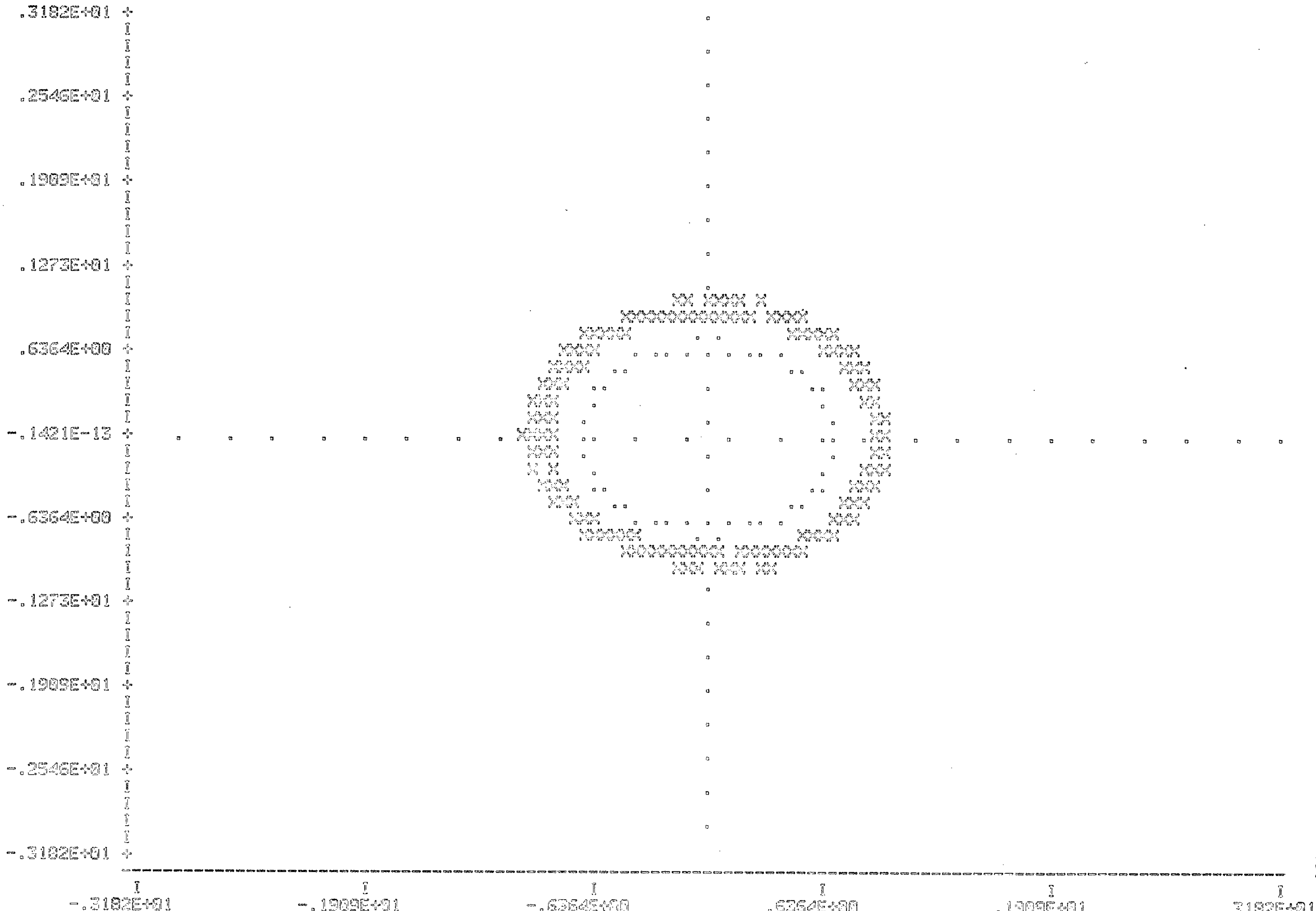


0 POINTS OUTSIDE DIAGRAM XMIN = -.3316E+01 XMAX = .3205E+01 KW(13) = 1 SQRT(BETY) = 2.9431

6.

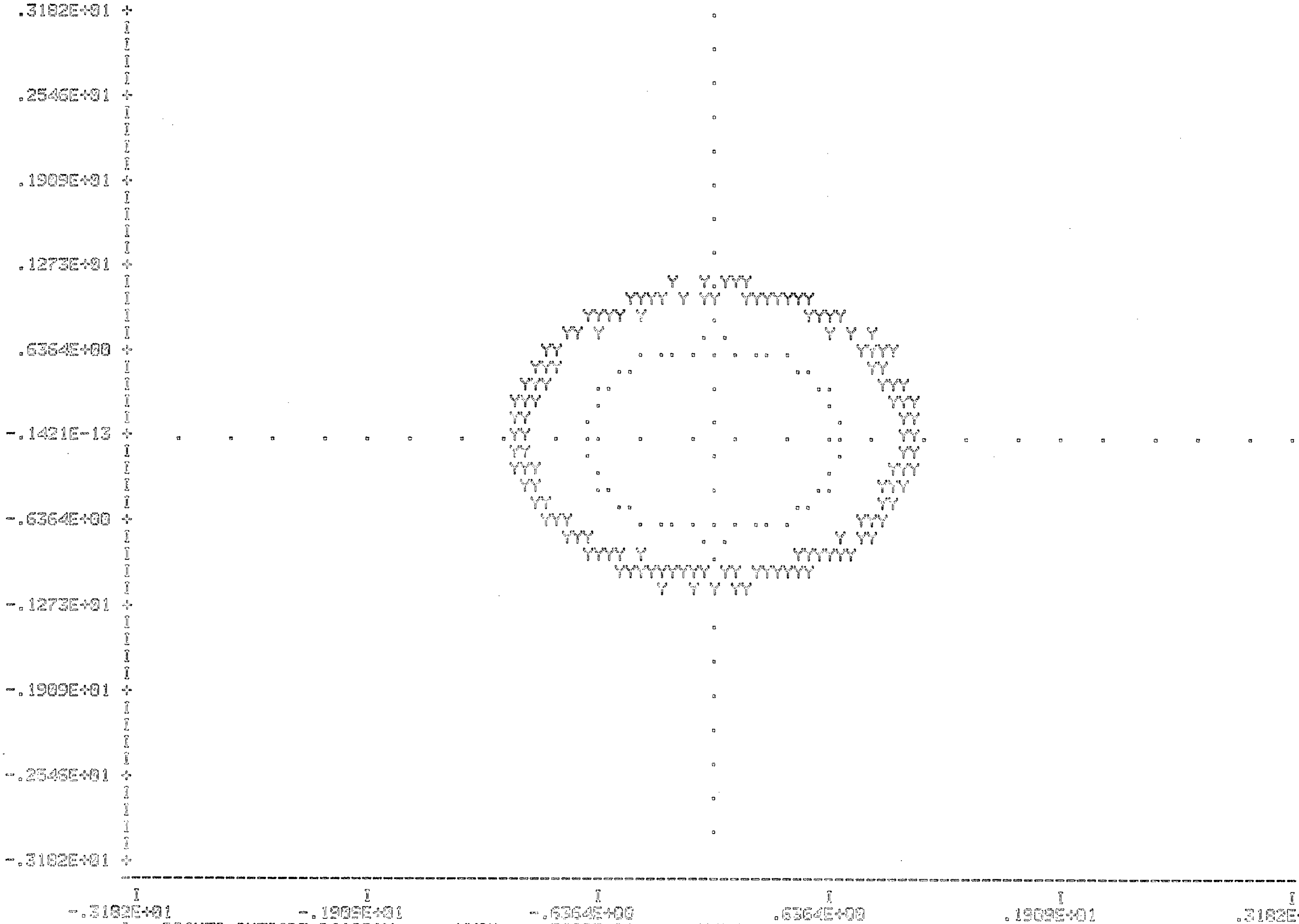
107

INITIAL PARAMETERS OF PARTICLE 02 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



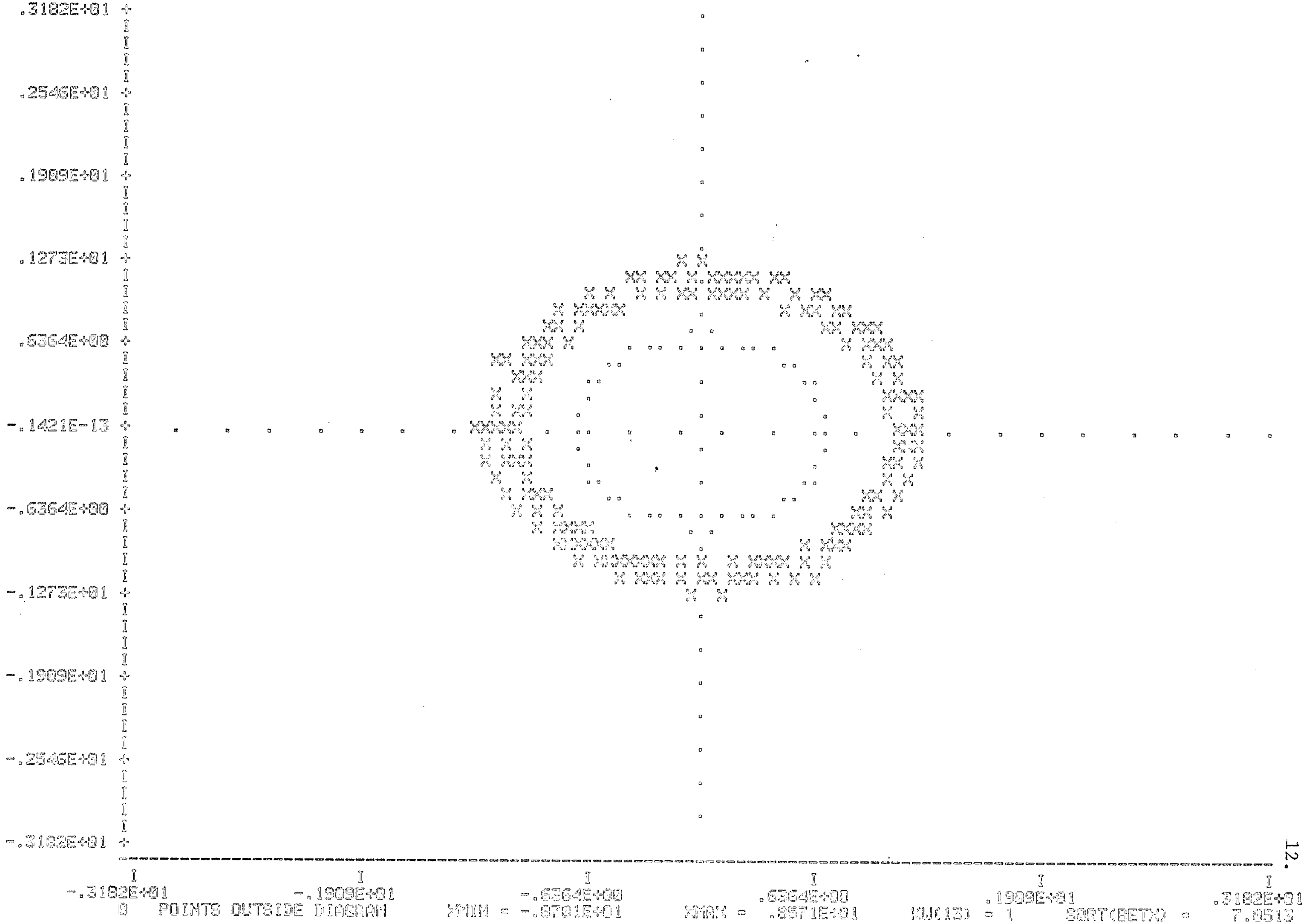
0 POINTS OUTSIDE DIAGRAM XMIN = -.7146E+01 XMAX = .7001E+01 KW(15) = 1 SQRT(BETX) = 7.0513

INITIAL PARAMETERS OF PARTICLE <2 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



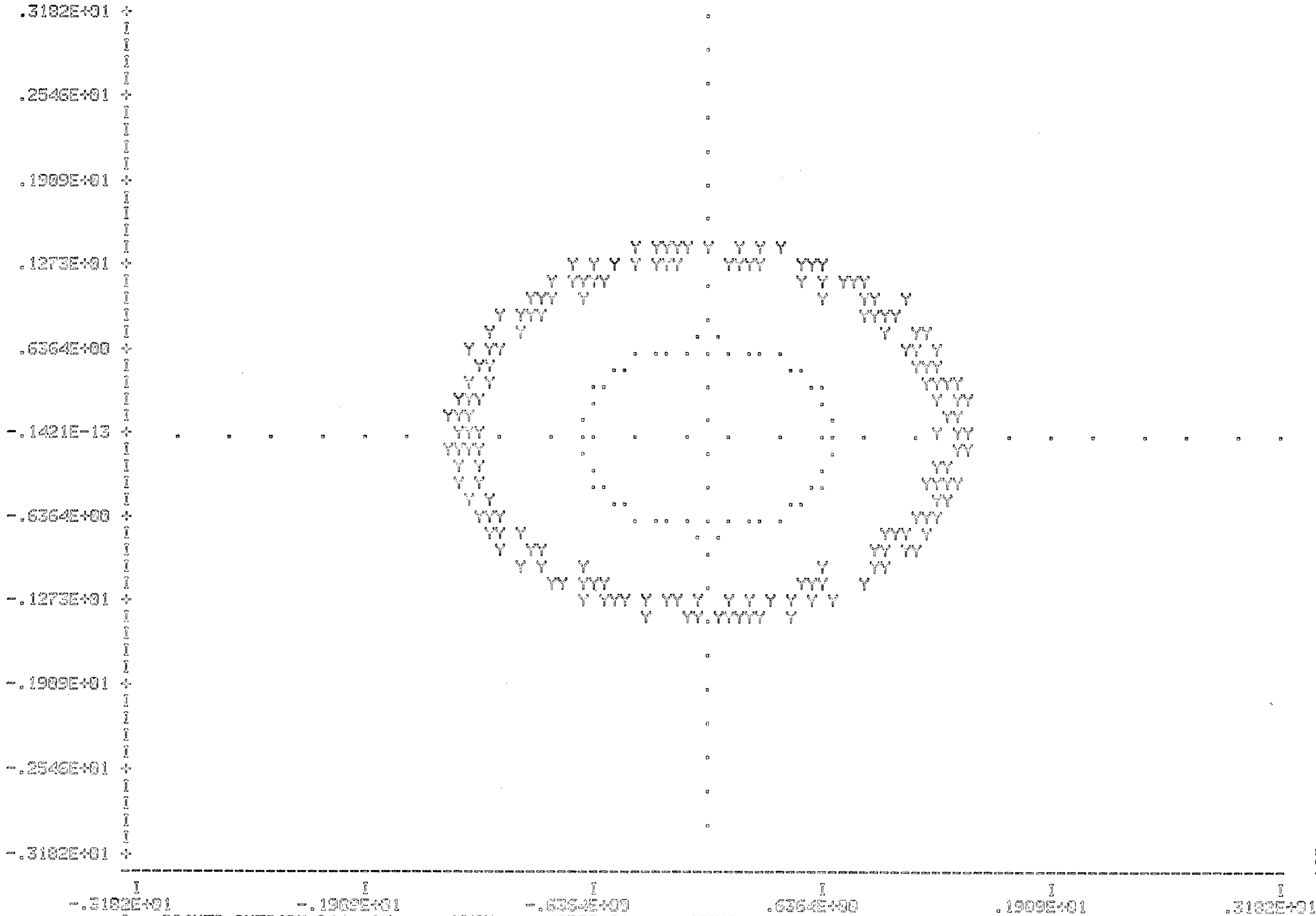
0 POINTS OUTSIDE DIAGRAM XMIN = -.3298E+01 XMAX = .3276E+01 KW(13) = 1 SQRT(BETY) = 2.9431

INITIAL PARAMETERS OF PARTICLE 03   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



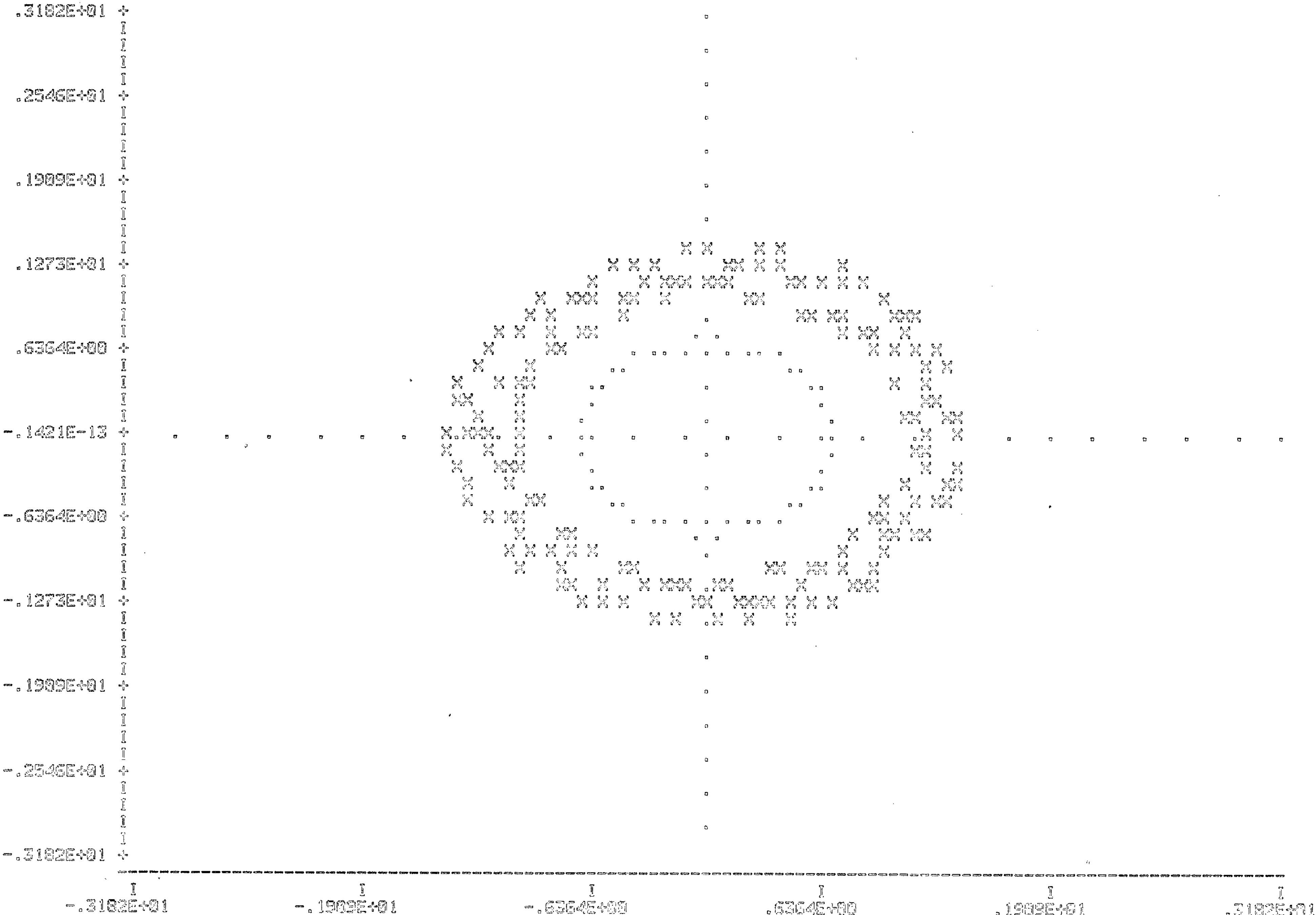
0 POINTS OUTSIDE DIAGRAM   XMIN = -.8701E+01   XMAX = .8571E+01   KW(13) = 1   SQRT(BETX) = 7.0513

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



0 POINTS OUTSIDE DIAGRAM XMIN = -.4237E+01 XMAX = .4221E+01 KW(13) = 1 SQRT(BETY) = 2.9451

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

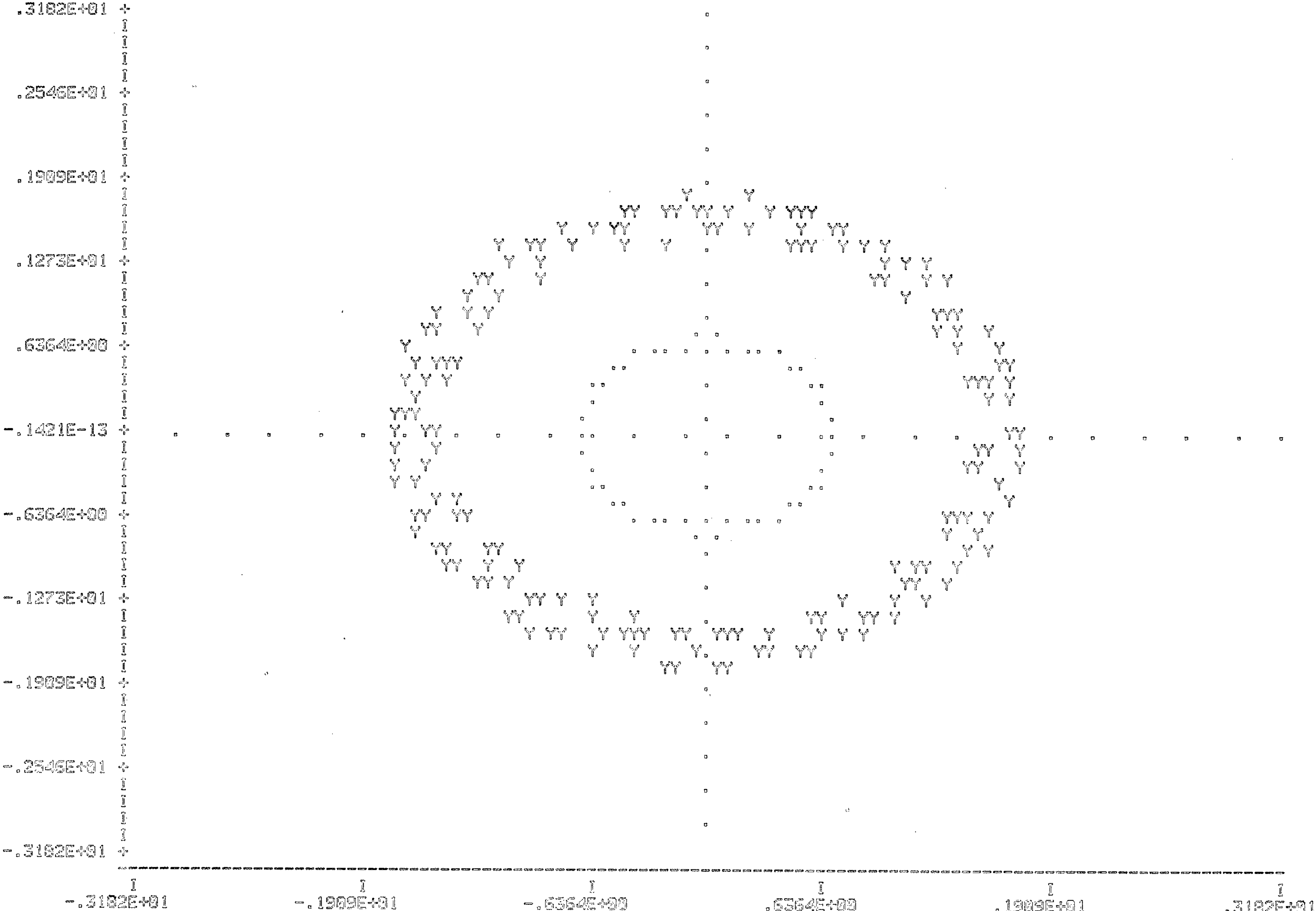


0 POINTS OUTSIDE DIAGRAM   XMIN = -.1017E+02   XMAX = .9860E+01   IW(13) = 1   SQRT(BETX) = 7.0512

14.

120

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



0 POINTS OUTSIDE DIAGRAM   XMIN = -.5136E+01   XMAX = .5113E+01   KW(15) = 1   SQRT(BETY) = 2.9431

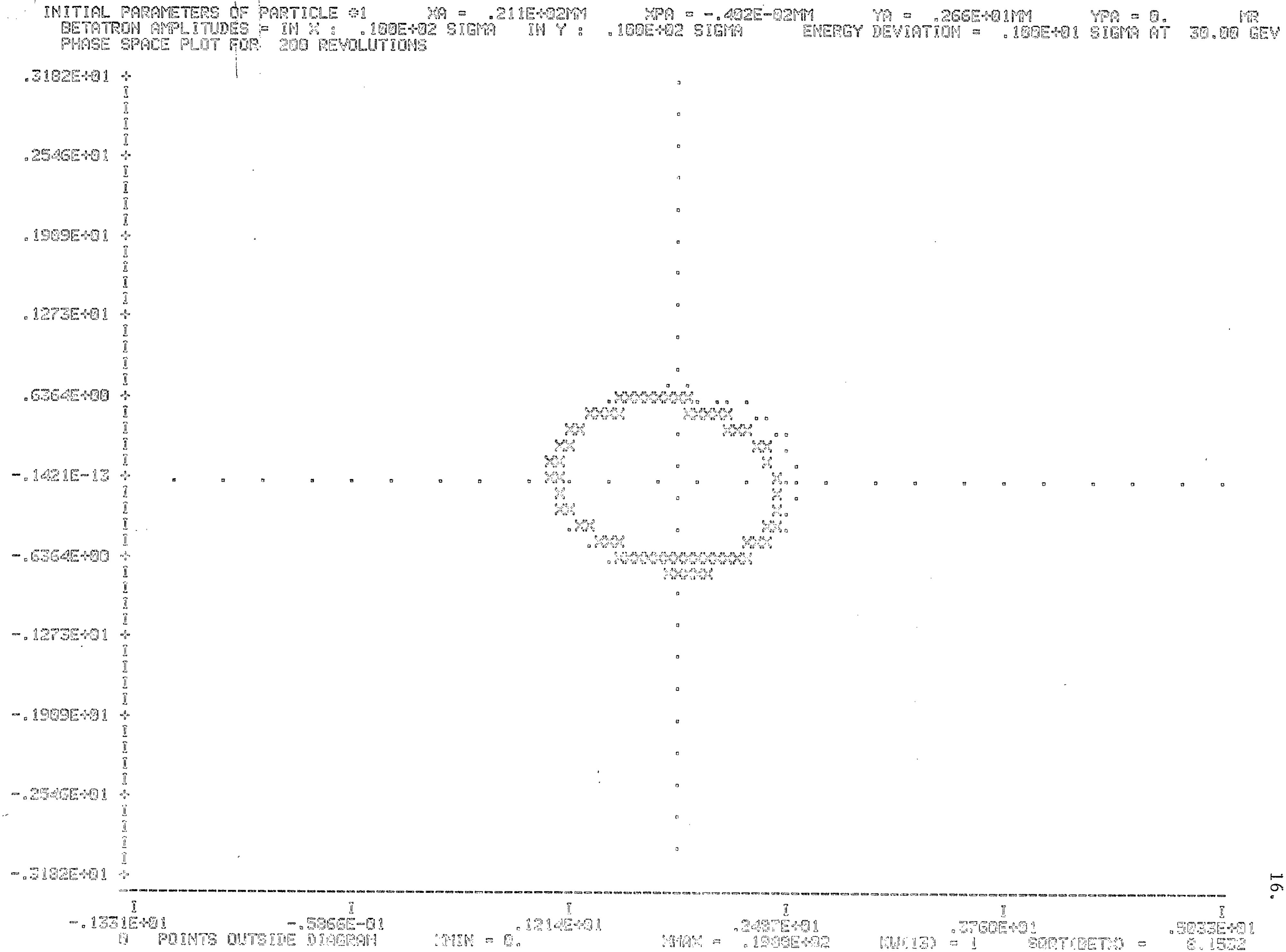
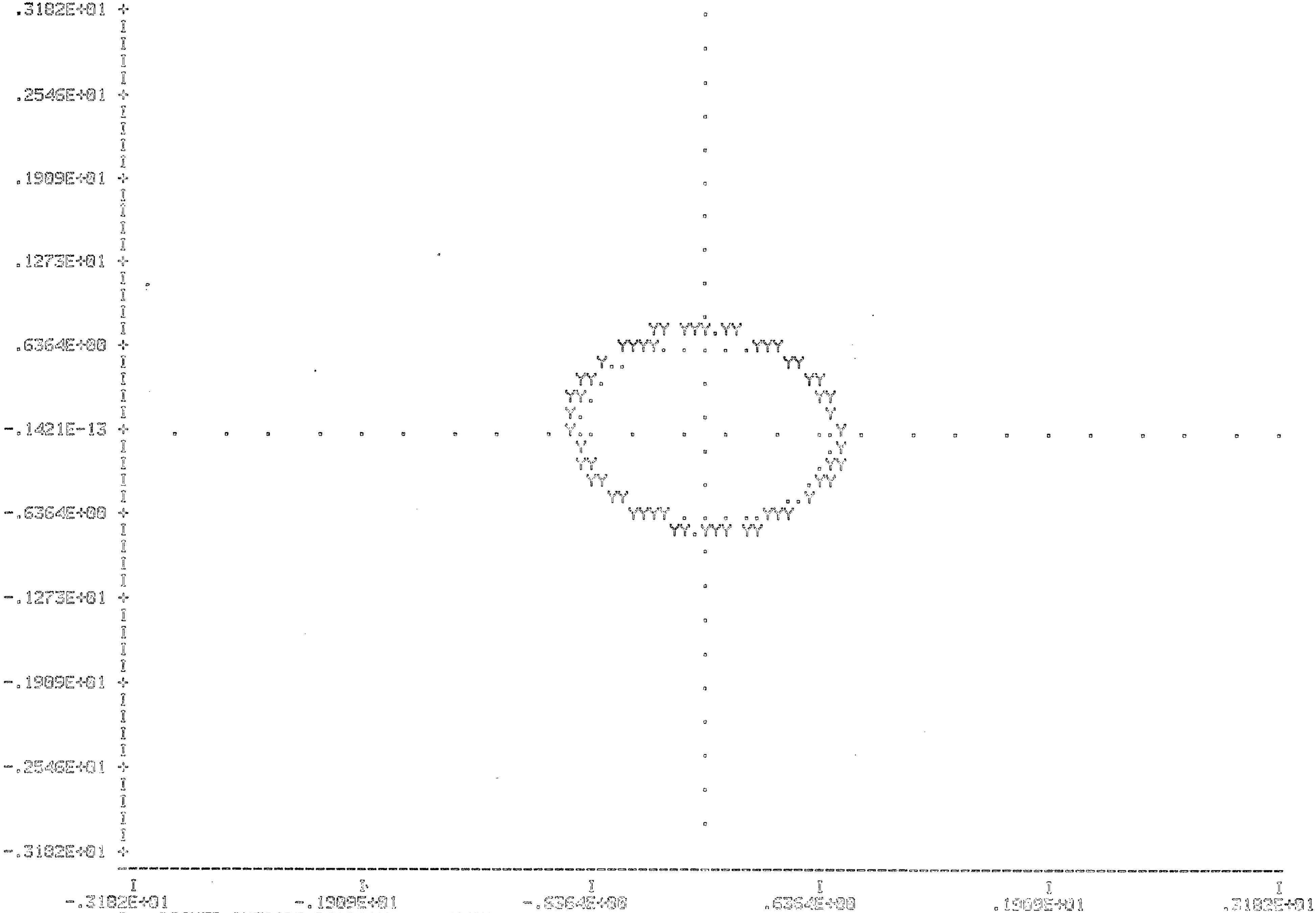

INITIAL PARAMETERS OF PARTICLE #1 XA = .211E+02MM XPA = -.402E-02MM YA = .266E+01MM YPA = 0. MR
BETATRON AMPLITUDES = IN X : .100E+02 SIGMA IN Y : .100E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS
.3182E+01
.2546E+01
.1909E+01
.1273E+01
.6364E+00
-.1421E-13
-.6364E+00
-.1273E+01
-.1909E+01
-.2546E+01
-.3182E+01
-.1331E+01
-.5866E-01
.1214E+01
.2487E+01
.3760E+01
.5033E+01
0 POINTS OUTSIDE DIAGRAM
XMIN = 0.
XMAX = .1999E+02
KW(13) = 1
SQRT(BETX) = 6.1522

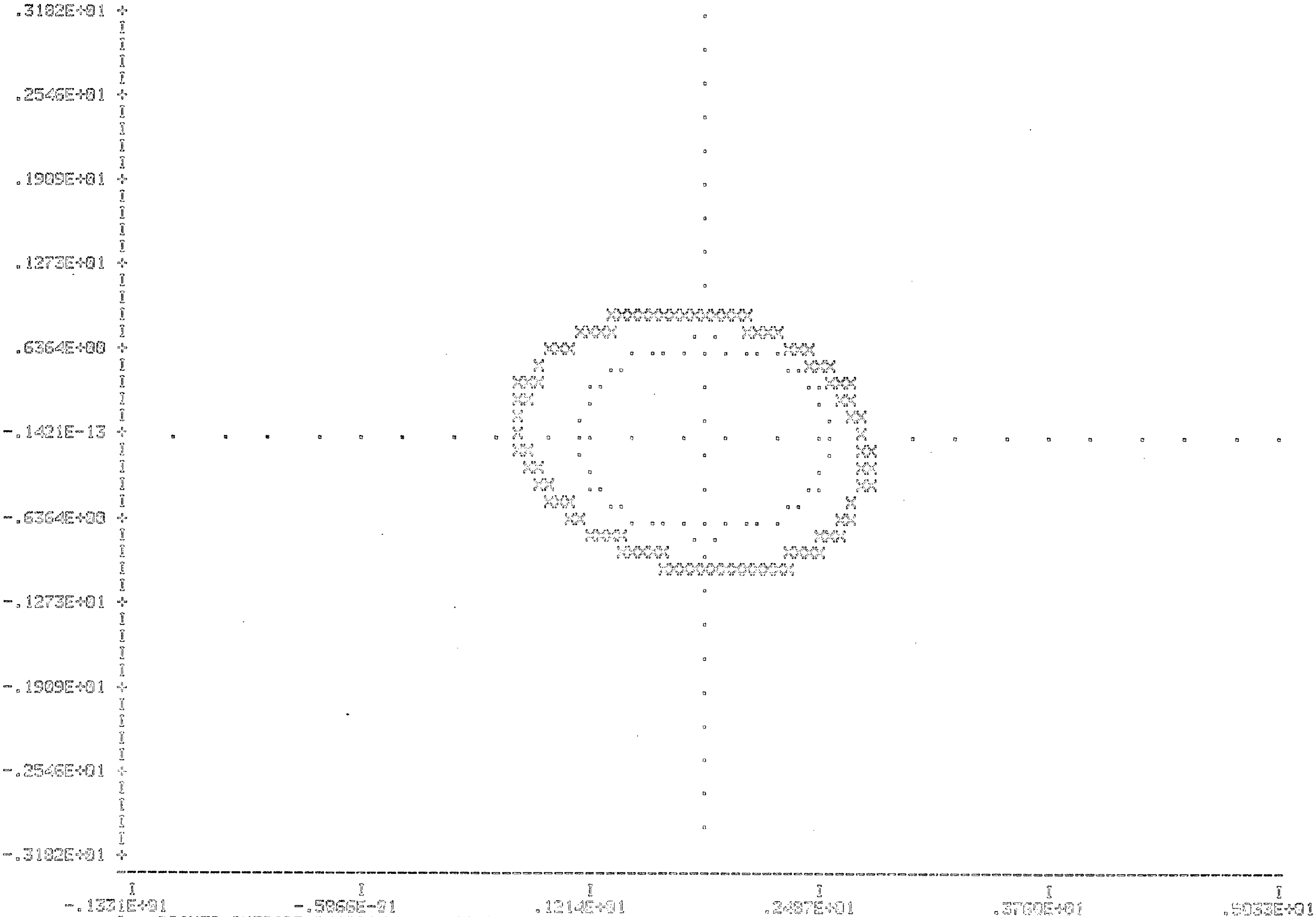
Fig. 5

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



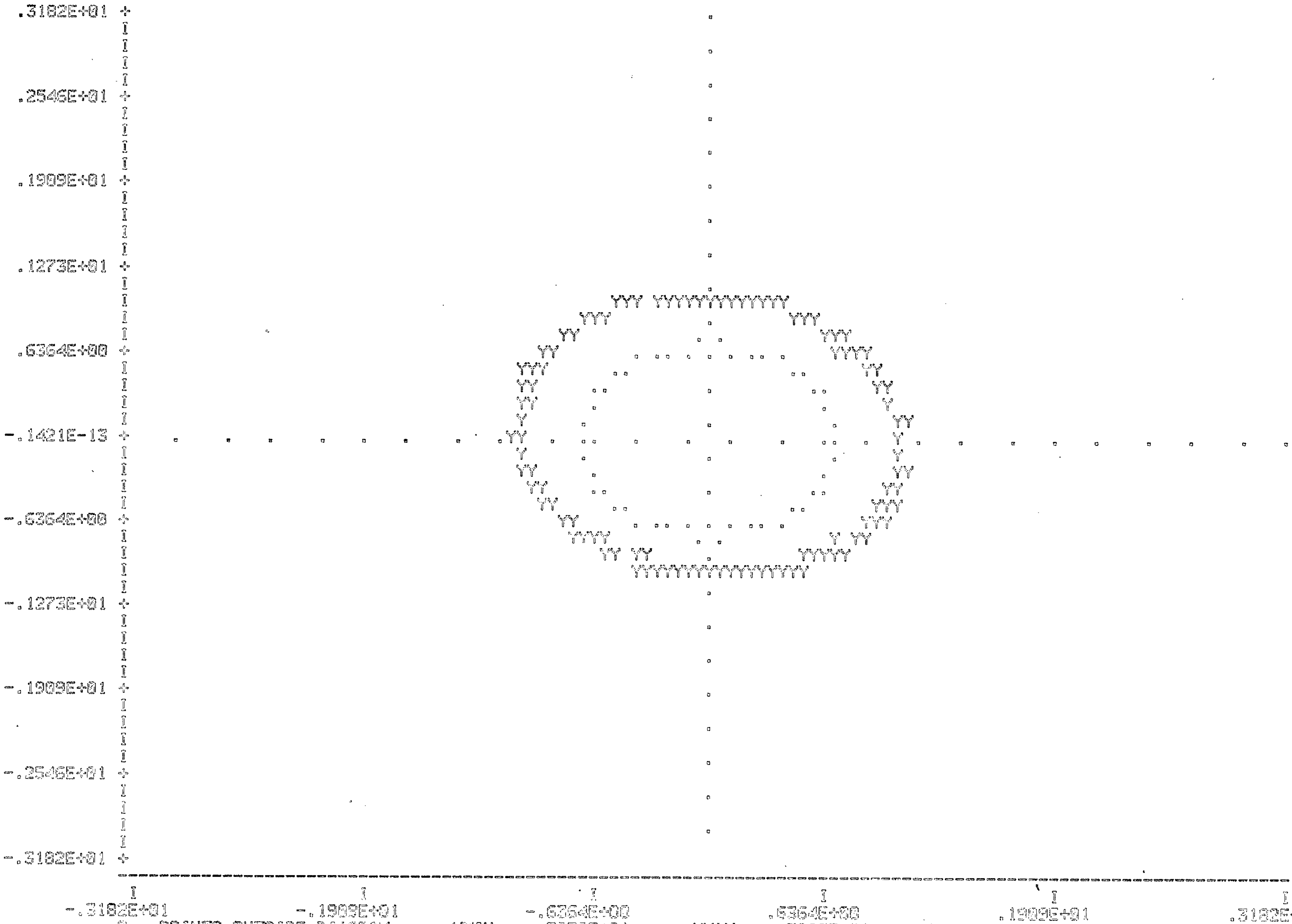
0 POINTS OUTSIDE DIAGRAM   XMIN = -.2720E+01   XMAX = .2713E+01   KW(13) = 1   SQRT(BETY) = 3.6551

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 GEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS



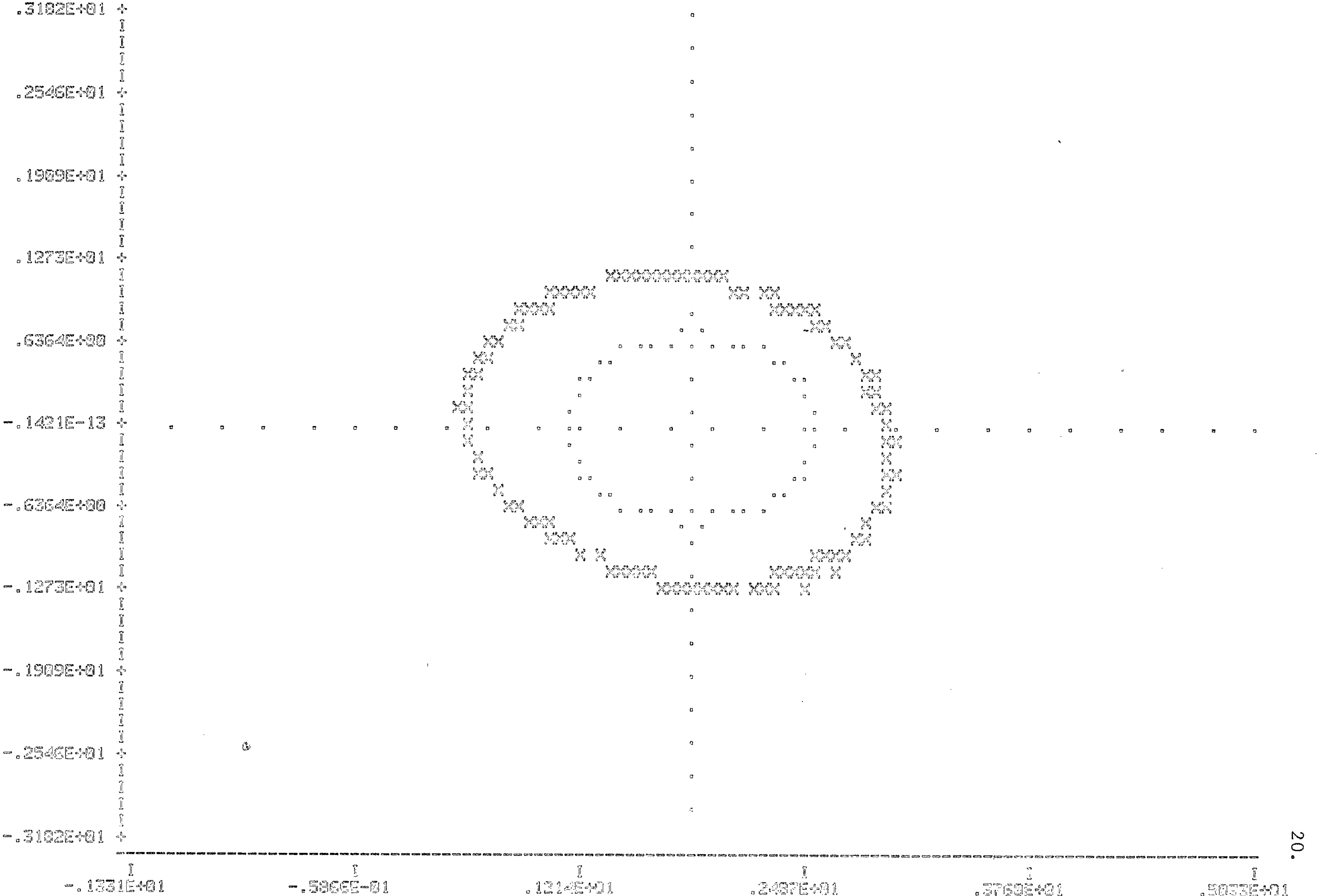
0 POINTS OUTSIDE DIAGRAM XMIN = 0. XMAX = .2248E+02 KW(13) = 1 SQRT(BETX) = 8.1532

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 GEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS



0 POINTS OUTSIDE DIAGRAM   XMIN = -.3930E+01   XMAX = .3923E+01   KW(13) = 1   SQRT(BETY) = 3.6551

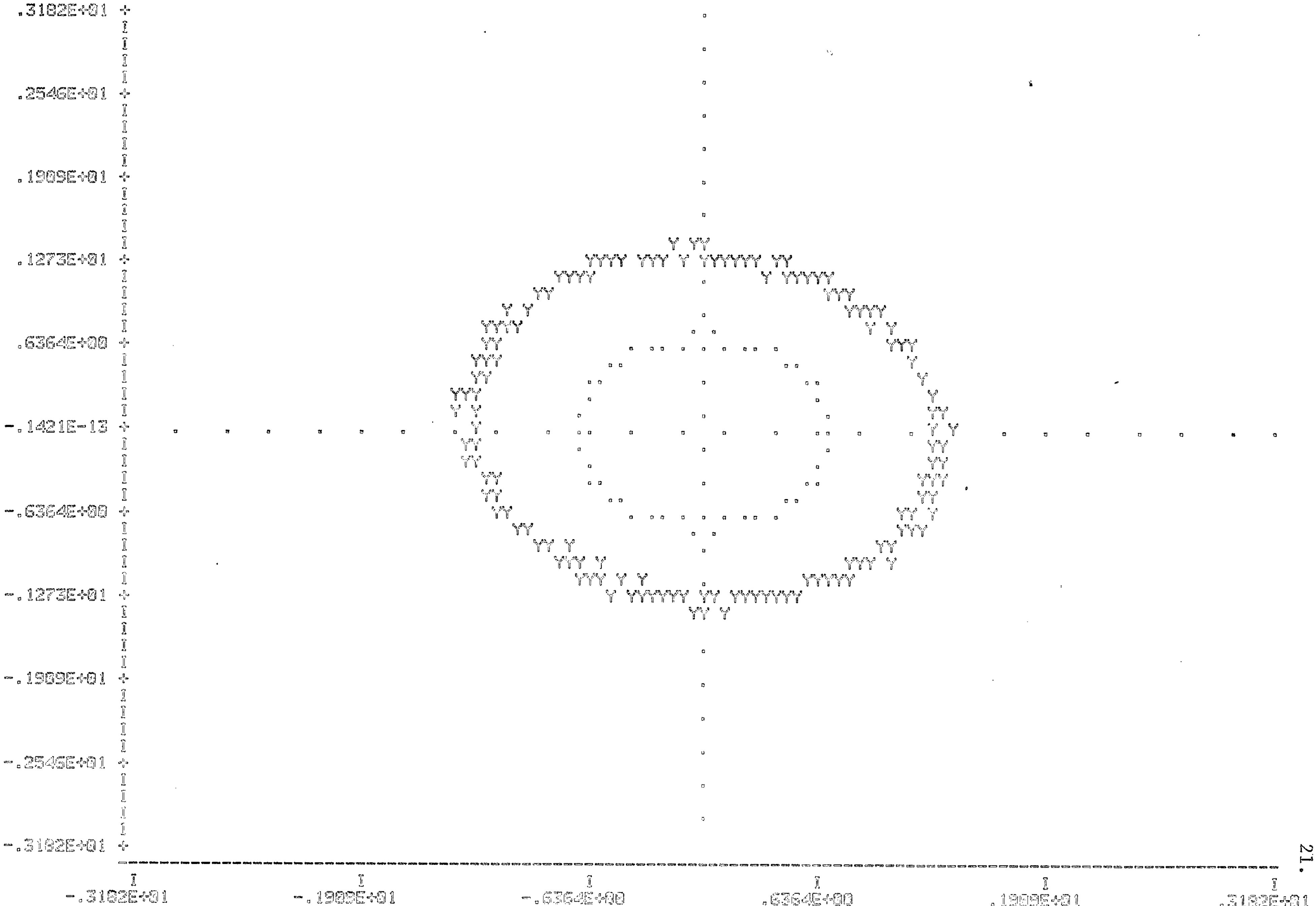
INITIAL PARAMETERS OF PARTICLE 3   XA = .253E+02MM   XPA = -.402E-02MM   YA = .460E+01MM   YPA = 0.   MR
BETATRON AMPLITUDES = IN X : .173E+02 SIGMA   IN Y : .173E+02 SIGMA   ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS



0 POINTS OUTSIDE DIAGRAM   XMIN = 0.   XMAX = .2456E+02   KW(13) = 1   SQRT(BETX) = 8.1532

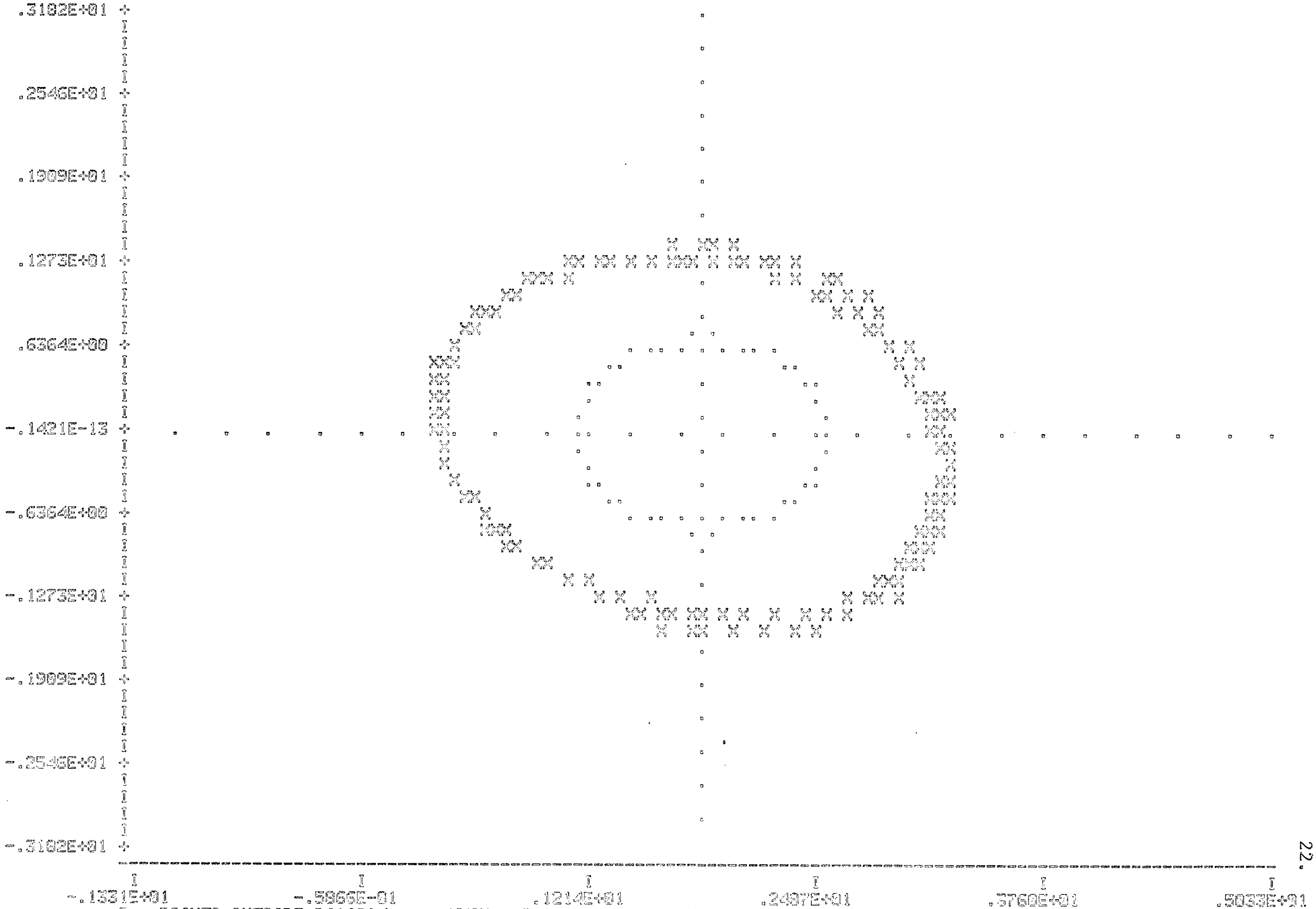
20.

INITIAL PARAMETERS OF PARTICLE #3   XA = .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



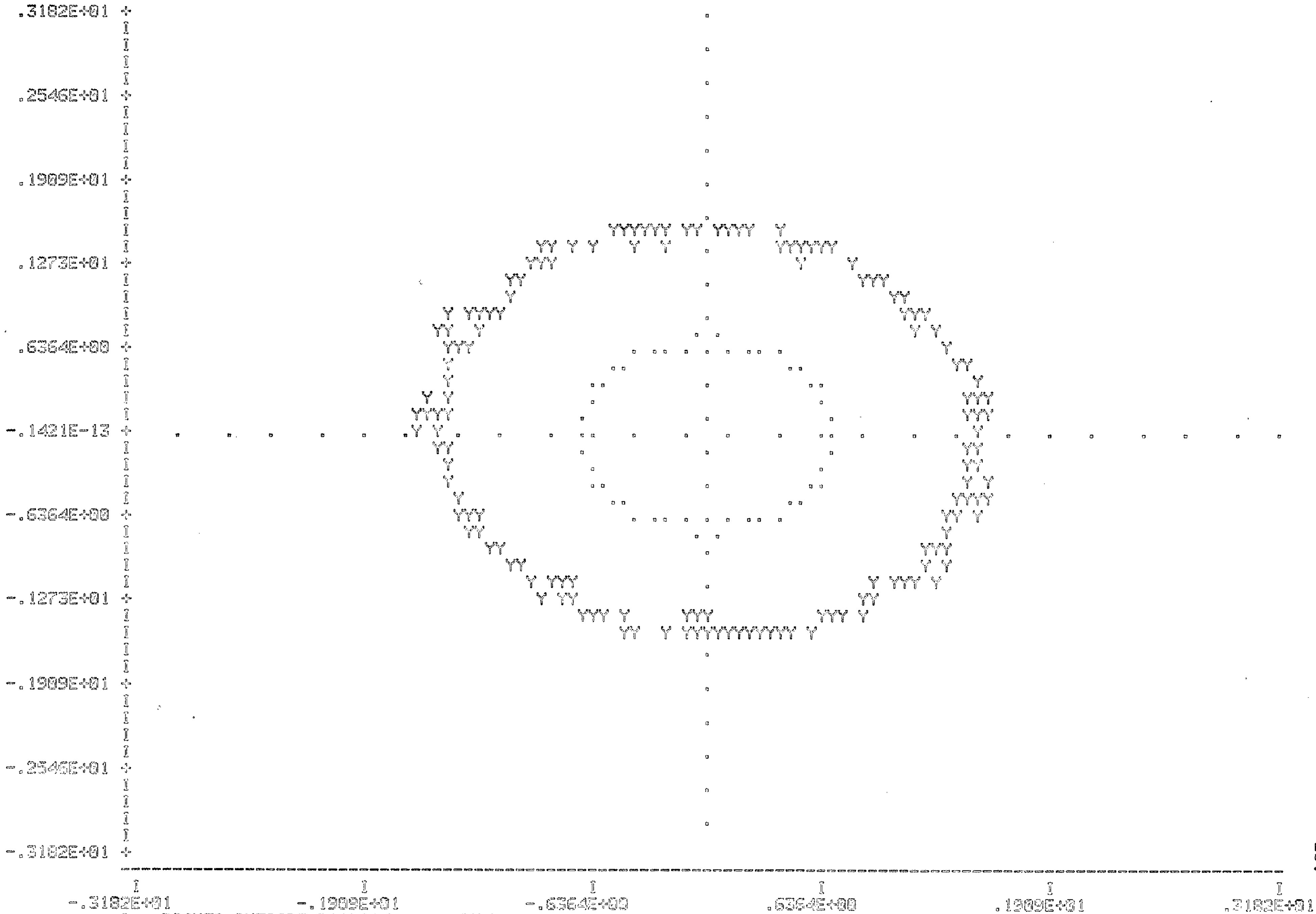
0 POINTS OUTSIDE DIAGRAM   XMIN = -.4895E+01   XMAX = .4974E+01   KW(13) = 1   SQRT(BETY) = 3.6551

INITIAL PARAMETERS OF PARTICLE *4 XA = .268E+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



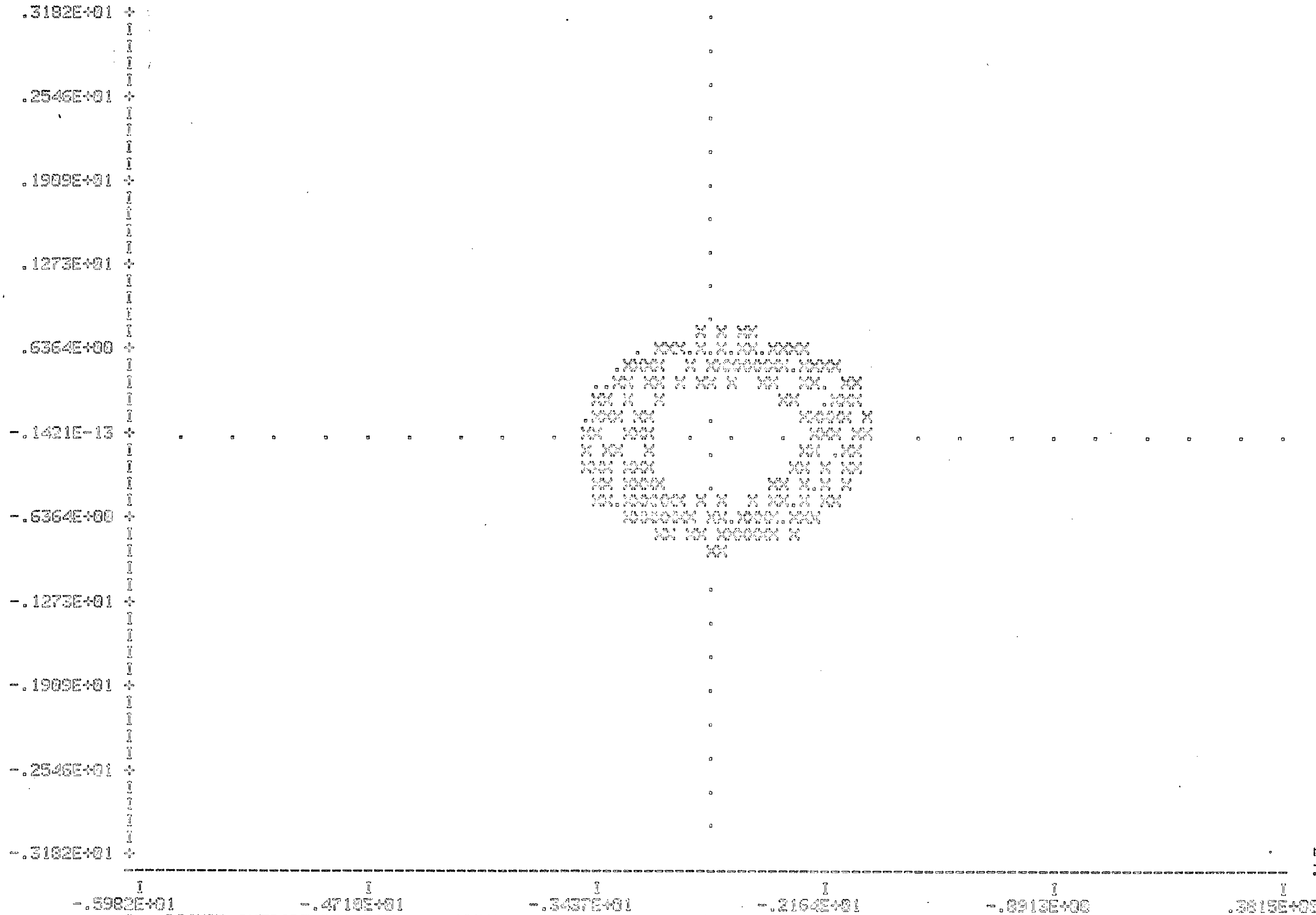
0 POINTS OUTSIDE DIAGRAM XMIN = 0. XMAX = .2636E+02 KW(13) = 1 SQRT(BETX) = 8.1532

INITIAL PARAMETERS OF PARTICLE #4   XA = .268E+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



0 POINTS OUTSIDE DIAGRAM   XMIN = -.5849E+01   XMAX = .5786E+01   KW(13) = 1   SQRT(BETY) = 3.6551

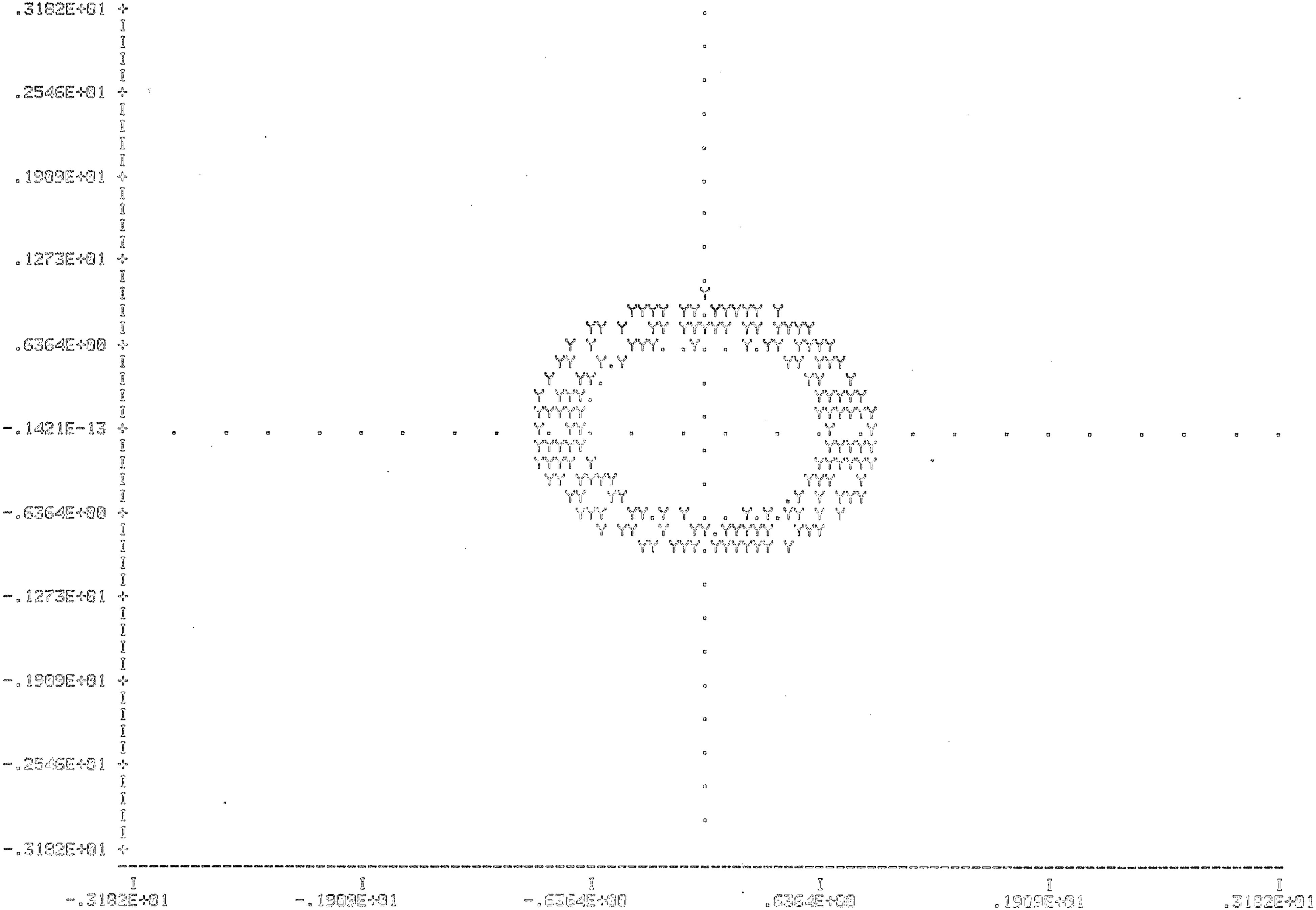
INITIAL PARAMETERS OF PARTICLE 1 XA = -.991E+01MM XPA = .996E-02MM YA = .156E+01MM YPA = 0. MR
BETATRON AMPLITUDES = IN X : .100E+02 SIGMA IN Y : .100E+02 SIGMA ENERGY DEVIATION = .100E+01 SIGMA AT 30.00 GEV
PHASE SPACE PLOT FOR 200 REVOLUTIONS



0 POINTS OUTSIDE DIAGRAM XMIN = -.2981E+02 XMAX = 0. MU(15) = 1 SQRT(BETX) = 5.9311

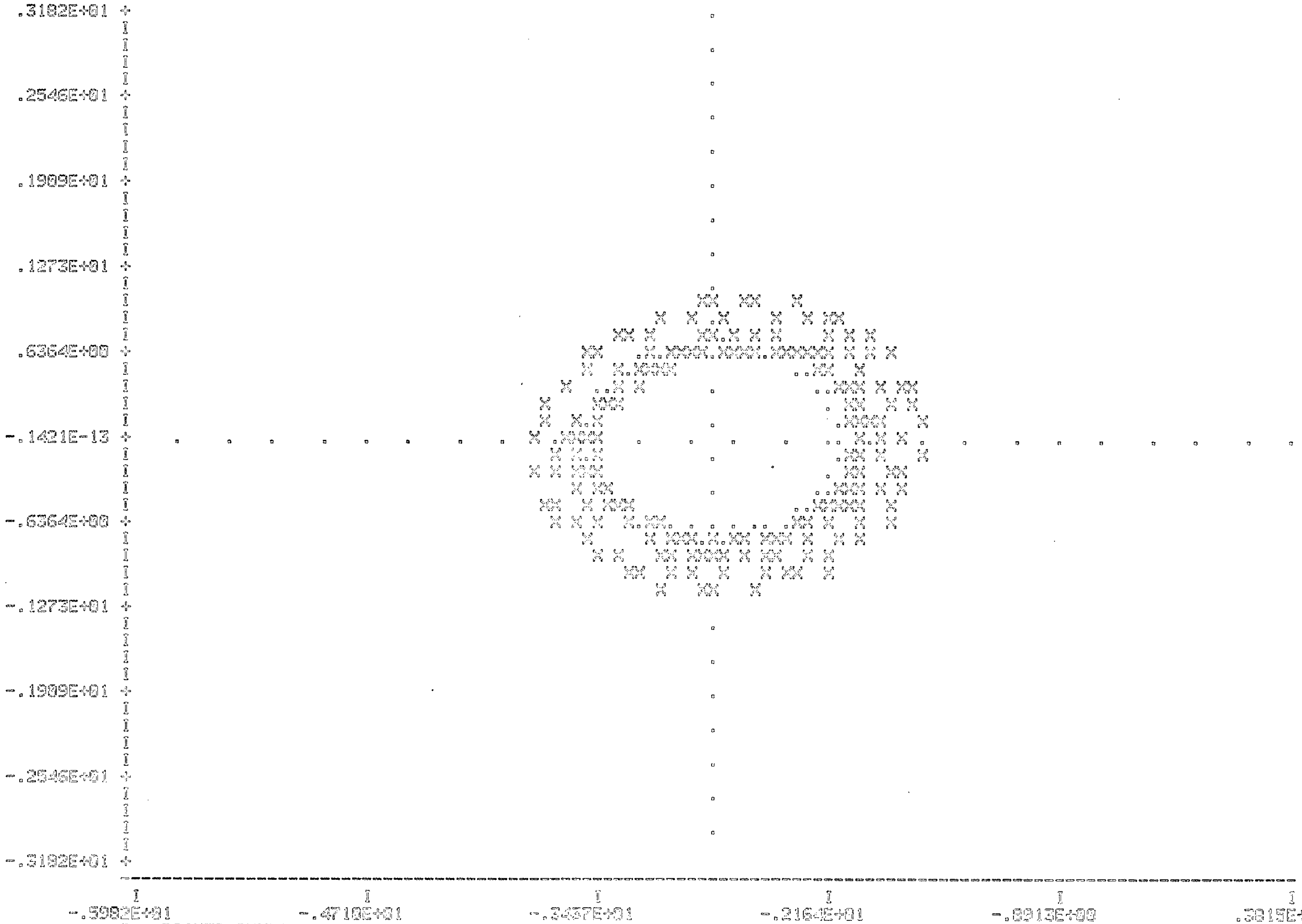
Fig. 6

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



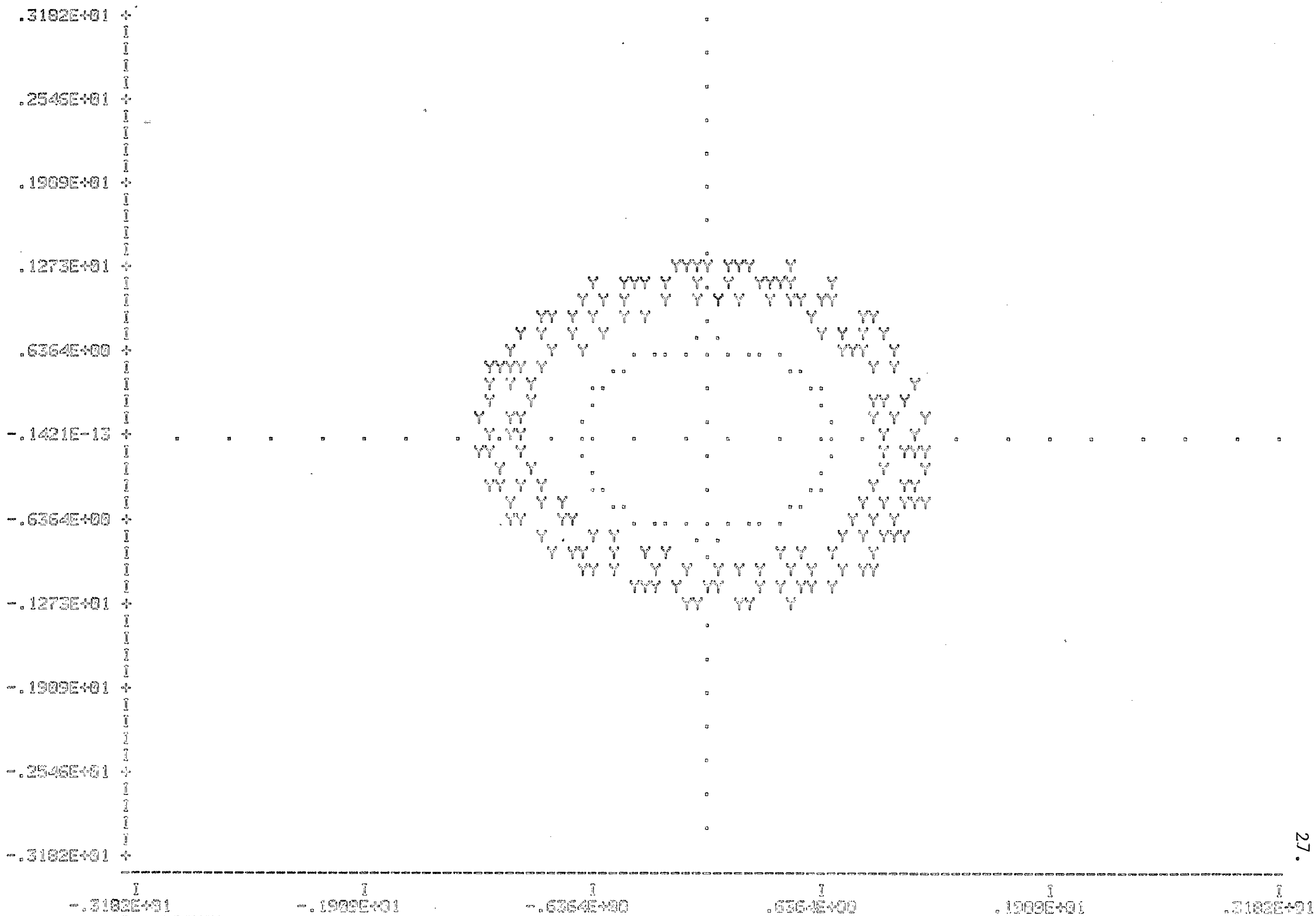
0 POINTS OUTSIDE DIAGRAM XMIN = -.2156E+01 XMAX = .2164E+01 KW(13) = 1 SQRT(BETY) = 2.2707

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



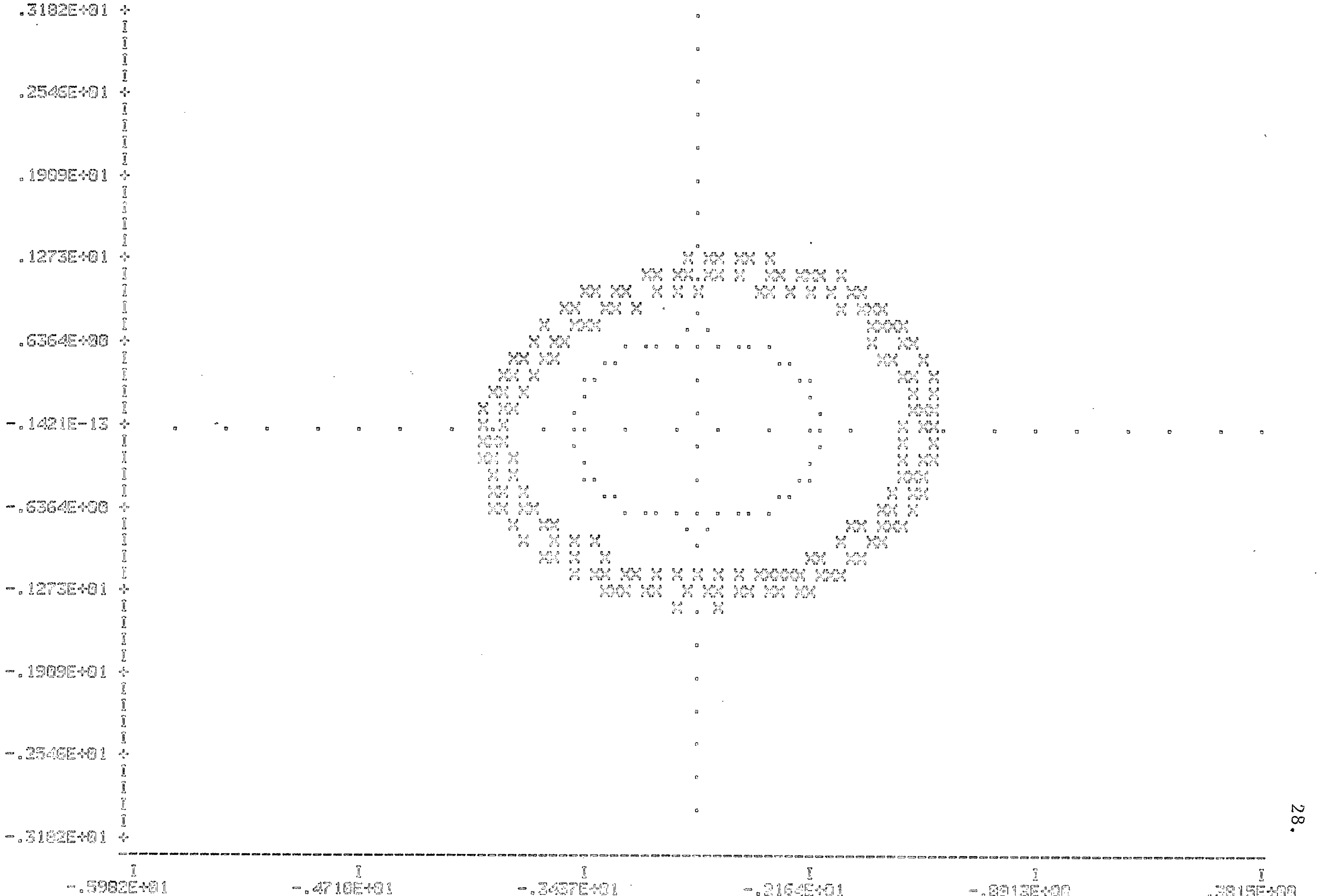
0 POINTS OUTSIDE DIAGRAM   XMIN = -.2257E+02   XMAX = 0.   KW(13) = 1   SQRT(BETX) = 5.9311

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



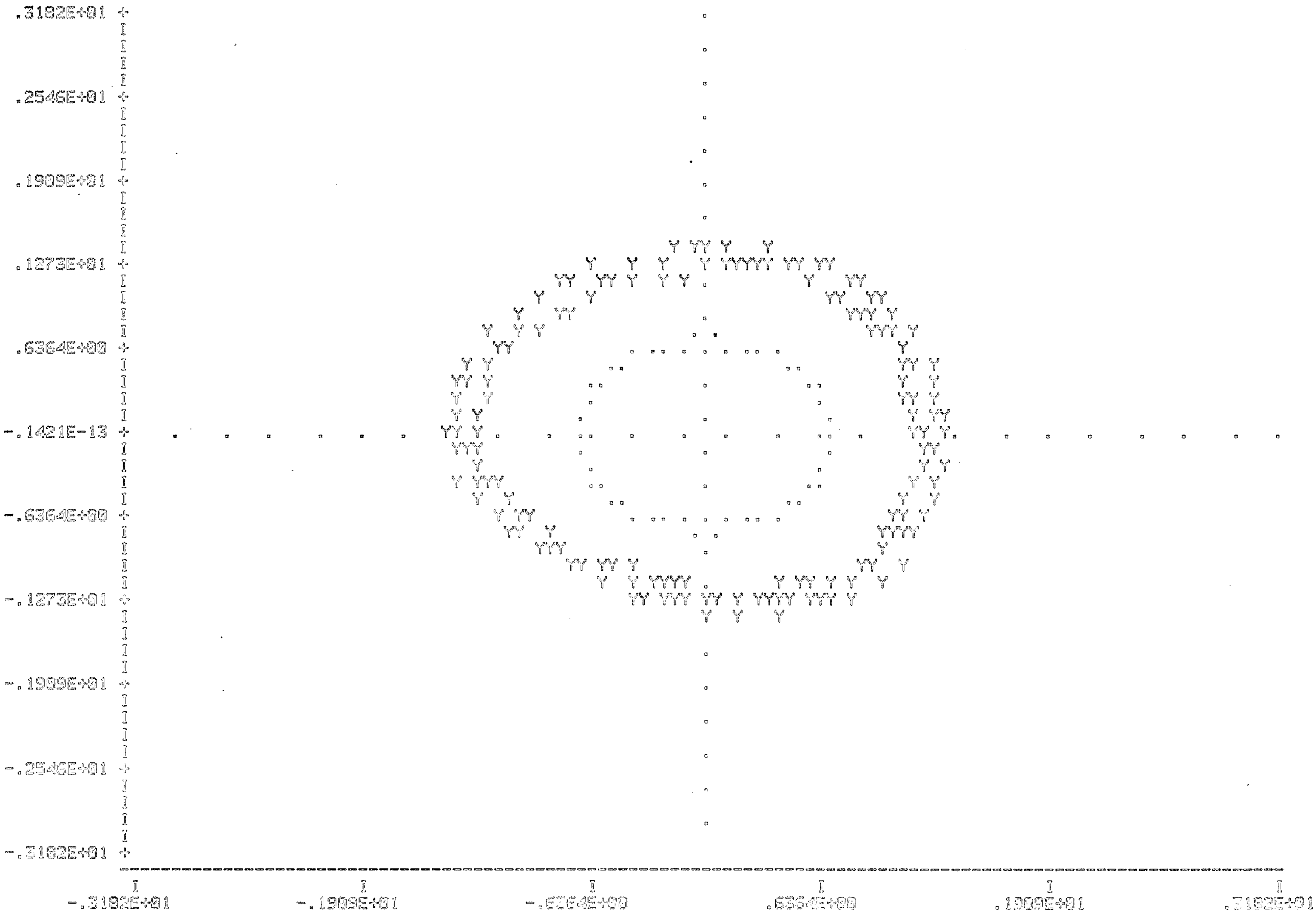
0 POINTS OUTSIDE DIAGRAM XMIN = -.2953E+01 XMAX = .2827E+01 KW(13) = 1 SQRT(BETY) = 2.2787

INITIAL PARAMETERS OF PARTICLE 3 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



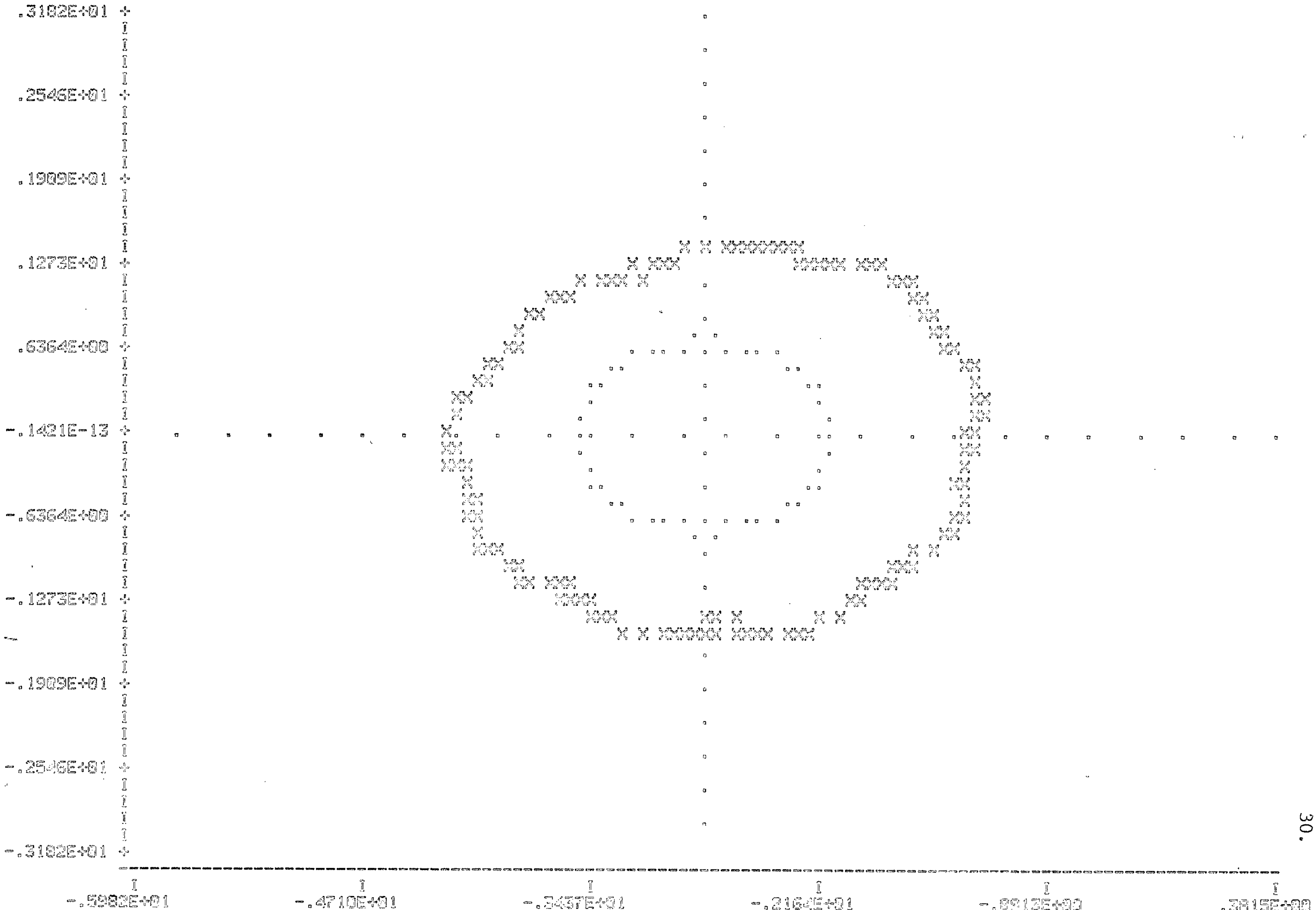
0 POINTS OUTSIDE DIAGRAM XMIN = -.2394E+02 XMAX = 0. NU(13) = 1 SQRT(BETX) = 5.9311

INITIAL PARAMETERS OF PARTICLE #3   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



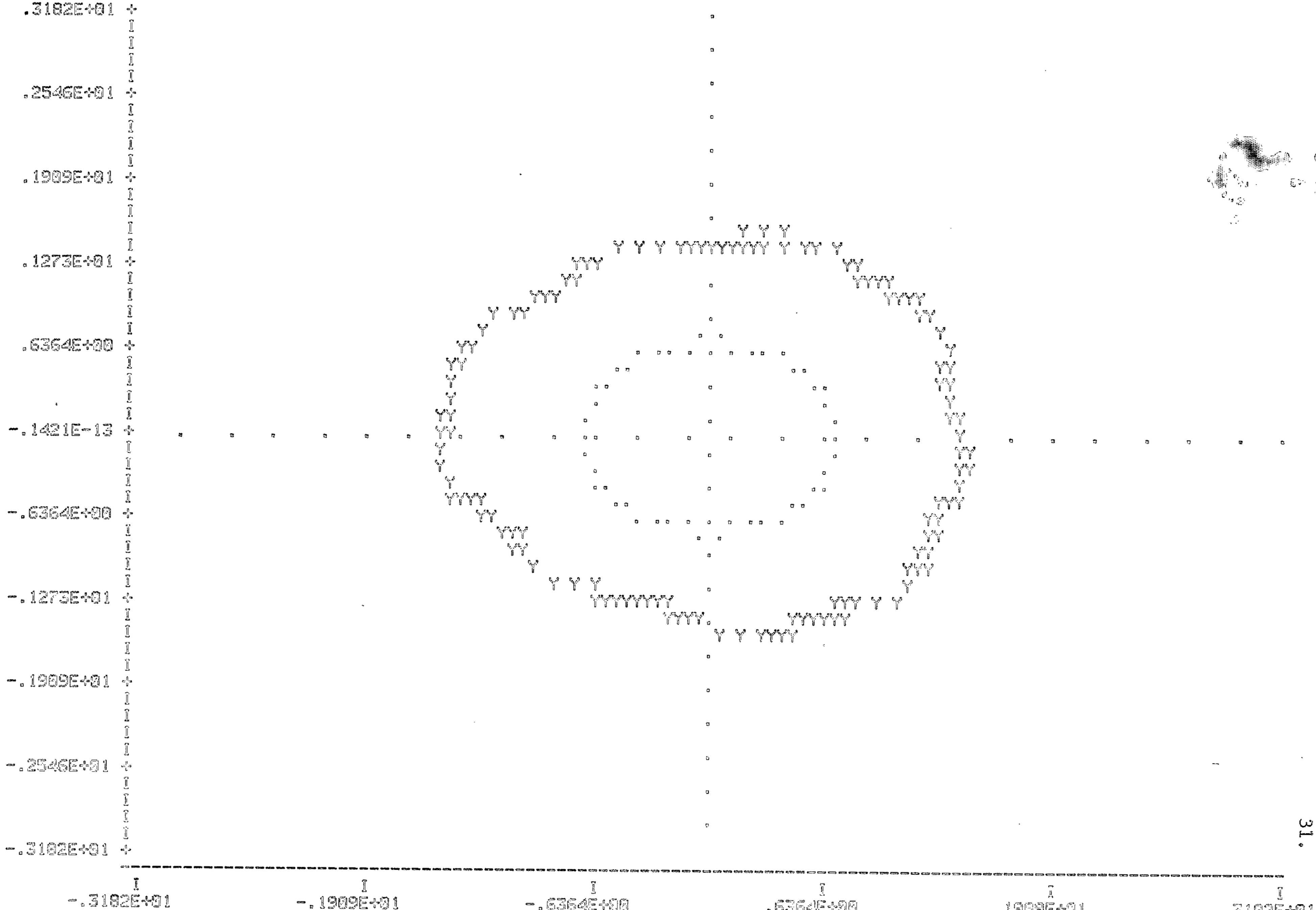
0 POINTS OUTSIDE DIAGRAM   XMIN = -.3238E+01   XMAX = .3048E+01   NW(13) = 1   SQRT(BETY) = 2.2787

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



0 POINTS OUTSIDE DIAGRAM   XMIN = -.2515E+02   XMAX = 0.   KW(13) = 1   SQRT(BETX) = 5.9311

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



0 POINTS OUTSIDE DIAGRAM   XMIN = -.3482E+01   XMAX = .3258E+01   KW(13) = 1   SQRT(BETY) = 2.2787