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COMPUTER MODELS OF THE AGS, I : The D. C. Bare Machine at High Fields

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March 1988

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Technical Note

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The D. C. "Bare" Machine at High Fields

E. Auerbach

March 7, 1988

This is the first of a series of computer model calculations of the transverse parameters of the AGS. We begin at high fields (beam momenta 15 GeV/c and greater) and the machine consisting of the main magnets only and without regard to the effects of time variation in the magnetic fields (no B-dot effects). Subsequent papers will add those effects, and then the high field correction system (quadrupoles and sextupoles) to obtain the "full" machine.

Calculation of the Courant-Snyder and associated parameters are presented both in tabular and graphical form; the input to the computer model program (MAD) which generated these results is also described.

INTRODUCTION

We present here, in both tabular and graphical form, values of the Courant-Snyder[1] and related parameters calculated using the accelerator modelling program MAD[2].

In this first set of calculations, descriptions of the Bare AGS (i.e., with main magnets only) at high fields (15-32 GeV/c) in an unramped state have been developed. The main magnets have both quadrupole and sextupole terms, but the effects of dB/dt are ignored. Later calculations will include effects of ramping and, beyond that, the inclusion of the high field correctors: dipoles, quadrupoles and sextupoles. Subsequently, we expect to do the same at low (injection) fields.

We are concerned here with transverse parameters: hence subscipts -x (horizontal) and -y (vertical) can be applied to most symbols. These are functions of the distance, s, along the machine. The zeros of x and y are on the design central orbit -- the path along which s is measured.

The important Courant-Snyder parameter is β, which describes the beam amplitude. Beam sizes and oscillations in them are proportional to $\beta^{1/2}$. β must be calculated for the particular machine lattice.

Associated parameters are α and γ. They are related by:

$$\alpha = -\tfrac{1}{2}\beta' = -\tfrac{1}{2}\, d\beta/ds$$

$$\gamma = \beta'(1+\alpha^2)$$

The phase parameter μ is obtained from the relation:

$$2\pi\mu = \int_{s_0}^{s_1} ds/\beta$$

where the choice of s_0 is arbitrary. The tune is the integral of $1/\beta$ around the accelerator:

$$2\pi Q = 2\pi\nu = \oint ds/\beta$$

Dispersion, dx, is defined as the transverse displacement of the beam per unit change in momentum from the nominal (central orbit) momentum:

$$dx = \Delta x \Big/ \frac{\Delta p}{p}$$

Thus, a dispersion of 1 meter produces a change in the transverse coordinate of 1 mm for a 0.1% momentum change (1/1000).

These quantities are calculated in the "TWISS" procedure of MAD.

I. MAD INPUT for D.C. "Bare Machine" -- High Fields: 15-32 GeV/c

A. Full Input for "TWISS" Run at 15 GeV/c with Print requested for 1st Superperiod only. (See MAD Input Manual [2] for full description of input lines.)

```
TITLE!
     P150D       (15 GeV/c)
!                                                !
CONSTANT, K1AF =  0.04874640                     !
CONSTANT, K1AD = -0.0486922                      !   replace
CONSTANT, K1BF =  K1AF                           !
CONSTANT, K1BD =  K1AD                           !     by
CONSTANT, K1CF =  0.04855743                     !
CONSTANT, K1CD = -0.0484907                      ! appropriate
CONSTANT, K2AF = -0.00729                        !
CONSTANT, K2AD = -0.00715                        !    block
CONSTANT, K2BF = -0.0087                         !
CONSTANT, K2BD = -0.00857                        !  for other
CONSTANT, K2CF = -0.00961                        !
CONSTANT, K2CD = -0.00939                        !  energies.
!
CONSTANT, CONV= 0.0254                           !  inches to meters
CONSTANT, LENA = 94*CONV
CONSTANT, LENB = 79*CONV
CONSTANT, LENC = 94*CONV
CONSTANT, ANGA = 0.0279650307
CONSTANT, ANGB = 0.0235023009
CONSTANT, ANGC = 0.0279650307
!
DRIFT, D2S, L=23.99664 *CONV
DRIFT, D2T, L=23.99548 *CONV
DRIFT, D2L, L=23.99428 *CONV
DRIFT, D2H, L=29.99714 *CONV
DRIFT, D5L, L=59.99428 *CONV
DRIFT, D10, L=59.99367 *CONV
!
!
RBEND, AF, L=LENA,  ANGLE=ANGA,  K1=K1AF, K2=K2AF
RBEND, AD, L=LENA,  ANGLE=ANGA,  K1=K1AD, K2=K2AD
RBEND, BF, L=LENB,  ANGLE=ANGB,  K1=K1BF, K2=K2BF
RBEND, BD, L=LENB,  ANGLE=ANGB,  K1=K1BD, K2=K2BD
RBEND, CF, L=LENC,  ANGLE=ANGC,  K1=K1CF, K2=K2CF
RBEND, CD, L=LENC,  ANGLE=ANGC,  K1=K1CD, K2=K2CD
!
!      sublines
!
L1A:  LINE = (D10,BF,D2S,BF,D2T,CD,D5L,CD,D2L,AF,D2H)
L2A:  LINE = (D10,BD,D2S,BD,D2T,CF,D5L,CF,D2L,AD,D2H)
!
!      superperiods and machine
!
LINE, SUPER = (L1A,-L1A, L2A,-L2A)
LINE,   AGS = (12 * SUPER)
!
!
 USE, (AGS)
!
   PRINT, SUPER[1]
!
 TWISS, DELTAP=0.
stop!
```

B. Changes in Constants defining quadrupole and sextupole strengths for main magnets at other energies (replaces area noted in 15 GeV/c input, preceding page):

```
     P200D      (20 GeV/c)
!
CONSTANT, K1AF =  0.04869689
CONSTANT, K1AD = -0.0486381
CONSTANT, K1BF =  K1AF
CONSTANT, K1BD =  K1AD
CONSTANT, K1CF =  0.04852880
CONSTANT, K1CD = -0.0484573
CONSTANT, K2AF = -0.00841
CONSTANT, K2AD = -0.00839
CONSTANT, K2BF = -0.00996
CONSTANT, K2BD = -0.00994
CONSTANT, K2CF = -0.01045
CONSTANT, K2CD = -0.01031

     P250D      (25 GeV/c)
!
CONSTANT, K1AF =  0.04855992
CONSTANT, K1AD = -0.0484901
CONSTANT, K1BF =  K1AF
CONSTANT, K1BD =  K1AD
CONSTANT, K1CF =  0.04841473
CONSTANT, K1CD = -0.0483322
CONSTANT, K2AF = -0.01136
CONSTANT, K2AD = -0.01148
CONSTANT, K2BF = -0.01333
CONSTANT, K2BD = -0.01341
CONSTANT, K2CF = -0.01320
CONSTANT, K2CD = -0.01318

     P270D      (27 GeV/c)
!
CONSTANT, K1AF =  0.04844988
CONSTANT, K1AD = -0.0483751
CONSTANT, K1BF =  K1AF
CONSTANT, K1BD =  K1AD
CONSTANT, K1CF =  0.04829478
CONSTANT, K1CD = -0.0482072
CONSTANT, K2AF = -0.01435
CONSTANT, K2AD = -0.01451
CONSTANT, K2BF = -0.01655
CONSTANT, K2BD = -0.01667
CONSTANT, K2CF = -0.01631
CONSTANT, K2CD = -0.01632

     P290D      (29 GeV/c)
!
CONSTANT, K1AF =  0.04824669
CONSTANT, K1AD = -0.0481701
CONSTANT, K1BF =  K1AF
CONSTANT, K1BD =  K1AD
CONSTANT, K1CF =  0.04808474
CONSTANT, K1CD = -0.0479969
CONSTANT, K2AF = -0.01984
CONSTANT, K2AD = -0.01991
CONSTANT, K2BF = -0.02221
CONSTANT, K2BD = -0.02226
CONSTANT, K2CF = -0.022
CONSTANT, K2CD = -0.02189
```

```
     P320D      (32 GeV/c)
!
CONSTANT, K1AF =  0.04755687
CONSTANT, K1AD = -0.0474825
CONSTANT, K1BF =  K1AF
CONSTANT, K1BD =  K1AD
CONSTANT, K1CF =  0.04734094
CONSTANT, K1CD = -0.0472565
CONSTANT, K2AF = -0.03396
CONSTANT, K2AD = -0.03404
CONSTANT, K2BF = -0.0365
CONSTANT, K2BD = -0.03656
CONSTANT, K2CF = -0.03691
CONSTANT, K2CD = -0.03676
```

COMMENTS:

Strengths:

The constants K1xx and K2xx give the quadrupole and sextupole strengths of the respective magnets for the D. C. machine. Eddy currents induced by changing magnetic fields will alter the sextupole strengths. MAD does provide for inclusion of higher multipoles, but we do not consider them at this time.

Magnets:

Magnets are named with the following conventions: the 2nd letter (F or D) indicates focussing or defocussing in the horizontal plane; the first letter is:

A for long open magnets (at "05", "06", "15" and "16"),
B for short open magnets (at "01", "02", "09", "10", "11", "12", "19" and "20"),
C for long closed magnets (at "03", "04", "07", "08","13", "14", "17" and "18").

Straight Sections:

D2S refers to the 2 ft. straight sections at "01", "09", "11" and "19".
D2L refers to the 2 ft. straight sections at "02", "08", "12" and "18".
D2T refers to the 2 ft. straight sections at "04", "06", "14" and "16".
D5L refers to the 5 ft. straight sections at "03", "07", "13" and "17".
D2H is half of the "05" and "15" straight sections.
D10 is half of the "10" and "20" straight sections.

To insert additional elements in the straight sections, it is necessary to replace these by an insert containing the appropriate element and the remaining drift lengths. E. g., an 8" quadrupole placed in an "08" 2 ft. straight section might be described by:

```
INS08 = (D1X,QF8,D1Y),
```

where QF8 describes that "quad" and D1X, D1Y are drift spaces.

Superperiods:

The superperiod of the "Bare" machine consists of the magnets and straight sections enumerated in order; in a fuller machine it may be necessary to define several different superperiods as the list of additional elements (in the straight sections) will be different. In that case, the AGS will be defined by listing the various superperiods rather than by the simple statement:

```
AGS = (12 * SUPER) .
```

II. SAMPLE MAD OUTPUT (from file "mad.out")
RUN: P320D (32 GeV/c)

Note that only Superperiod "A" is given in detail, but that the last line (END USE...01) is for the end of the whole (12 superperiod) machine and that the tunes, etc. are also for the whole machine --- i. e., Q-x is 12 times the value of MUX at the end of the 1st sector, etc. Note further that since this is an "on-momentum" calculation with no magnet displacements (or misalignments) specified in the input, X(CO), X'(CO), Y(CO), Y'(CO) are 0. at all locations.

```
... SEARCHING FOR CLOSED ORBIT FOR BEAM LINE "USE...01", DELTA(P)/P =     0.000000, SYMM = F
... ITER.        X              PX              Y              PY             ERROR
...      1    0.000000       0.000000       0.000000       0.000000   0.000000E+00
1     P320D                32 GeV/c                                "MAD" VERSION: 6.01/01    RUN: 01/29/88  09:07:23
LINEAR LATTICE PARAMETERS FOR BEAM LINE: "USE...01", RANGE = "#S / #E"
DELTA(P)/P =      0.000000    SYMM = F                                                                        PAGE     1
```

POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	I	BETAX [M]	ALFAX	HORIZONTAL MUX [2PI]	X(CO) [MM]	X'(CO) [MRAD]	DX [M]	DX'	I	BETAY [M]	ALFAY	VERTICAL MUY [2PI]	Y(CO) [MM]	Y'(CO) [MRAD]	DY [M]	DY'
BEGIN	USE...01	1	0.000		15.773	-1.298	0.000	0.000	0.000	1.916	0.153		15.697	1.293	0.000	0.000	0.000	0.000	0.000
BEGIN	SUPER	1	0.000		15.773	-1.298	0.000	0.000	0.000	1.916	0.153		15.697	1.293	0.000	0.000	0.000	0.000	0.000
BEGIN	L1A	1	0.000		15.773	-1.298	0.000	0.000	0.000	1.916	0.153		15.697	1.293	0.000	0.000	0.000	0.000	0.000
1	D10	1	1.524		20.125	-1.558	0.014	0.000	0.000	2.150	0.153		12.152	1.034	0.018	0.000	0.000	0.000	0.000
2	BF	1	3.530		22.637	0.387	0.028	0.000	0.000	2.268	-0.037		10.657	-0.242	0.047	0.000	0.000	0.000	0.000
3	D2S	1	4.140		22.184	0.356	0.032	0.000	0.000	2.246	-0.037		10.989	-0.302	0.056	0.000	0.000	0.000	0.000
4	BF	2	6.147		17.139	1.996	0.048	0.000	0.000	1.986	-0.218		15.024	-1.835	0.081	0.000	0.000	0.000	0.000
5	D2T	1	6.756		14.814	1.819	0.054	0.000	0.000	1.853	-0.218		17.369	-2.012	0.087	0.000	0.000	0.000	0.000
6	CD	1	9.144		10.660	0.075	0.086	0.000	0.000	1.597	0.000		22.566	0.035	0.106	0.000	0.000	0.000	0.000
7	D5L	1	10.667		10.649	-0.068	0.109	0.000	0.000	1.597	0.000		22.562	-0.033	0.117	0.000	0.000	0.000	0.000
8	CD	2	13.055		14.761	-1.806	0.141	0.000	0.000	1.850	0.217		17.356	2.013	0.135	0.000	0.000	0.000	0.000
9	D2L	1	13.665		17.069	-1.982	0.147	0.000	0.000	1.982	0.217		15.011	1.835	0.141	0.000	0.000	0.000	0.000
10	AF	1	16.052		22.190	0.034	0.166	0.000	0.000	2.247	0.000		10.830	0.071	0.172	0.000	0.000	0.000	0.000
11	D2H	1	16.814		22.164	0.000	0.171	0.000	0.000	2.247	0.000		10.776	0.000	0.184	0.000	0.000	0.000	0.000
END	L1A	1	16.814		22.164	0.000	0.171	0.000	0.000	2.247	0.000		10.776	0.000	0.184	0.000	0.000	0.000	0.000
BEGIN	L1A	2	16.814		22.164	0.000	0.171	0.000	0.000	2.247	0.000		10.776	0.000	0.184	0.000	0.000	0.000	0.000
12	D2H	2	17.576		22.190	-0.034	0.177	0.000	0.000	2.247	0.000		10.830	-0.071	0.195	0.000	0.000	0.000	0.000
13	AF	2	19.964		17.069	1.982	0.195	0.000	0.000	1.982	-0.217		15.011	-1.835	0.226	0.000	0.000	0.000	0.000
14	D2L	2	20.573		14.761	1.806	0.202	0.000	0.000	1.850	-0.217		17.356	-2.013	0.232	0.000	0.000	0.000	0.000
15	CD	3	22.961		10.649	0.068	0.233	0.000	0.000	1.597	0.000		22.562	0.033	0.251	0.000	0.000	0.000	0.000
16	D5L	2	24.485		10.660	-0.075	0.256	0.000	0.000	1.597	0.000		22.566	-0.035	0.261	0.000	0.000	0.000	0.000
17	CD	4	26.872		14.814	-1.819	0.288	0.000	0.000	1.853	0.218		17.369	2.012	0.280	0.000	0.000	0.000	0.000
18	D2T	2	27.482		17.139	-1.996	0.294	0.000	0.000	1.986	0.218		15.024	1.835	0.286	0.000	0.000	0.000	0.000
19	BF	3	29.488		22.184	-0.356	0.310	0.000	0.000	2.246	0.037		10.989	0.302	0.312	0.000	0.000	0.000	0.000
20	D2S	2	30.098		22.637	-0.387	0.314	0.000	0.000	2.268	0.037		10.657	0.242	0.321	0.000	0.000	0.000	0.000
21	BF	4	32.104		20.125	1.558	0.329	0.000	0.000	2.150	-0.153		12.152	-1.034	0.350	0.000	0.000	0.000	0.000
22	D10	2	33.628		15.773	1.298	0.343	0.000	0.000	1.916	-0.153		15.697	-1.293	0.367	0.000	0.000	0.000	0.000
END	L1A	2	33.628		15.773	1.298	0.343	0.000	0.000	1.916	-0.153		15.697	-1.293	0.367	0.000	0.000	0.000	0.000
BEGIN	L2A	1	33.628		15.773	1.298	0.343	0.000	0.000	1.916	-0.153		15.697	-1.293	0.367	0.000	0.000	0.000	0.000
23	D10	3	35.152		12.212	1.039	0.360	0.000	0.000	1.682	-0.153		20.033	-1.552	0.381	0.000	0.000	0.000	0.000
24	BD	1	37.159		10.709	-0.243	0.389	0.000	0.000	1.551	0.021		22.537	0.385	0.396	0.000	0.000	0.000	0.000
25	D2S	3	37.768		11.042	-0.303	0.398	0.000	0.000	1.564	0.021		22.087	0.354	0.400	0.000	0.000	0.000	0.000
26	BD	2	39.775		15.092	-1.842	0.424	0.000	0.000	1.784	0.202		17.063	1.988	0.416	0.000	0.000	0.000	0.000
27	D2T	3	40.384		17.446	-2.020	0.430	0.000	0.000	1.907	0.202		14.747	1.811	0.422	0.000	0.000	0.000	0.000
28	CF	1	42.772		22.662	0.035	0.448	0.000	0.000	2.148	-0.004		10.608	0.076	0.454	0.000	0.000	0.000	0.000
29	D5L	3	44.296		22.658	-0.032	0.459	0.000	0.000	2.141	-0.004		10.598	-0.069	0.477	0.000	0.000	0.000	0.000
30	CF	2	46.683		17.431	2.021	0.477	0.000	0.000	1.881	-0.208		14.697	-1.799	0.509	0.000	0.000	0.000	0.000
31	D2L	3	47.293		15.076	1.843	0.483	0.000	0.000	1.754	-0.208		16.997	-1.975	0.515	0.000	0.000	0.000	0.000
32	AD	1	49.680		10.880	0.070	0.514	0.000	0.000	1.511	0.000		22.101	0.035	0.534	0.000	0.000	0.000	0.000
33	D2H	3	50.442		10.826	0.000	0.525	0.000	0.000	1.511	0.000		22.075	0.000	0.539	0.000	0.000	0.000	0.000
END	L2A	1	50.442		10.826	0.000	0.525	0.000	0.000	1.511	0.000		22.075	0.000	0.539	0.000	0.000	0.000	0.000
BEGIN	L2A	2	50.442		10.826	0.000	0.525	0.000	0.000	1.511	0.000		22.075	0.000	0.539	0.000	0.000	0.000	0.000
34	D2H	4	51.204		10.880	-0.070	0.536	0.000	0.000	1.511	0.000		22.101	-0.035	0.545	0.000	0.000	0.000	0.000
35	AD	2	53.592		15.076	-1.843	0.568	0.000	0.000	1.754	0.208		16.997	1.975	0.564	0.000	0.000	0.000	0.000
36	D2L	4	54.201		17.431	-2.021	0.574	0.000	0.000	1.881	0.208		14.697	1.799	0.570	0.000	0.000	0.000	0.000
37	CF	3	56.589		22.658	0.032	0.592	0.000	0.000	2.141	0.004		10.598	0.069	0.602	0.000	0.000	0.000	0.000
38	D5L	4	58.113		22.662	-0.035	0.603	0.000	0.000	2.148	0.004		10.608	-0.076	0.625	0.000	0.000	0.000	0.000
39	CF	4	60.500		17.446	2.020	0.621	0.000	0.000	1.907	-0.202		14.747	-1.811	0.657	0.000	0.000	0.000	0.000

```
1     P320D                                                   "MAD" VERSION: 6.01/01    RUN: 01/29/88  09:07:23
LINEAR LATTICE PARAMETERS FOR BEAM LINE: "USE...01", RANGE = "#S / #E"
DELTA(P)/P =      0.000000    SYMM = F                                                                        PAGE     2
```

POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	I	BETAX [M]	ALFAX	HORIZONTAL MUX [2PI]	X(CO) [MM]	X'(CO) [MRAD]	DX [M]	DX'	I	BETAY [M]	ALFAY	VERTICAL MUY [2PI]	Y(CO) [MM]	Y'(CO) [MRAD]	DY [M]	DY'
40	D2T	4	61.110		15.092	1.842	0.627	0.000	0.000	1.784	-0.202		17.063	-1.988	0.663	0.000	0.000	0.000	0.000
41	BD	3	63.116		11.042	0.303	0.653	0.000	0.000	1.564	-0.021		22.087	-0.354	0.679	0.000	0.000	0.000	0.000
42	D2S	4	63.726		10.709	0.243	0.662	0.000	0.000	1.551	-0.021		22.537	-0.385	0.683	0.000	0.000	0.000	0.000
43	BD	4	65.732		12.212	-1.039	0.691	0.000	0.000	1.682	0.153		20.033	1.552	0.698	0.000	0.000	0.000	0.000
44	D10	4	67.256		15.773	-1.298	0.708	0.000	0.000	1.916	0.153		15.697	1.293	0.711	0.000	0.000	0.000	0.000
END	L2A	2	67.256		15.773	-1.298	0.708	0.000	0.000	1.916	0.153		15.697	1.293	0.711	0.000	0.000	0.000	0.000
END	SUPER	1	67.256		15.773	-1.298	0.708	0.000	0.000	1.916	0.153		15.697	1.293	0.711	0.000	0.000	0.000	0.000
END	USE...01	1	807.076		15.773	-1.298	8.497	0.000	0.000	1.916	0.153		15.697	1.293	8.537	0.000	0.000	0.000	0.000

```
TOTAL LENGTH =        807.075641          QX          =        8.496780          QY          =        8.536931
                                          QX'         =      -58.274315          QY'         =       36.700898
ALFA         =          0.146667E-01      BETAX(MAX)  =       22.661810          BETAY(MAX)  =       22.566020
GAMMA(TR)    =          8.257205          DX(MAX)     =        2.268471          DY(MAX)     =        0.000000

... END OF "TWISS" COMMAND, ELAPSED CPU TIME =       3.195 SECONDS

          stop!
... ... ... END PROGRAM.                SPACE = 10700 TO  12803        01/29/88  09:08:22
```

III. Courant-Snyder Parameters for D. C. "Bare Machine" at High Fields:

For the "Bare Machine", all 12 superperiods are alike; thus the parameters are given for one superperiod only.

In the following tables, the parameters are given for full superperiods from the middle of straight-section of L20 through the middle of straight-section A20. (These boundaries have been chosen for the superperiods because they then have symmetries which would be less obvious had we used the conventional nomenclature and gone from the beginning of magnet A01 through the end of the A20 straight section.)

Each beam momentum is given on a separate page.

The top two lines identify the run from the title card of the MAD input (and also include a "MAD" version number and date and time of the run).

DELTA(P)/P = 0.000 indicates an "on-momentum" calculation.

Contents of the columns of the main table are:

MACHINE LOCATION ID: Description in the standard AGS nomenclature:
A01 through A20 denote the points of exit from these magnets
A01-SS, etc. denote the downstream ends of the respective straight sections; for the 05, 10, 15 and 20 straight-sections (which have been split in halves for calculation), notations are A05(Mid), A05-End, etc. to denote the middle and downstream ends.

ELEMENT SEQUENCE:

POS. NO. "MAD" sequence number for the element -- each magnet, straight section (if not split) and half of a long straight section counts as an element.

ELEMENT NAME "MAD" element name, as given in the input:
Our conventions are:
Main magnets are named: AD, AF, BD, BF, CD, CF
Straight sections (or parts) have element names beginning with D (for drift)
"SUPER" refers to the super-period -- middle of a "20" straight section to the middle of the next "20".

SEQUENCE OCC. NO. sequential occurrence (ordinal) number for that element in this run

HORIZONTAL (respectively, VERTICAL):

BETAX The Courant-Snyder parameter Beta (for the horizontal plane), in meters

ALFX The Courant-Snyder parameter Alpha (for the horizontal plane) -- dimensionless

MUX The Phase Advance (horizontal) in units of 2*pi
Due to symmetry, the tunes are exactly 12 times the phase advances in one sector.

DX The Dispersion (in the horizontal plane), in meters

DX' The derivative of Dispersion (horizontal plane) -- dimensionless

Note that vertical dispersions zero everywhere and thus omitted.

In the table at the bottom (values refer to full machine):

TOTAL LENGTH is the total over all elements in the full machine (survey length, not central-orbit length).

GAMMA-TR is the calculated transition-gamma for the full machine

QX (rep., QY) is the horizontal (resp., vertical) tune.

QX' (resp., QY') is the derivative of the horizontal (resp., vertical) tune with respect to momentum change. Chromaticity is obtained by taking QX'/QX (horizontal; resp., QY'/QY for vertical).

BETAX(MAX), BETAY(MAX), DX(MAX) and DY(MAX) are the maximum values of these respective quantities appearing in the tables above (not the separately calculated maxima covering intermediate points).

P150D (15 GeV/c) "BARE MACHINE" "MAD" VERSION: 6.01/01
DELTA(P)/P = 0.000000 RUN: 01/29/88 08:51

MACHINE LOCATION ID	ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]
L20(Mid)	BEGIN	SUPER	1	0.000	15.411	-1.308	0.000	1.826	0.150	15.315	1.301	0.000
L20-End	1	D10	1	1.524	19.807	-1.576	0.014	2.055	0.150	11.757	1.033	0.018
A01	2	BF	1	3.530	22.360	0.388	0.029	2.170	-0.036	10.258	-0.238	0.048
A01-SS	3	D2S	1	4.140	21.906	0.357	0.033	2.148	-0.036	10.586	-0.301	0.058
A02	4	BF	2	6.147	16.823	2.009	0.049	1.893	-0.213	14.611	-1.834	0.084
A02-SS	5	D2T	1	6.756	14.485	1.826	0.055	1.763	-0.213	16.958	-2.016	0.090
A03	6	CD	1	9.144	10.323	0.075	0.088	1.513	-0.001	22.171	0.038	0.109
A03-SS	7	D5L	1	10.667	10.321	-0.073	0.112	1.512	-0.001	22.160	-0.031	0.120
A04	8	CD	2	13.055	14.474	-1.824	0.144	1.758	0.212	16.919	2.019	0.139
A04-SS	9	D2L	1	13.665	16.808	-2.006	0.151	1.887	0.212	14.570	1.836	0.145
A05	10	AF	1	16.052	22.004	0.035	0.170	2.146	0.000	10.390	0.074	0.178
A05(Mid)	11	D2H	1	16.814	21.977	0.000	0.175	2.146	0.000	10.333	0.000	0.189
A05-End	12	D2H	2	17.576	22.004	-0.035	0.181	2.146	0.000	10.390	-0.074	0.201
A06	13	AF	2	19.964	16.808	2.006	0.199	1.887	-0.212	14.570	-1.836	0.234
A06-SS	14	D2L	2	20.573	14.474	1.824	0.206	1.758	-0.212	16.919	-2.019	0.240
A07	15	CD	3	22.961	10.321	0.073	0.238	1.512	0.001	22.160	0.031	0.259
A07-SS	16	D5L	2	24.485	10.323	-0.075	0.262	1.513	0.001	22.171	-0.038	0.270
A08	17	CD	4	26.872	14.485	-1.826	0.295	1.763	0.213	16.958	2.016	0.288
A08-SS	18	D2T	2	27.482	16.823	-2.009	0.301	1.893	0.213	14.611	1.834	0.294
A09	19	BF	3	29.488	21.906	-0.357	0.317	2.148	0.036	10.586	0.301	0.321
A09-SS	20	D2S	2	30.098	22.360	-0.388	0.322	2.170	0.036	10.258	0.238	0.330
A10	21	BF	4	32.104	19.807	1.576	0.336	2.055	-0.150	11.757	-1.033	0.361
A10(Mid)	22	D10	2	33.628	15.411	1.308	0.350	1.826	-0.150	15.315	-1.301	0.379
A10-End	23	D10	3	35.152	11.832	1.040	0.368	1.598	-0.150	19.690	-1.569	0.393
A11	24	BD	1	37.159	10.322	-0.239	0.398	1.471	0.021	22.234	0.386	0.408
A11-SS	25	D2S	3	37.768	10.652	-0.301	0.407	1.484	0.021	21.783	0.354	0.412
A12	26	BD	2	39.775	14.694	-1.843	0.434	1.699	0.197	16.726	1.998	0.428
A12-SS	27	D2T	3	40.384	17.052	-2.026	0.440	1.819	0.197	14.401	1.816	0.434
A13	28	CF	1	42.772	22.289	0.038	0.459	2.055	-0.004	10.258	0.075	0.467
A13-SS	29	D5L	3	44.296	22.277	-0.030	0.470	2.048	-0.004	10.257	-0.074	0.491
A14	30	CF	2	46.683	17.011	2.029	0.488	1.794	-0.204	14.395	-1.815	0.524
A14-SS	31	D2L	3	47.293	14.650	1.845	0.494	1.670	-0.204	16.718	-1.997	0.530
A15	32	AD	1	49.680	10.451	0.073	0.527	1.432	0.000	21.892	0.035	0.549
A15(Mid)	33	D2H	3	50.442	10.395	0.000	0.538	1.432	0.000	21.866	0.000	0.555
A15-End	34	D2H	4	51.204	10.451	-0.073	0.550	1.432	0.000	21.892	-0.035	0.560
A16	35	AD	2	53.592	14.650	-1.845	0.582	1.670	0.204	16.718	1.997	0.579
A16-SS	36	D2L	4	54.201	17.011	-2.029	0.589	1.794	0.204	14.395	1.815	0.586
A17	37	CF	3	56.589	22.277	0.030	0.607	2.048	0.004	10.257	0.074	0.619
A17-SS	38	D5L	4	58.113	22.289	-0.038	0.618	2.055	0.004	10.258	-0.075	0.642
A18	39	CF	4	60.500	17.052	2.026	0.637	1.819	-0.197	14.401	-1.816	0.675
A18-SS	40	D2T	4	61.110	14.694	1.843	0.643	1.699	-0.197	16.726	-1.998	0.682
A19	41	BD	3	63.116	10.652	0.301	0.669	1.484	-0.021	21.783	-0.354	0.698
A19-SS	42	D2S	4	63.726	10.322	0.239	0.679	1.471	-0.021	22.234	-0.386	0.702
A20	43	BD	4	65.732	11.832	-1.040	0.709	1.598	0.150	19.690	1.569	0.717
A20(Mid)	44	D10	4	67.256	15.411	-1.308	0.727	1.826	0.150	15.315	1.301	0.731
A20(Mid)	END	SUPER	1	67.256	15.411	-1.308	0.727	1.826	0.150	15.315	1.301	0.731

TOTAL LENGTH = 807.075641 QX = 8.720065 QY = 8.772418
QX' = -20.156010 QY' = 0.925753
ALFA = 0.139714E-01 BETAX(MAX) = 22.360054 BETAY(MAX) = 22.234183
GAMMA(TR) = 8.460189 DX(MAX) = 2.170248 DY(MAX) = 0.000000

P200D (20 GeV/c) "BARE MACHINE" "MAD" VERSION: 6.01/01
DELTA(P)/P = 0.000000 RUN: 01/29/88 08:57

MACHINE LOCATION ID	ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]
L20(Mid)	BEGIN	SUPER	1	0.000	15.420	-1.309	0.000	1.829	0.149	15.330	1.302	0.000
L20-End	1	D10	1	1.524	19.817	-1.577	0.014	2.056	0.149	11.769	1.034	0.018
A01	2	BF	1	3.530	22.375	0.387	0.029	2.171	-0.037	10.265	-0.237	0.048
A01-SS	3	D2S	1	4.140	21.922	0.355	0.033	2.149	-0.037	10.593	-0.300	0.058
A02	4	BF	2	6.147	16.845	2.008	0.049	1.893	-0.214	14.610	-1.831	0.084
A02-SS	5	D2T	1	6.756	14.508	1.826	0.055	1.763	-0.214	16.953	-2.013	0.090
A03	6	CD	1	9.144	10.350	0.074	0.088	1.513	-0.001	22.155	0.039	0.109
A03-SS	7	D5L	1	10.667	10.351	-0.074	0.111	1.511	-0.001	22.141	-0.030	0.120
A04	8	CD	2	13.055	14.515	-1.827	0.144	1.757	0.211	16.905	2.016	0.139
A04-SS	9	D2L	1	13.665	16.854	-2.010	0.150	1.885	0.211	14.560	1.833	0.145
A05	10	AF	1	16.052	22.059	0.035	0.169	2.143	0.000	10.384	0.074	0.178
A05(Mid)	11	D2H	1	16.814	22.033	0.000	0.175	2.143	0.000	10.328	0.000	0.189
A05-End	12	D2H	2	17.576	22.059	-0.035	0.180	2.143	0.000	10.384	-0.074	0.201
A06	13	AF	2	19.964	16.854	2.010	0.199	1.885	-0.211	14.560	-1.833	0.234
A06-SS	14	D2L	2	20.573	14.515	1.827	0.205	1.757	-0.211	16.905	-2.016	0.240
A07	15	CD	3	22.961	10.351	0.074	0.238	1.511	0.001	22.141	0.030	0.259
A07-SS	16	D5L	2	24.485	10.350	-0.074	0.261	1.513	0.001	22.155	-0.039	0.270
A08	17	CD	4	26.872	14.508	-1.826	0.294	1.763	0.214	16.953	2.013	0.288
A08-SS	18	D2T	2	27.482	16.845	-2.008	0.300	1.893	0.214	14.610	1.831	0.295
A09	19	BF	3	29.488	21.922	-0.355	0.316	2.149	0.037	10.593	0.300	0.321
A09-SS	20	D2S	2	30.098	22.375	-0.387	0.321	2.171	0.037	10.265	0.237	0.331
A10	21	BF	4	32.104	19.817	1.577	0.336	2.056	-0.149	11.769	-1.034	0.361
A10(Mid)	22	D10	2	33.628	15.420	1.309	0.349	1.829	-0.149	15.330	-1.302	0.379
A10-End	23	D10	3	35.152	11.839	1.041	0.367	1.601	-0.149	19.707	-1.570	0.393
A11	24	BD	1	37.159	10.326	-0.238	0.397	1.475	0.021	22.256	0.384	0.408
A11-SS	25	D2S	3	37.768	10.654	-0.300	0.407	1.488	0.021	21.807	0.353	0.412
A12	26	BD	2	39.775	14.688	-1.840	0.433	1.704	0.198	16.753	1.998	0.428
A12-SS	27	D2T	3	40.384	17.041	-2.022	0.439	1.825	0.198	14.428	1.817	0.434
A13	28	CF	1	42.772	22.265	0.039	0.458	2.062	-0.004	10.288	0.074	0.467
A13-SS	29	D5L	3	44.296	22.250	-0.029	0.469	2.055	-0.004	10.291	-0.075	0.491
A14	30	CF	2	46.683	16.991	2.025	0.488	1.801	-0.204	14.439	-1.819	0.524
A14-SS	31	D2L	3	47.293	14.633	1.842	0.494	1.677	-0.204	16.768	-2.001	0.530
A15	32	AD	1	49.680	10.441	0.073	0.526	1.438	0.000	21.953	0.035	0.549
A15(Mid)	33	D2H	3	50.442	10.385	0.000	0.538	1.438	0.000	21.926	0.000	0.555
A15-End	34	D2H	4	51.204	10.441	-0.073	0.549	1.438	0.000	21.953	-0.035	0.560
A16	35	AD	2	53.592	14.633	-1.842	0.582	1.677	0.204	16.768	2.001	0.579
A16-SS	36	D2L	4	54.201	16.991	-2.025	0.588	1.801	0.204	14.439	1.819	0.585
A17	37	CF	3	56.589	22.250	0.029	0.607	2.055	0.004	10.291	0.075	0.618
A17-SS	38	D5L	4	58.113	22.265	-0.039	0.618	2.062	0.004	10.288	-0.074	0.642
A18	39	CF	4	60.500	17.041	2.022	0.636	1.825	-0.198	14.428	-1.817	0.675
A18-SS	40	D2T	4	61.110	14.688	1.840	0.642	1.704	-0.198	16.753	-1.998	0.681
A19	41	BD	3	63.116	10.654	0.300	0.669	1.488	-0.021	21.807	-0.353	0.697
A19-SS	42	D2S	4	63.726	10.326	0.238	0.678	1.475	-0.021	22.256	-0.384	0.701
A20	43	BD	4	65.732	11.839	-1.041	0.708	1.601	0.149	19.707	1.570	0.716
A20(Mid)	44	D10	4	67.256	15.420	-1.309	0.726	1.829	0.149	15.330	1.302	0.730
A20(Mid)	END	SUPER	1	67.256	15.420	-1.309	0.726	1.829	0.149	15.330	1.302	0.730

TOTAL LENGTH =	807.075641	QX =	8.713461	QY =	8.762655
		QX' =	-21.561643	QY' =	2.267100
ALFA =	0.139920E-01	BETAX(MAX) =	22.374626	BETAY(MAX) =	22.256231
GAMMA(TR) =	8.453955	DX(MAX) =	2.171203	DY(MAX) =	0.000000

P250D (25 GeV/c) "BARE MACHINE" "MAD" VERSION: 6.01/01
DELTA(P)/P = 0.000000 RUN: 01/29/88 09:00

MACHINE LOCATION ID	ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]
L20(Mid)	BEGIN	SUPER	1	0.000	15.451	-1.309	0.000	1.837	0.149	15.375	1.303	0.000
L20-End	1	D10	1	1.524	19.847	-1.576	0.014	2.064	0.149	11.811	1.036	0.018
A01	2	BF	1	3.530	22.407	0.385	0.029	2.178	-0.037	10.303	-0.236	0.048
A01-SS	3	D2S	1	4.140	21.957	0.353	0.033	2.155	-0.037	10.628	-0.298	0.057
A02	4	BF	2	6.147	16.890	2.006	0.049	1.899	-0.214	14.638	-1.828	0.084
A02-SS	5	D2T	1	6.756	14.555	1.824	0.055	1.769	-0.214	16.976	-2.009	0.090
A03	6	CD	1	9.144	10.403	0.072	0.088	1.518	-0.001	22.164	0.040	0.109
A03-SS	7	D5L	1	10.667	10.408	-0.075	0.111	1.516	-0.001	22.147	-0.029	0.120
A04	8	CD	2	13.055	14.582	-1.831	0.144	1.760	0.211	16.920	2.013	0.139
A04-SS	9	D2L	1	13.665	16.924	-2.013	0.150	1.889	0.211	14.577	1.831	0.145
A05	10	AF	1	16.052	22.136	0.034	0.169	2.146	0.000	10.407	0.074	0.177
A05(Mid)	11	D2H	1	16.814	22.110	0.000	0.174	2.146	0.000	10.351	0.000	0.189
A05-End	12	D2H	2	17.576	22.136	-0.034	0.180	2.146	0.000	10.407	-0.074	0.201
A06	13	AF	2	19.964	16.924	2.013	0.198	1.889	-0.211	14.577	-1.831	0.233
A06-SS	14	D2L	2	20.573	14.582	1.831	0.204	1.760	-0.211	16.920	-2.013	0.239
A07	15	CD	3	22.961	10.408	0.075	0.237	1.516	0.001	22.147	0.029	0.258
A07-SS	16	D5L	2	24.485	10.403	-0.072	0.260	1.518	0.001	22.164	-0.040	0.269
A08	17	CD	4	26.872	14.555	-1.824	0.293	1.769	0.214	16.976	2.009	0.288
A08-SS	18	D2T	2	27.482	16.890	-2.006	0.299	1.899	0.214	14.638	1.828	0.294
A09	19	BF	3	29.488	21.957	-0.353	0.315	2.155	0.037	10.628	0.298	0.321
A09-SS	20	D2S	2	30.098	22.407	-0.385	0.320	2.178	0.037	10.303	0.236	0.330
A10	21	BF	4	32.104	19.847	1.576	0.334	2.064	-0.149	11.811	-1.036	0.360
A10(Mid)	22	D10	2	33.628	15.451	1.309	0.348	1.837	-0.149	15.375	-1.303	0.378
A10-End	23	D10	3	35.152	11.870	1.041	0.366	1.609	-0.149	19.755	-1.571	0.392
A11	24	BD	1	37.159	10.353	-0.237	0.396	1.484	0.022	22.307	0.383	0.407
A11-SS	25	D2S	3	37.768	10.680	-0.299	0.405	1.497	0.022	21.859	0.352	0.411
A12	26	BD	2	39.775	14.703	-1.835	0.432	1.716	0.199	16.812	1.997	0.427
A12-SS	27	D2T	3	40.384	17.050	-2.016	0.438	1.837	0.199	14.487	1.817	0.433
A13	28	CF	1	42.772	22.256	0.040	0.456	2.075	-0.004	10.350	0.072	0.466
A13-SS	29	D5L	3	44.296	22.238	-0.028	0.467	2.069	-0.004	10.355	-0.076	0.490
A14	30	CF	2	46.683	16.991	2.020	0.486	1.814	-0.205	14.516	-1.823	0.522
A14-SS	31	D2L	3	47.293	14.639	1.838	0.492	1.689	-0.205	16.849	-2.005	0.529
A15	32	AD	1	49.680	10.454	0.073	0.525	1.450	0.000	22.042	0.035	0.547
A15(Mid)	33	D2H	3	50.442	10.399	0.000	0.536	1.450	0.000	22.016	0.000	0.553
A15-End	34	D2H	4	51.204	10.454	-0.073	0.548	1.450	0.000	22.042	-0.035	0.558
A16	35	AD	2	53.592	14.639	-1.838	0.580	1.689	0.205	16.849	2.005	0.577
A16-SS	36	D2L	4	54.201	16.991	-2.020	0.586	1.814	0.205	14.516	1.823	0.583
A17	37	CF	3	56.589	22.238	0.028	0.605	2.069	0.004	10.355	0.076	0.616
A17-SS	38	D5L	4	58.113	22.256	-0.040	0.616	2.075	0.004	10.350	-0.072	0.640
A18	39	CF	4	60.500	17.050	2.016	0.635	1.837	-0.199	14.487	-1.817	0.672
A18-SS	40	D2T	4	61.110	14.703	1.835	0.641	1.716	-0.199	16.812	-1.997	0.679
A19	41	BD	3	63.116	10.680	0.299	0.667	1.497	-0.022	21.859	-0.352	0.695
A19-SS	42	D2S	4	63.726	10.353	0.237	0.676	1.484	-0.022	22.307	-0.383	0.699
A20	43	BD	4	65.732	11.870	-1.041	0.706	1.609	0.149	19.755	1.571	0.714
A20(Mid)	44	D10	4	67.256	15.451	-1.309	0.724	1.837	0.149	15.375	1.303	0.728
A20(Mid)	END	SUPER	1	67.256	15.451	-1.309	0.724	1.837	0.149	15.375	1.303	0.728

TOTAL LENGTH =	807.075641	QX =	8.691952	QY =	8.733685
		QX' =	-25.566044	QY' =	6.050744
ALFA =	0.140574E-01	BETAX(MAX) =	22.407113	BETAY(MAX) =	22.306816
GAMMA(TR) =	8.434267	DX(MAX) =	2.178077	DY(MAX) =	0.000000

P270D (27 GeV/c) "BARE MACHINE" "MAD" VERSION: 6.01/01
DELTA(P)/P = 0.000000 RUN: 01/29/88 09:02

MACHINE LOCATION ID	ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]
L20(Mid)	BEGIN	SUPER	1	0.000	15.484	-1.307	0.000	1.845	0.150	15.414	1.302	0.000
L20-End	1	D10	1	1.524	19.874	-1.574	0.014	2.073	0.150	11.852	1.036	0.018
A01	2	BF	1	3.530	22.428	0.385	0.029	2.187	-0.037	10.345	-0.237	0.048
A01-SS	3	D2S	1	4.140	21.978	0.354	0.033	2.165	-0.037	10.671	-0.299	0.057
A02	4	BF	2	6.147	16.913	2.004	0.049	1.908	-0.214	14.684	-1.829	0.084
A02-SS	5	D2T	1	6.756	14.580	1.823	0.055	1.778	-0.214	17.024	-2.010	0.090
A03	6	CD	1	9.144	10.428	0.072	0.088	1.526	-0.001	22.214	0.039	0.108
A03-SS	7	D5L	1	10.667	10.432	-0.075	0.111	1.524	-0.001	22.199	-0.029	0.119
A04	8	CD	2	13.055	14.597	-1.827	0.143	1.770	0.212	16.973	2.013	0.138
A04-SS	9	D2L	1	13.665	16.935	-2.008	0.150	1.899	0.212	14.630	1.832	0.144
A05	10	AF	1	16.052	22.135	0.034	0.168	2.157	0.000	10.457	0.073	0.177
A05(Mid)	11	D2H	1	16.814	22.109	0.000	0.174	2.157	0.000	10.401	0.000	0.188
A05-End	12	D2H	2	17.576	22.135	-0.034	0.179	2.157	0.000	10.457	-0.073	0.200
A06	13	AF	2	19.964	16.935	2.008	0.198	1.899	-0.212	14.630	-1.832	0.232
A06-SS	14	D2L	2	20.573	14.597	1.827	0.204	1.770	-0.212	16.973	-2.013	0.239
A07	15	CD	3	22.961	10.432	0.075	0.237	1.524	0.001	22.199	0.029	0.257
A07-SS	16	D5L	2	24.485	10.428	-0.072	0.260	1.526	0.001	22.214	-0.039	0.268
A08	17	CD	4	26.872	14.580	-1.823	0.292	1.778	0.214	17.024	2.010	0.287
A08-SS	18	D2T	2	27.482	16.913	-2.004	0.299	1.908	0.214	14.684	1.829	0.293
A09	19	BF	3	29.488	21.978	-0.354	0.315	2.165	0.037	10.671	0.299	0.319
A09-SS	20	D2S	2	30.098	22.428	-0.385	0.319	2.187	0.037	10.345	0.237	0.329
A10	21	BF	4	32.104	19.874	1.574	0.334	2.073	-0.150	11.852	-1.036	0.359
A10(Mid)	22	D10	2	33.628	15.484	1.307	0.348	1.845	-0.150	15.414	-1.302	0.377
A10-End	23	D10	3	35.152	11.906	1.041	0.365	1.617	-0.150	19.789	-1.569	0.391
A11	24	BD	1	37.159	10.391	-0.237	0.395	1.491	0.022	22.336	0.383	0.405
A11-SS	25	D2S	3	37.768	10.718	-0.299	0.404	1.504	0.022	21.888	0.352	0.410
A12	26	BD	2	39.775	14.744	-1.836	0.431	1.722	0.199	16.841	1.997	0.426
A12-SS	27	D2T	3	40.384	17.092	-2.017	0.437	1.844	0.199	14.517	1.816	0.432
A13	28	CF	1	42.772	22.299	0.040	0.456	2.082	-0.004	10.379	0.073	0.465
A13-SS	29	D5L	3	44.296	22.283	-0.029	0.466	2.076	-0.004	10.383	-0.075	0.488
A14	30	CF	2	46.683	17.038	2.020	0.485	1.820	-0.205	14.535	-1.820	0.521
A14-SS	31	D2L	3	47.293	14.687	1.839	0.491	1.695	-0.205	16.865	-2.001	0.527
A15	32	AD	1	49.680	10.501	0.073	0.524	1.456	0.000	22.048	0.035	0.546
A15(Mid)	33	D2H	3	50.442	10.445	0.000	0.535	1.456	0.000	22.021	0.000	0.551
A15-End	34	D2H	4	51.204	10.501	-0.073	0.547	1.456	0.000	22.048	-0.035	0.557
A16	35	AD	2	53.592	14.687	-1.839	0.579	1.695	0.205	16.865	2.001	0.576
A16-SS	36	D2L	4	54.201	17.038	-2.020	0.585	1.820	0.205	14.535	1.820	0.582
A17	37	CF	3	56.589	22.283	0.029	0.604	2.076	0.004	10.383	0.075	0.614
A17-SS	38	D5L	4	58.113	22.299	-0.040	0.615	2.082	0.004	10.379	-0.073	0.638
A18	39	CF	4	60.500	17.092	2.017	0.633	1.844	-0.199	14.517	-1.816	0.670
A18-SS	40	D2T	4	61.110	14.744	1.836	0.639	1.722	-0.199	16.841	-1.997	0.677
A19	41	BD	3	63.116	10.718	0.299	0.666	1.504	-0.022	21.888	-0.352	0.693
A19-SS	42	D2S	4	63.726	10.391	0.237	0.675	1.491	-0.022	22.336	-0.383	0.697
A20	43	BD	4	65.732	11.906	-1.041	0.705	1.617	0.150	19.789	1.569	0.712
A20(Mid)	44	D10	4	67.256	15.484	-1.307	0.723	1.845	0.150	15.414	1.302	0.726
A20(Mid)	END	SUPER	1	67.256	15.484	-1.307	0.723	1.845	0.150	15.414	1.302	0.726

TOTAL LENGTH =	807.075641	QX =	8.671489	QY =	8.709868
		QX' =	-29.723339	QY' =	9.946212
ALFA =	0.141190E-01	BETAX(MAX) =	22.427681	BETAY(MAX) =	22.335744
GAMMA(TR) =	8.415839	DX(MAX) =	2.187402	DY(MAX) =	0.000000

P290D (29 GeV/c) "BARE MACHINE" "MAD" VERSION: 6.01/01
DELTA(P)/P = 0.000000 RUN: 01/29/88 09:05

MACHINE LOCATION ID	ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]
L20(Mid)	BEGIN	SUPER	1	0.000	15.547	-1.306	0.000	1.860	0.150	15.478	1.301	0.000
L20-End	1	D10	1	1.524	19.930	-1.571	0.014	2.089	0.150	11.918	1.036	0.018
A01	2	BF	1	3.530	22.476	0.385	0.028	2.204	-0.037	10.411	-0.237	0.048
A01-SS	3	D2S	1	4.140	22.026	0.354	0.033	2.182	-0.037	10.738	-0.299	0.057
A02	4	BF	2	6.147	16.968	2.002	0.049	1.925	-0.215	14.753	-1.829	0.083
A02-SS	5	D2T	1	6.756	14.637	1.822	0.055	1.793	-0.215	17.093	-2.009	0.089
A03	6	CD	1	9.144	10.486	0.073	0.087	1.541	-0.001	22.280	0.039	0.108
A03-SS	7	D5L	1	10.667	10.487	-0.074	0.110	1.539	-0.001	22.266	-0.030	0.119
A04	8	CD	2	13.055	14.645	-1.824	0.143	1.786	0.213	17.046	2.012	0.137
A04-SS	9	D2L	1	13.665	16.978	-2.004	0.149	1.916	0.213	14.704	1.832	0.144
A05	10	AF	1	16.052	22.165	0.034	0.168	2.175	0.000	10.531	0.073	0.176
A05(Mid)	11	D2H	1	16.814	22.139	0.000	0.173	2.175	0.000	10.476	0.000	0.187
A05-End	12	D2H	2	17.576	22.165	-0.034	0.179	2.175	0.000	10.531	-0.073	0.199
A06	13	AF	2	19.964	16.978	2.004	0.197	1.916	-0.213	14.704	-1.832	0.231
A06-SS	14	D2L	2	20.573	14.645	1.824	0.204	1.786	-0.213	17.046	-2.012	0.237
A07	15	CD	3	22.961	10.487	0.074	0.236	1.539	0.001	22.266	0.030	0.256
A07-SS	16	D5L	2	24.485	10.486	-0.073	0.259	1.541	0.001	22.280	-0.039	0.267
A08	17	CD	4	26.872	14.637	-1.822	0.291	1.793	0.215	17.093	2.009	0.285
A08-SS	18	D2T	2	27.482	16.968	-2.002	0.297	1.925	0.215	14.753	1.829	0.292
A09	19	BF	3	29.488	22.026	-0.354	0.314	2.182	0.037	10.738	0.299	0.318
A09-SS	20	D2S	2	30.098	22.476	-0.385	0.318	2.204	0.037	10.411	0.237	0.327
A10	21	BF	4	32.104	19.930	1.571	0.332	2.089	-0.150	11.918	-1.036	0.357
A10(Mid)	22	D10	2	33.628	15.547	1.306	0.346	1.860	-0.150	15.478	-1.301	0.375
A10-End	23	D10	3	35.152	11.972	1.040	0.364	1.631	-0.150	19.845	-1.566	0.389
A11	24	BD	1	37.159	10.458	-0.238	0.394	1.504	0.022	22.385	0.383	0.403
A11-SS	25	D2S	3	37.768	10.785	-0.299	0.403	1.518	0.022	21.937	0.352	0.408
A12	26	BD	2	39.775	14.813	-1.836	0.429	1.737	0.200	16.897	1.995	0.424
A12-SS	27	D2T	3	40.384	17.161	-2.016	0.435	1.858	0.200	14.575	1.815	0.430
A13	28	CF	1	42.772	22.365	0.039	0.454	2.098	-0.004	10.437	0.073	0.462
A13-SS	29	D5L	3	44.296	22.350	-0.029	0.465	2.092	-0.004	10.439	-0.074	0.486
A14	30	CF	2	46.683	17.112	2.019	0.483	1.835	-0.206	14.585	-1.817	0.518
A14-SS	31	D2L	3	47.293	14.761	1.838	0.489	1.709	-0.206	16.910	-1.997	0.524
A15	32	AD	1	49.680	10.575	0.072	0.521	1.469	0.000	22.080	0.035	0.543
A15(Mid)	33	D2H	3	50.442	10.520	0.000	0.533	1.469	0.000	22.054	0.000	0.549
A15-End	34	D2H	4	51.204	10.575	-0.072	0.544	1.469	0.000	22.080	-0.035	0.554
A16	35	AD	2	53.592	14.761	-1.838	0.576	1.709	0.206	16.910	1.997	0.573
A16-SS	36	D2L	4	54.201	17.112	-2.019	0.582	1.835	0.206	14.585	1.817	0.579
A17	37	CF	3	56.589	22.350	0.029	0.601	2.092	0.004	10.439	0.074	0.612
A17-SS	38	D5L	4	58.113	22.365	-0.039	0.612	2.098	0.004	10.437	-0.073	0.635
A18	39	CF	4	60.500	17.161	2.016	0.630	1.858	-0.200	14.575	-1.815	0.667
A18-SS	40	D2T	4	61.110	14.813	1.836	0.637	1.737	-0.200	16.897	-1.995	0.674
A19	41	BD	3	63.116	10.785	0.299	0.663	1.518	-0.022	21.937	-0.352	0.690
A19-SS	42	D2S	4	63.726	10.458	0.238	0.672	1.504	-0.022	22.385	-0.383	0.694
A20	43	BD	4	65.732	11.972	-1.040	0.702	1.631	0.150	19.845	1.566	0.709
A20(Mid)	44	D10	4	67.256	15.547	-1.306	0.719	1.860	0.150	15.478	1.301	0.723
A20(Mid)	END	SUPER	1	67.256	15.547	-1.306	0.719	1.860	0.150	15.478	1.301	0.723

TOTAL LENGTH =	807.075641	QX =	8.632619	QY =	8.670353
		QX' =	-37.307979	QY' =	16.998239
ALFA =	0.142383E-01	BETAX(MAX) =	22.476140	BETAY(MAX) =	22.384957
GAMMA(TR) =	8.380511	DX(MAX) =	2.204457	DY(MAX) =	0.000000

P320D (32 GeV/c) "BARE MACHINE" "MAD" VERSION: 6.01/01
DELTA(P)/P = 0.000000 RUN: 01/29/88 09:07

MACHINE LOCATION ID	ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX	MUX [2PI]	DX [M]	DX'	VERTICAL BETAY [M]	ALFAY	MUY [2PI]
L20(Mid)	BEGIN	SUPER	1	0.000	15.773	-1.298	0.000	1.916	0.153	15.697	1.293	0.000
L20-End	1	D10	1	1.524	20.125	-1.558	0.014	2.150	0.153	12.152	1.034	0.018
A01	2	BF	1	3.530	22.637	0.387	0.028	2.268	-0.037	10.657	-0.242	0.047
A01-SS	3	D2S	1	4.140	22.184	0.356	0.032	2.246	-0.037	10.989	-0.302	0.056
A02	4	BF	2	6.147	17.139	1.996	0.048	1.986	-0.218	15.024	-1.835	0.081
A02-SS	5	D2T	1	6.756	14.814	1.819	0.054	1.853	-0.218	17.369	-2.012	0.087
A03	6	CD	1	9.144	10.660	0.075	0.086	1.597	0.000	22.566	0.035	0.106
A03-SS	7	D5L	1	10.667	10.649	-0.068	0.109	1.597	0.000	22.562	-0.033	0.117
A04	8	CD	2	13.055	14.761	-1.806	0.141	1.850	0.217	17.356	2.013	0.135
A04-SS	9	D2L	1	13.665	17.069	-1.982	0.147	1.982	0.217	15.011	1.835	0.141
A05	10	AF	1	16.052	22.190	0.034	0.166	2.247	0.000	10.830	0.071	0.172
A05(Mid)	11	D2H	1	16.814	22.164	0.000	0.171	2.247	0.000	10.776	0.000	0.184
A05-End	12	D2H	2	17.576	22.190	-0.034	0.177	2.247	0.000	10.830	-0.071	0.195
A06	13	AF	2	19.964	17.069	1.982	0.195	1.982	-0.217	15.011	-1.835	0.226
A06-SS	14	D2L	2	20.573	14.761	1.806	0.202	1.850	-0.217	17.356	-2.013	0.232
A07	15	CD	3	22.961	10.649	0.068	0.233	1.597	0.000	22.562	0.033	0.251
A07-SS	16	D5L	2	24.485	10.660	-0.075	0.256	1.597	0.000	22.566	-0.035	0.261
A08	17	CD	4	26.872	14.814	-1.819	0.288	1.853	0.218	17.369	2.012	0.280
A08-SS	18	D2T	2	27.482	17.139	-1.996	0.294	1.986	0.218	15.024	1.835	0.286
A09	19	BF	3	29.488	22.184	-0.356	0.310	2.246	0.037	10.989	0.302	0.312
A09-SS	20	D2S	2	30.098	22.637	-0.387	0.314	2.268	0.037	10.657	0.242	0.321
A10	21	BF	4	32.104	20.125	1.558	0.329	2.150	-0.153	12.152	-1.034	0.350
A10(Mid)	22	D10	2	33.628	15.773	1.298	0.343	1.916	-0.153	15.697	-1.293	0.367
A10-End	23	D10	3	35.152	12.212	1.039	0.360	1.682	-0.153	20.033	-1.552	0.381
A11	24	BD	1	37.159	10.709	-0.243	0.389	1.551	0.021	22.537	0.385	0.396
A11-SS	25	D2S	3	37.768	11.042	-0.303	0.398	1.564	0.021	22.087	0.354	0.400
A12	26	BD	2	39.775	15.092	-1.842	0.424	1.784	0.202	17.063	1.988	0.416
A12-SS	27	D2T	3	40.384	17.446	-2.020	0.430	1.907	0.202	14.747	1.811	0.422
A13	28	CF	1	42.772	22.662	0.035	0.448	2.148	-0.004	10.608	0.076	0.454
A13-SS	29	D5L	3	44.296	22.658	-0.032	0.459	2.141	-0.004	10.598	-0.069	0.477
A14	30	CF	2	46.683	17.431	2.021	0.477	1.881	-0.208	14.697	-1.799	0.509
A14-SS	31	D2L	3	47.293	15.076	1.843	0.483	1.754	-0.208	16.997	-1.975	0.515
A15	32	AD	1	49.680	10.880	0.070	0.514	1.511	0.000	22.101	0.035	0.534
A15(Mid)	33	D2H	3	50.442	10.826	0.000	0.525	1.511	0.000	22.075	0.000	0.539
A15-End	34	D2H	4	51.204	10.880	-0.070	0.536	1.511	0.000	22.101	-0.035	0.545
A16	35	AD	2	53.592	15.076	-1.843	0.568	1.754	0.208	16.997	1.975	0.564
A16-SS	36	D2L	4	54.201	17.431	-2.021	0.574	1.881	0.208	14.697	1.799	0.570
A17	37	CF	3	56.589	22.658	0.032	0.592	2.141	0.004	10.598	0.069	0.602
A17-SS	38	D5L	4	58.113	22.662	-0.035	0.603	2.148	0.004	10.608	-0.076	0.625
A18	39	CF	4	60.500	17.446	2.020	0.621	1.907	-0.202	14.747	-1.811	0.657
A18-SS	40	D2T	4	61.110	15.092	1.842	0.627	1.784	-0.202	17.063	-1.988	0.663
A19	41	BD	3	63.116	11.042	0.303	0.653	1.564	-0.021	22.087	-0.354	0.679
A19-SS	42	D2S	4	63.726	10.709	0.243	0.662	1.551	-0.021	22.537	-0.385	0.683
A20	43	BD	4	65.732	12.212	-1.039	0.691	1.682	0.153	20.033	1.552	0.698
A20(Mid)	44	D10	4	67.256	15.773	-1.298	0.708	1.916	0.153	15.697	1.293	0.711
A20(Mid)	END	SUPER	1	67.256	15.773	-1.298	0.708	1.916	0.153	15.697	1.293	0.711

TOTAL LENGTH =	807.075641	QX =	8.496780	QY =	8.536931
		QX' =	-58.274315	QY' =	36.700898
ALFA =	0.146667E-01	BETAX(MAX) =	22.661810	BETAY(MAX) =	22.566020
GAMMA(TR) =	8.257205	DX(MAX) =	2.268471	DY(MAX) =	0.000000

IV. GRAPHICAL PRESENTATIONS

The figures that follow present the data of the tables in the preceding section in graphical form. In all figures, calculated points have been joined by straight lines without interpolation.

Data were computed for beam momenta of 15, 20, 25, 27, 29 and 32 GeV/c. The 15 GeV/c results apply for momenta down to about 1-2 GeV/c.

All data in this high-field regime are for a D. C. (not ramped) Bare Machine. "Bare" means with main magnets only -- that is: not including any corrections effected by the high-field quadrupoles and sextupoles. "D. C." or "unramped" means excluding any effects due to changing magnetic fields (i.e., no dB/dt effects).

Summary of Figures:

Figures 1-8 present data for the parameters Beta-x, Beta-y, Alpha-x, Alpha-y, Mu-x, Mu-y, dx and dx'. Each parameter is given for all six energies (beam momenta) on the same panel.

Figures 9-13 and 14-18 present data for the respective beam momenta 15 GeV/c and 29 GeV/c. (Alpha-x, Alpha-y and dx' are not given separately, since their energy variations are mini- and these parameters can be read just as easily from Figures 3, 4, and 8.)

Figures 19-24 present the energy (beam momentum) variations in the minima and maxima of Beta-x, Beta-y and dx (dispersion).

Figures 25-26 present the energy (beam momentum) variations in tunes and chromaticities, both horizontal and vertical.

Figures 27-32 present the Courant-Snyder parameters, Beta and Alpha, and the phase function, Mu, showing both the horizontal and vertical parameters on the same panel at each of the two beam momenta: 15 and 29 GeV/c.

Figures 33-34 repeat the data of Figures 1 and 2 (Beta-s) but with a square root scale and zero not suppressed. This shows the relative beam sizes along the supereperiod (as beam size is proportional to the square root of Beta).

Figure 35 presents beam size for the 15 GeV/c case, given in actual size units (mm). These were calculated using emittances measured at 1 GeV and scaled, appropriately, to this momentum.

Notations of Axes:

In Figures 1-18 and 27-35, the horizontal axis represents distance along the machine, starting from the middle of the "20"-straight section of one superperiod and running through the middle of the "20"-straight section of the next superperiod.

The bottom horizontal axis is noted with rectangles showing the positions of the main magnets: with horizontal focussing magnets above the axis and horizontal defocussing ones below.

Above the frame are the section numbers -- 01 to 20; the heavier vertical grid lines mark section boundaries. Note that the second half of straight section 20 (of the preceding superperiod) is to the left of magnet 01.

In Figures 19-26, the horizontal axis represents machine beam momentum and runs from 15 to 32 GeV/c.

The vertical axes are marked with the respective parameters and have a scale chosen to fill most of the panel. Note that this axis does not necessarily contain the zero-point.

Units:

Beta's and dispersions (dx) are given in meters.

Phase advance is given in units of 2*pi -- a phase advance of 8.7 corresponds to 8.7 cycles (or approximately 54.66 rad).

Alpha, dx', tune and chromaticity are dimensionless.

Comments:

Since we have chosen to connect the calculated points with straight lines, the plots of the beta-functions show sharp corners. In reality, the beta-functions are smooth (their derivatives exist everywhere). In contrast, the alpha-functions do not have a derivative everywhere and, therefore, the sharp corners shown in the plots are real. It should be noted that the derivatives of the alpha-s in drift spaces (straight sections) are always negative; consequently, the second derivative of the beta-function is always positive in these spaces. Thus, the beta-s, though they may appear to be flat there, are in fact going through a local minimum. Where the beta-functions are at a maximum in a straight section (05, 13 and 17 in x; 03, 07 and 15 in y), the true maxima occur on the boundaries of these straight sections (at the ends of the magnets); there is a local minimum inside the straight section. To a good approximation, the curves there may be considered to be flat-topped.

REFERENCES

[1] E. D. Courant and H. S. Snyder, "Theory of the Alternating Gradient Synchrotron", Ann. of Phys. 3,1 (1958). See also chapters covering this material in the various Summer Study volumes: Fermilab, 1981 (AIP Conf. Proceedings No. 87, pp. 1-34); BNL-SUNY, 1983 (AIP Conf. Proceedings No.127, pp. 3-27).

[2] F. C. Iselin and J. Niederer, "The MAD Program -- User's Reference Manual", CERN/LEP-TH/87-33, April, 1987.

ACKNOWLEDGEMENTS

I would like to thank E. Bleser for collaboration in formulating the input which specifies the magnets of the bare machine; this was based, in part, on earlier field measurements by R. Thern.

Thanks are also due to M. Tanaka and R. Thern for comments and suggestions on the material to be displayed and for the manner of presentation in this note.

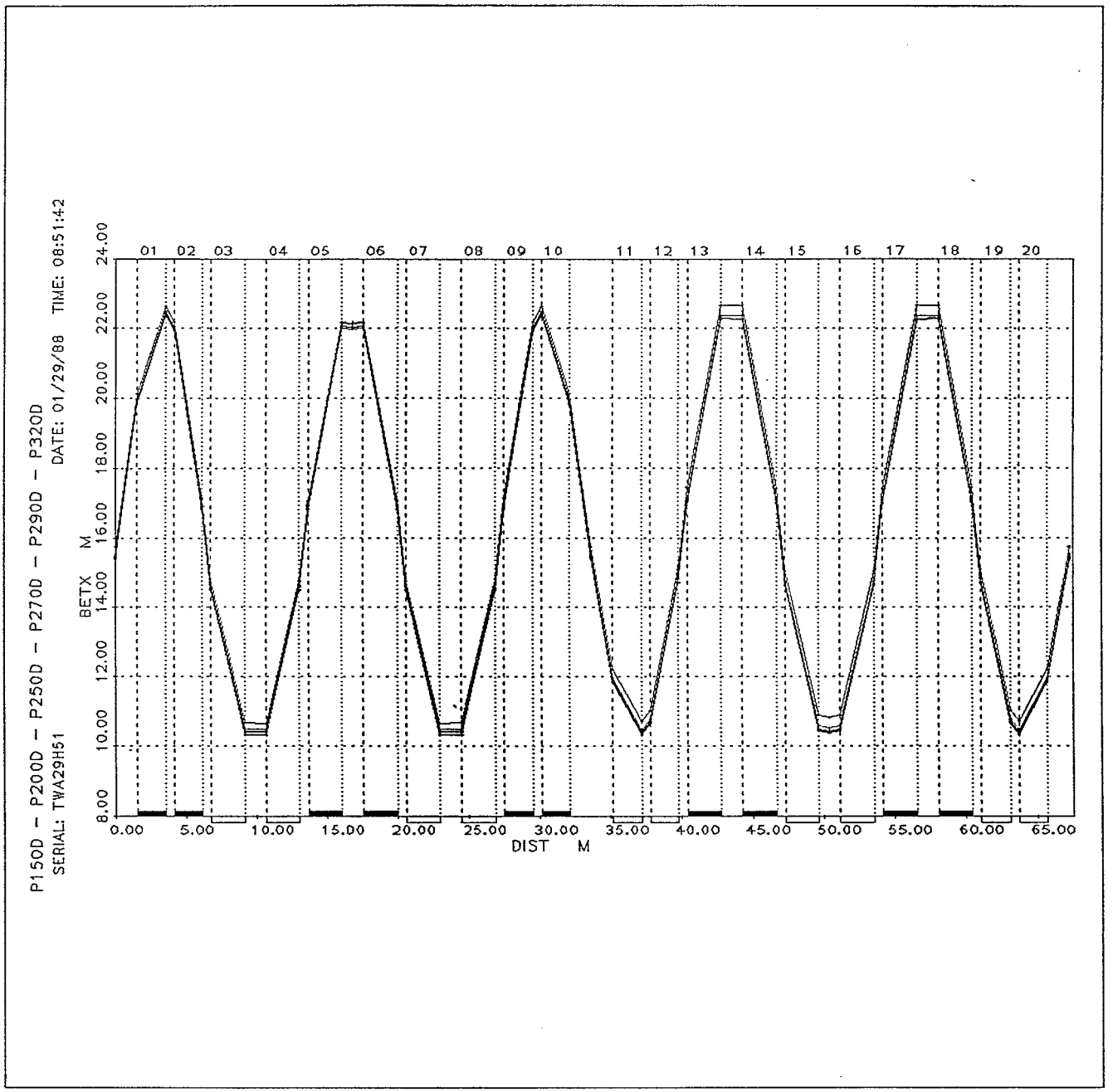

Figure 1. Courant-Snyder Parameter Beta-x (in meters) for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

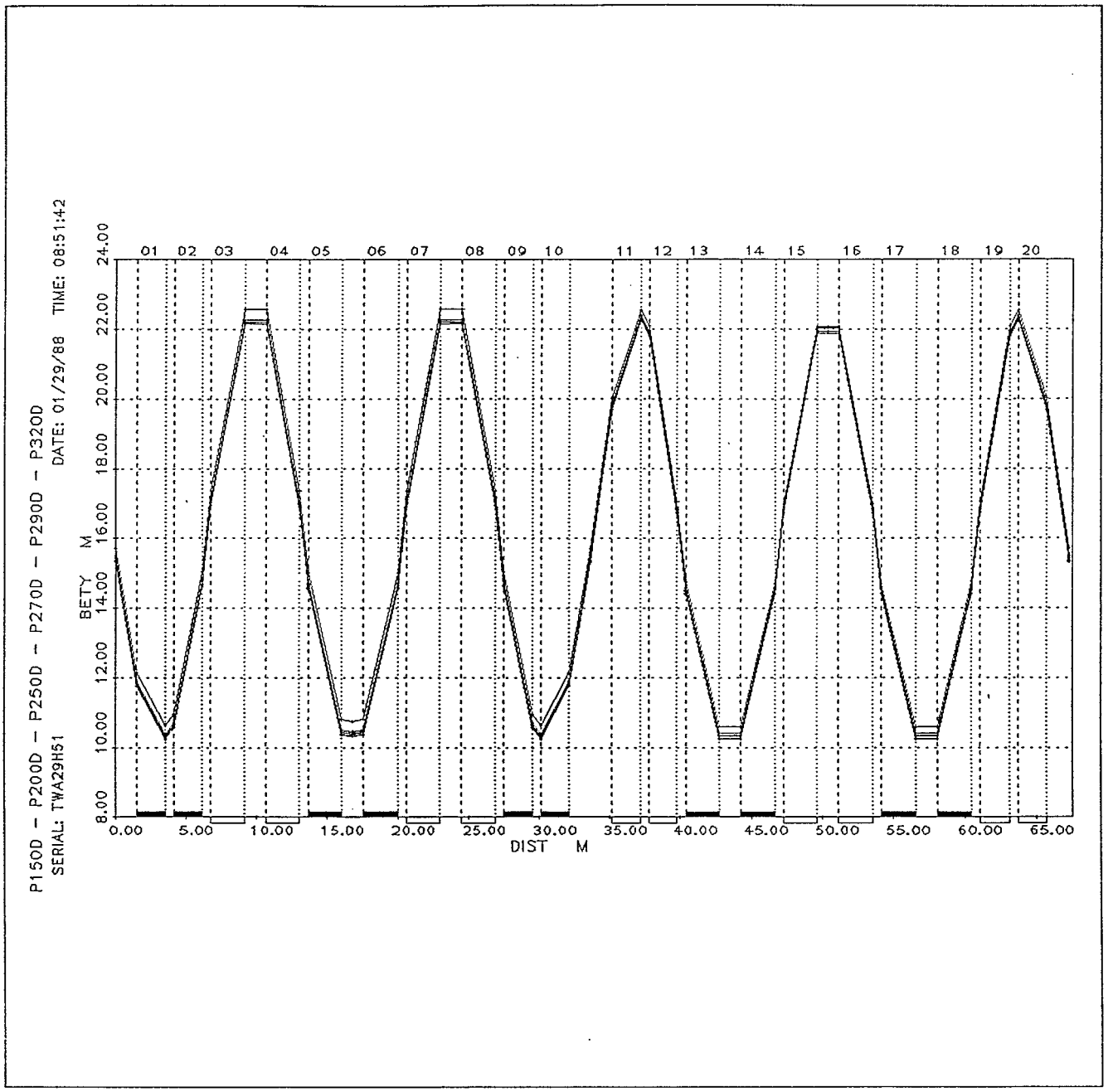

Figure 2. Courant-Snyder Parameter Beta-y (in meters) for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

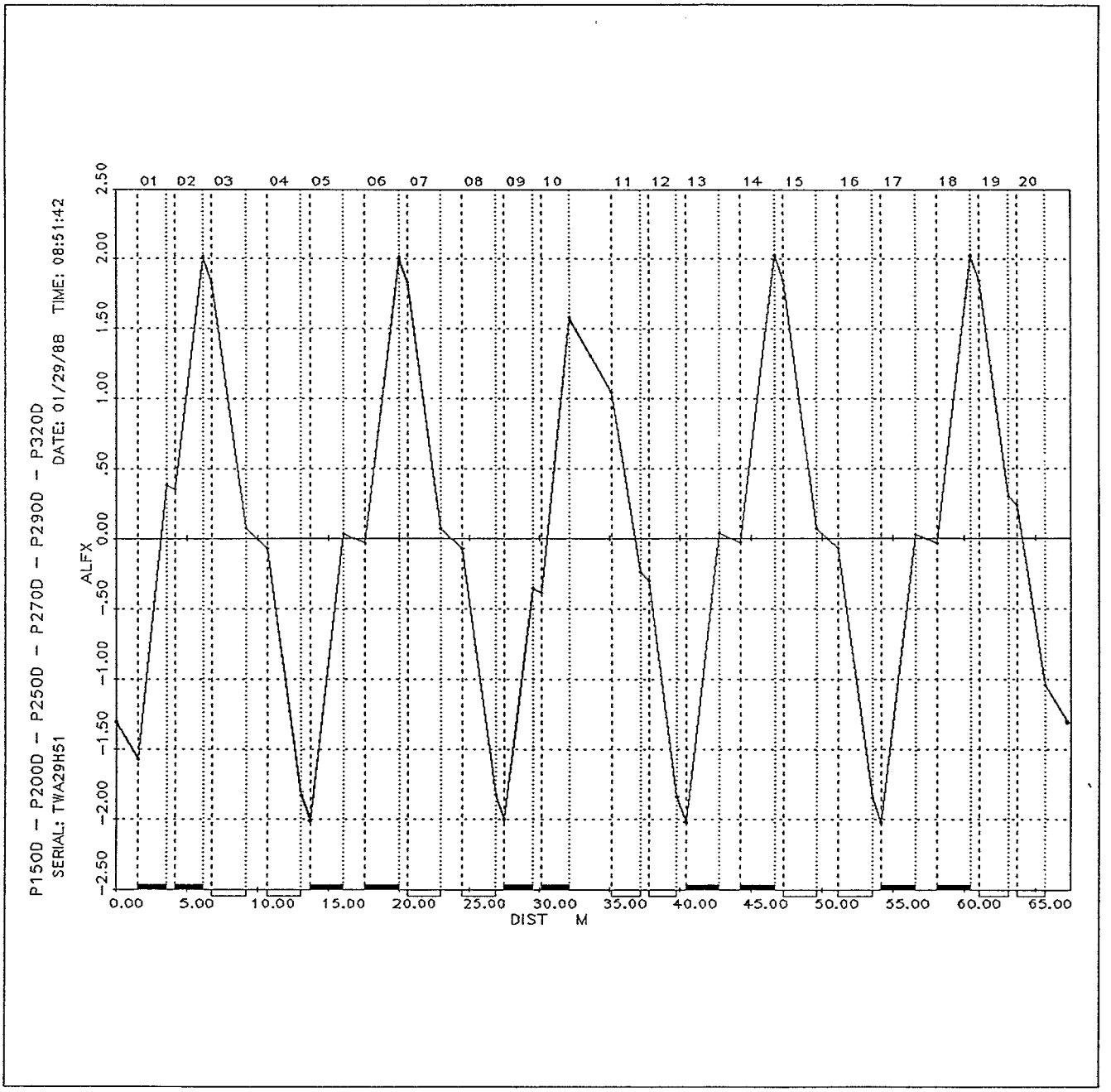

Figure 3. Courant-Snyder Parameter Alpha-x (dimensionless) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

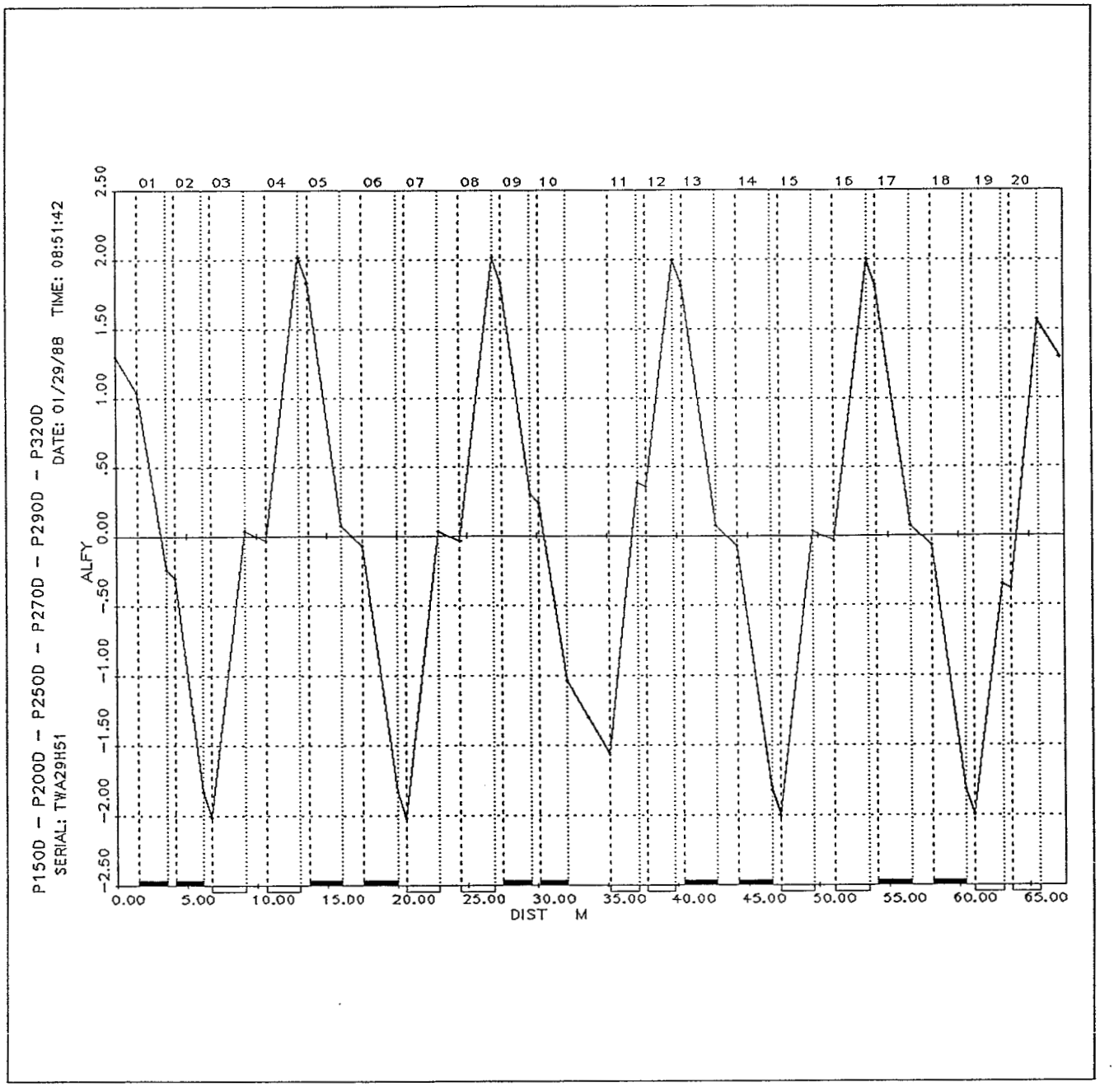

Figure 4. Courant-Snyder Parameter Alpha-y (dimensionless) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

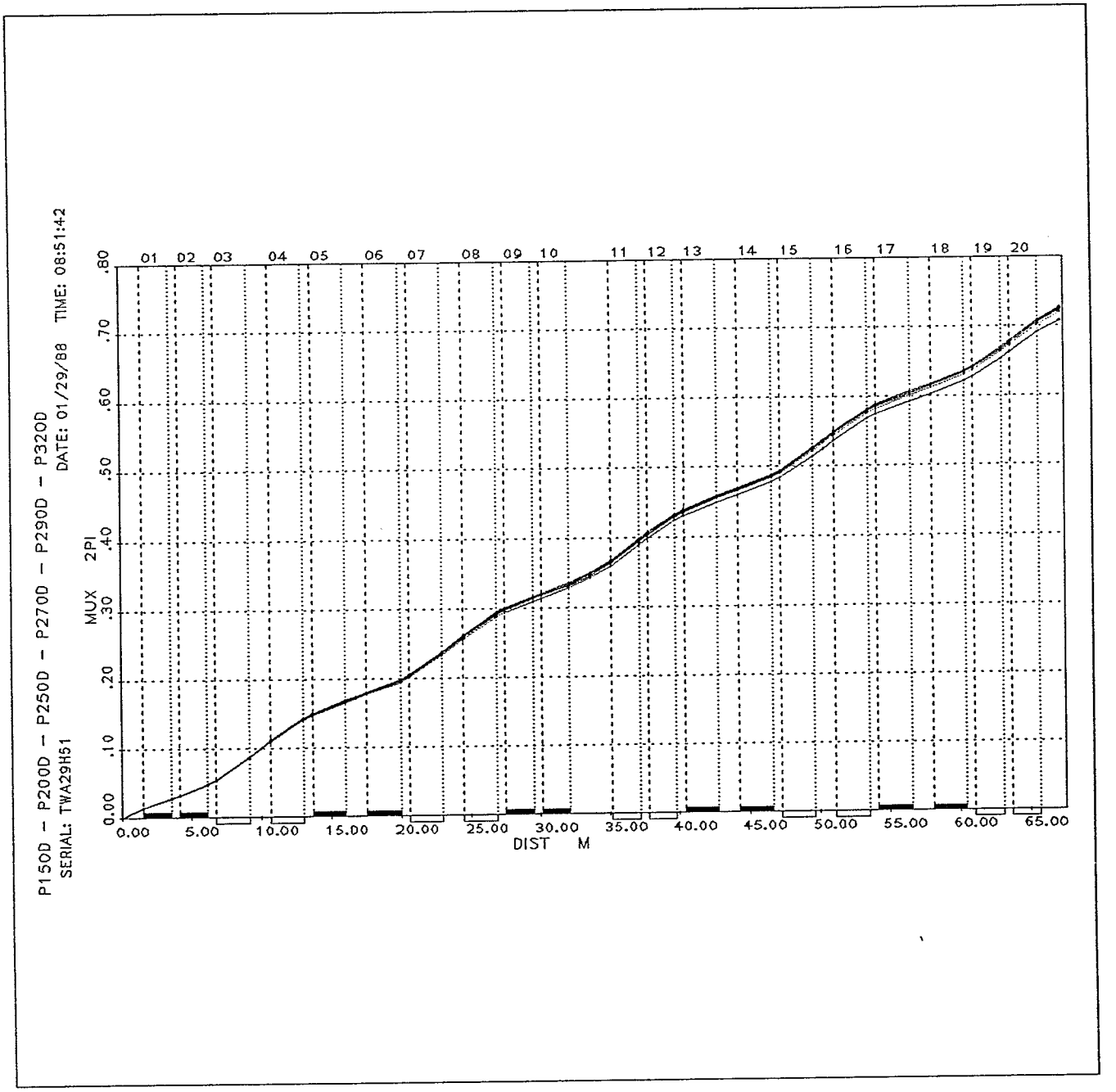

Figure 5. Phase Function Mu-x (in units of 2*pi radians) for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

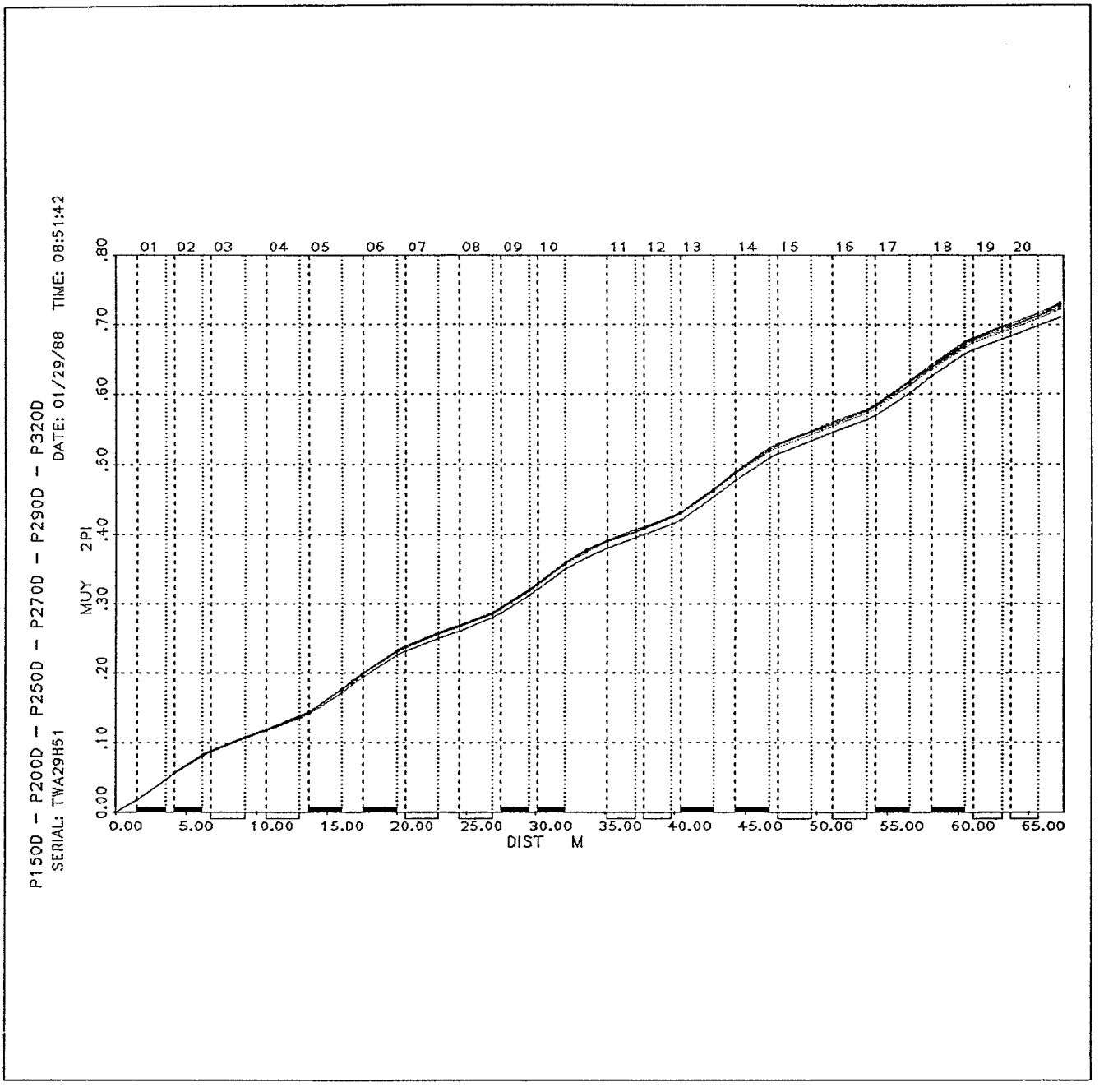

Figure 6. Phase Function Mu-y (in units of 2*pi radians) for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

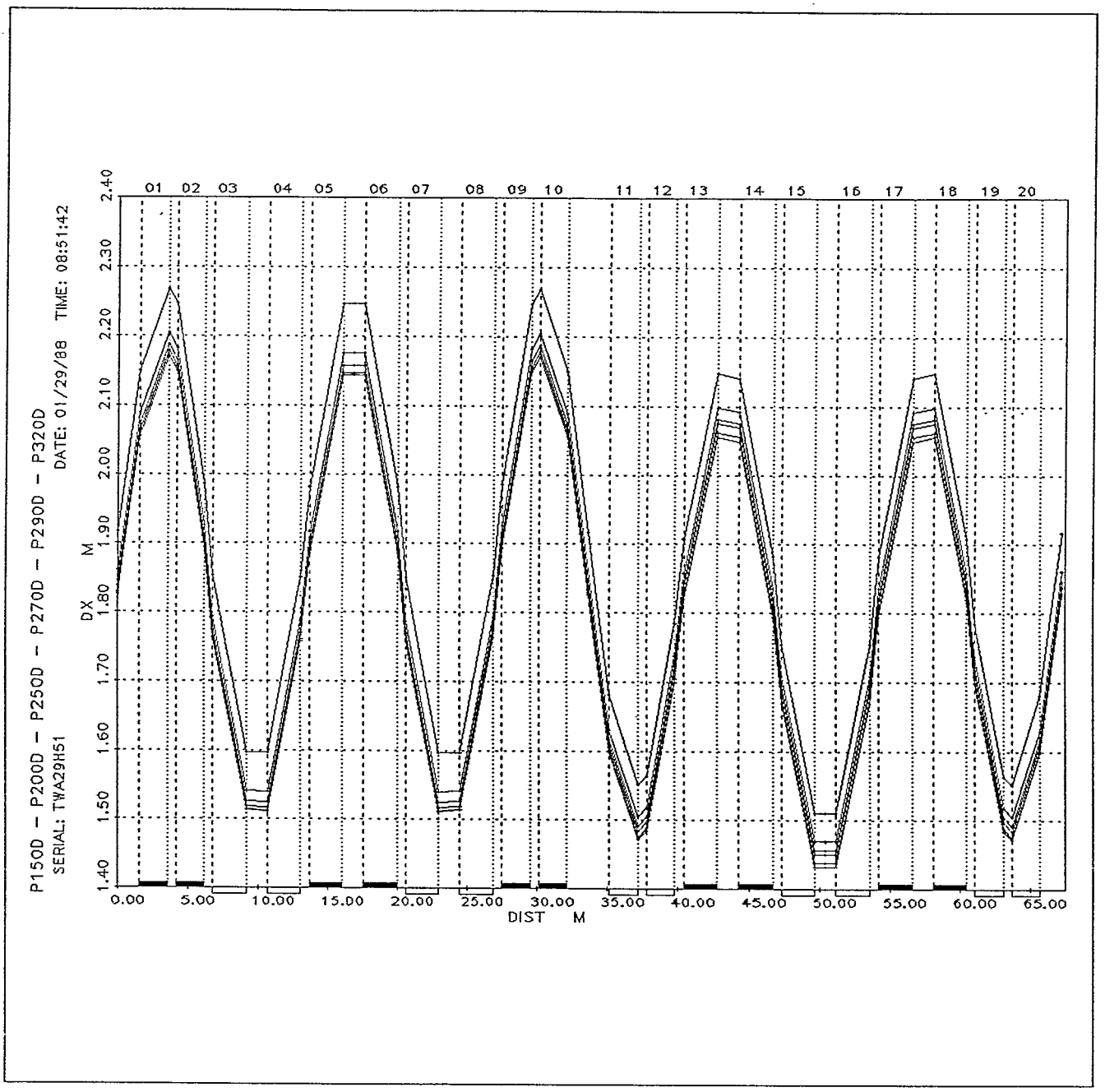

Figure 7. Dispersion Function dx (in meters) for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

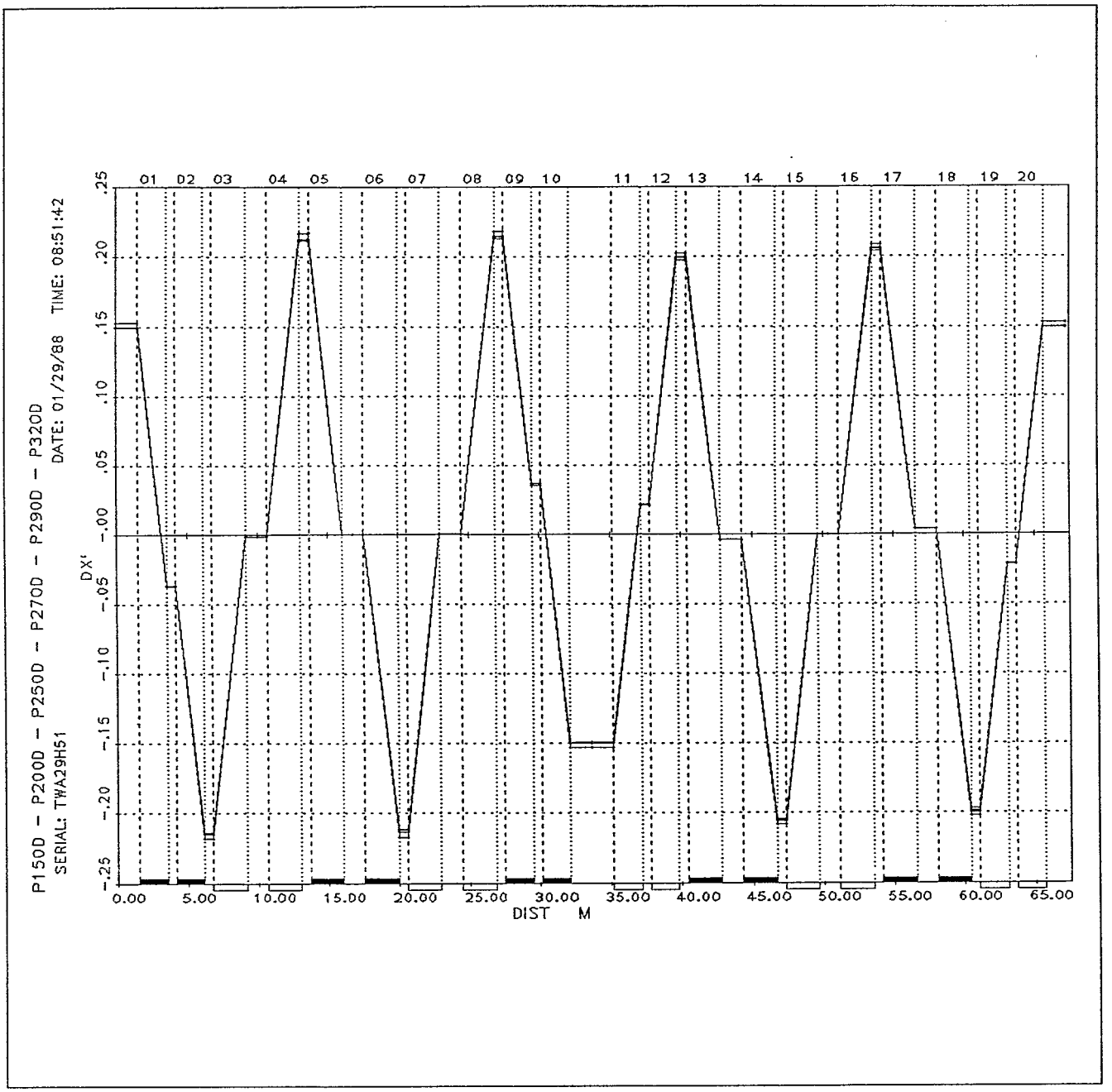

Figure 8. Derivative of Dispersion dx′ (dimensionless) for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod.

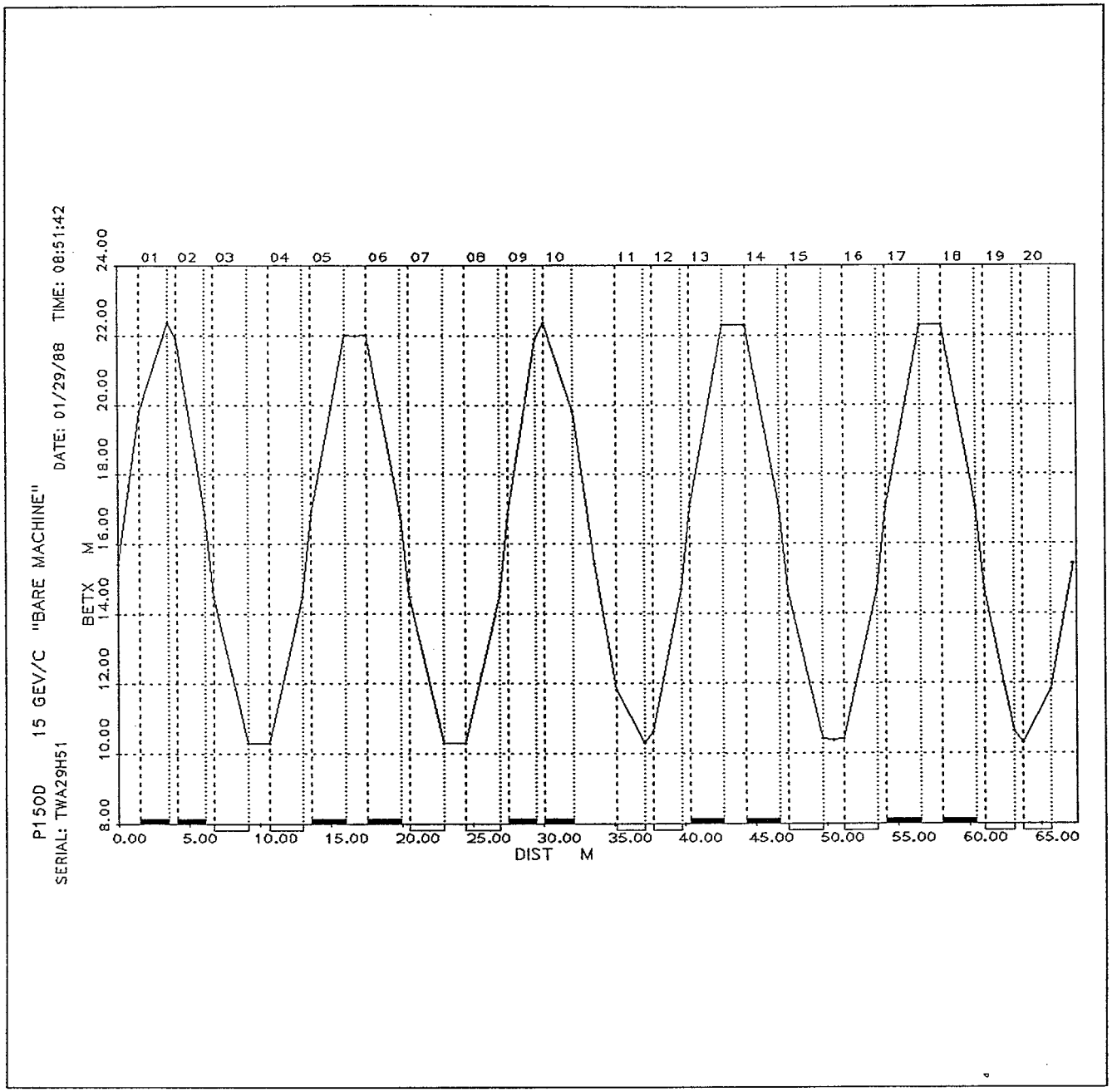

Figure 9. Courant-Snyder Parameter Beta-x (in meters) for the D. C. "Bare" Machine (main magnets only) at 15 GeV/c, given for one superperiod.

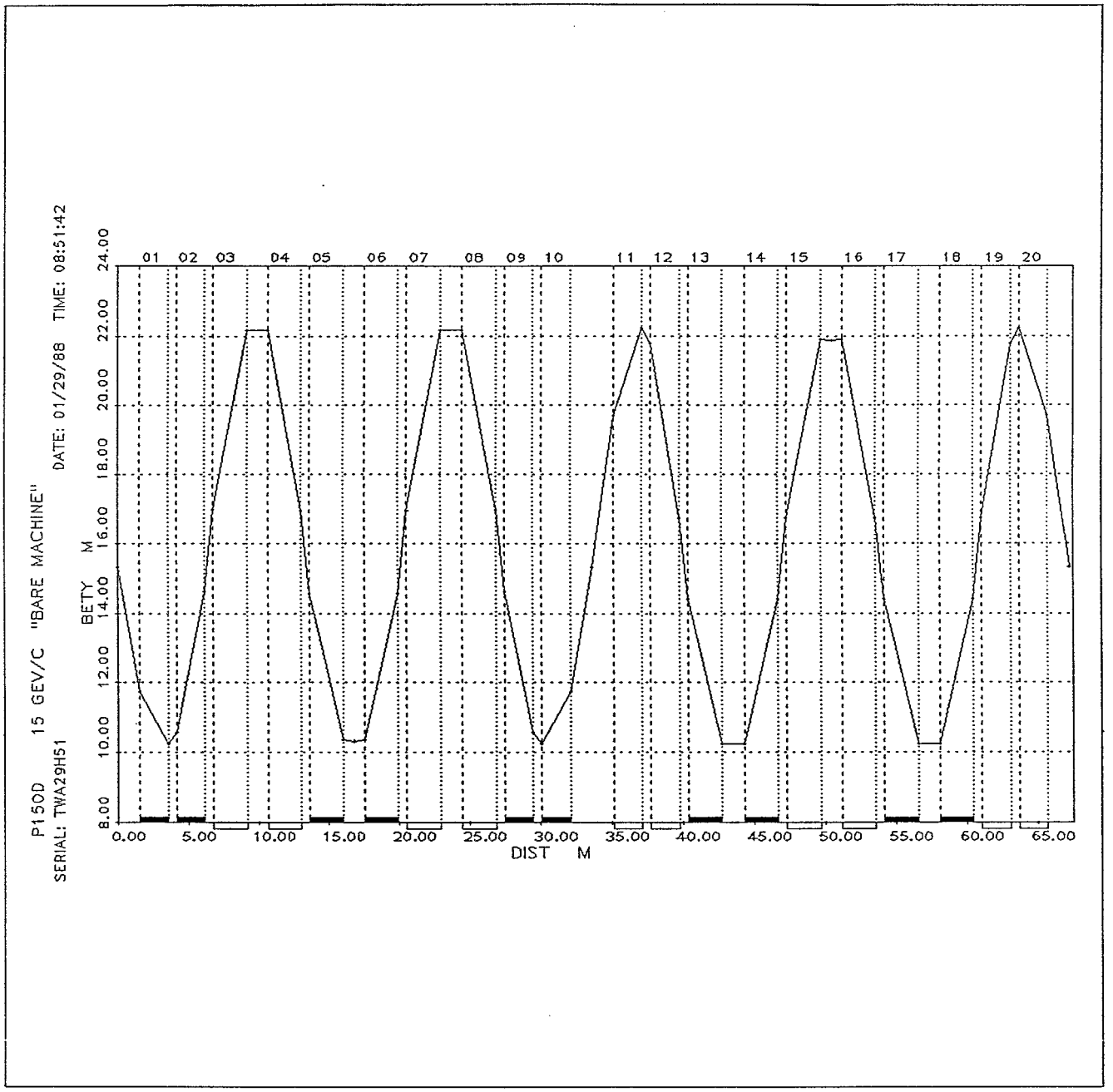

Figure 10. Courant-Snyder Parameter Beta-y (in meters) for the D. C. "Bare" Machine (main magnets only) at 15 GeV/c, given for one superperiod.

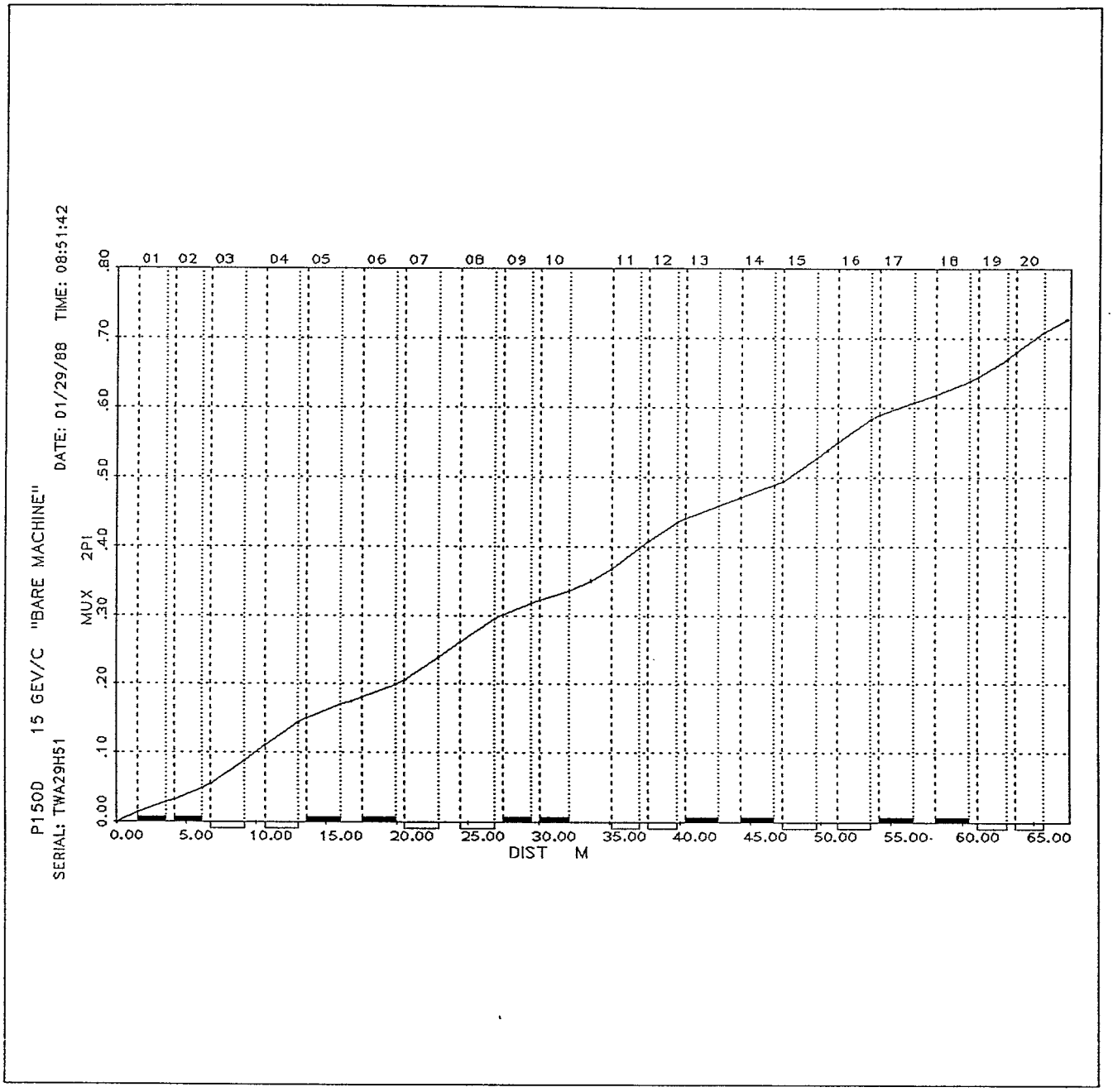

Figure 11. Phase Function Mu-x (in units of 2*pi radians) for the D. C. "Bare" Machine (main magnets only) at 15 GeV/c, given for one superperiod.

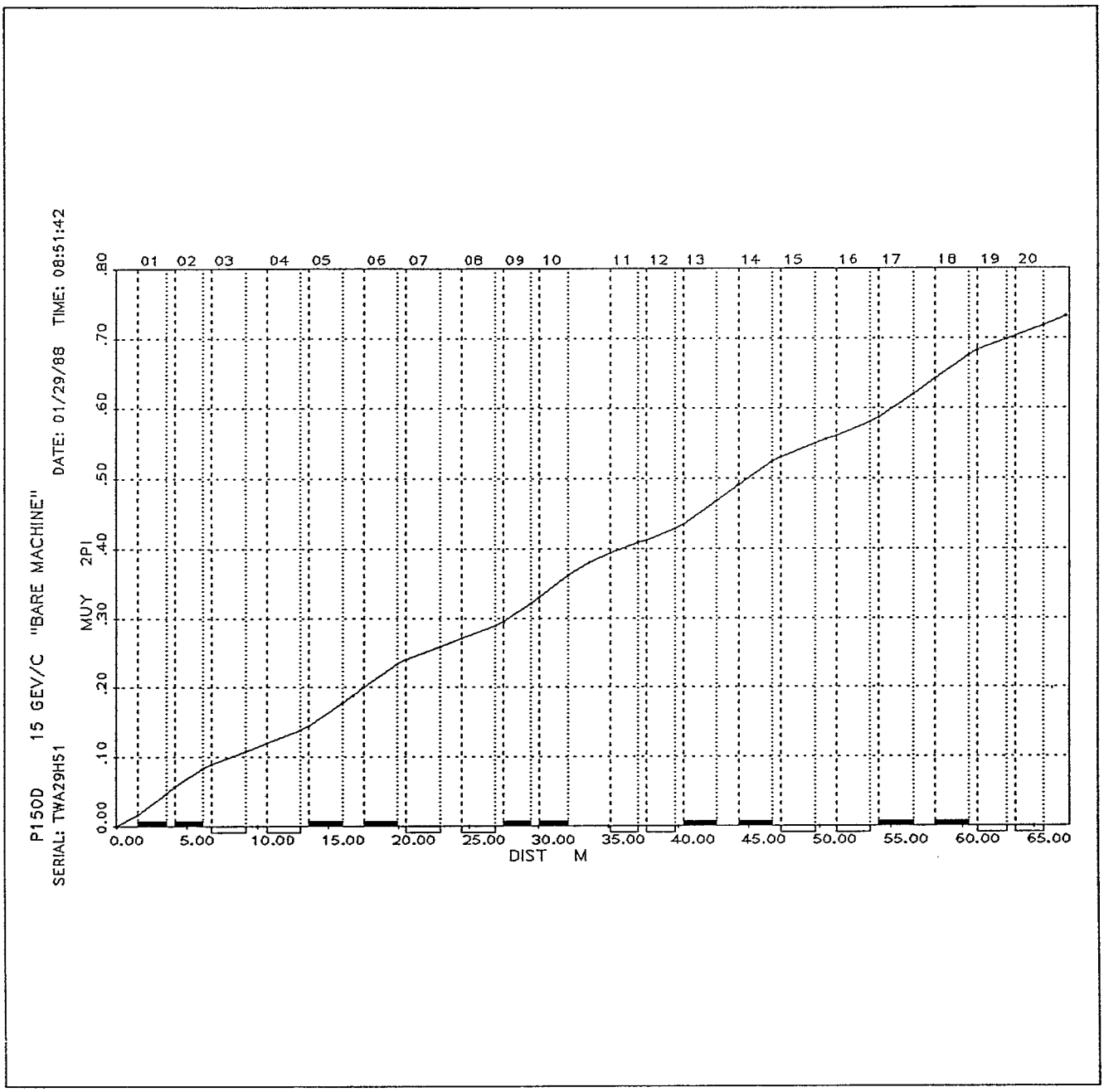

Figure 12. Phase Function Mu-y (in units of 2*pi radians) for the D. C. "Bare" Machine (main magnets only) at 15 GeV/c, given for one superperiod.

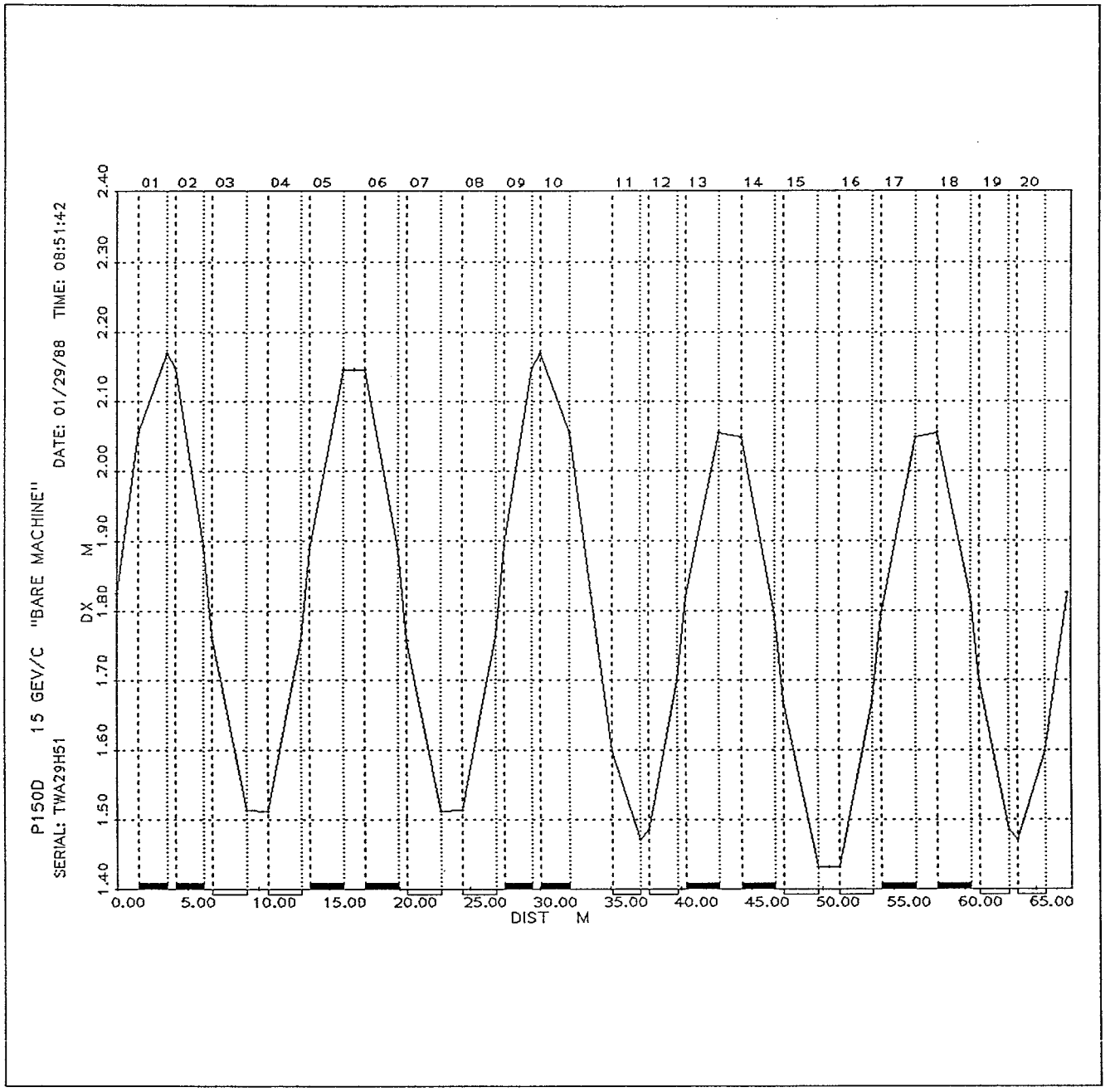

Figure 13. Dispersion Function dx (in meters) for the D. C. "Bare" Machine (main magnets only) at 15 GeV/c, given for one superperiod.

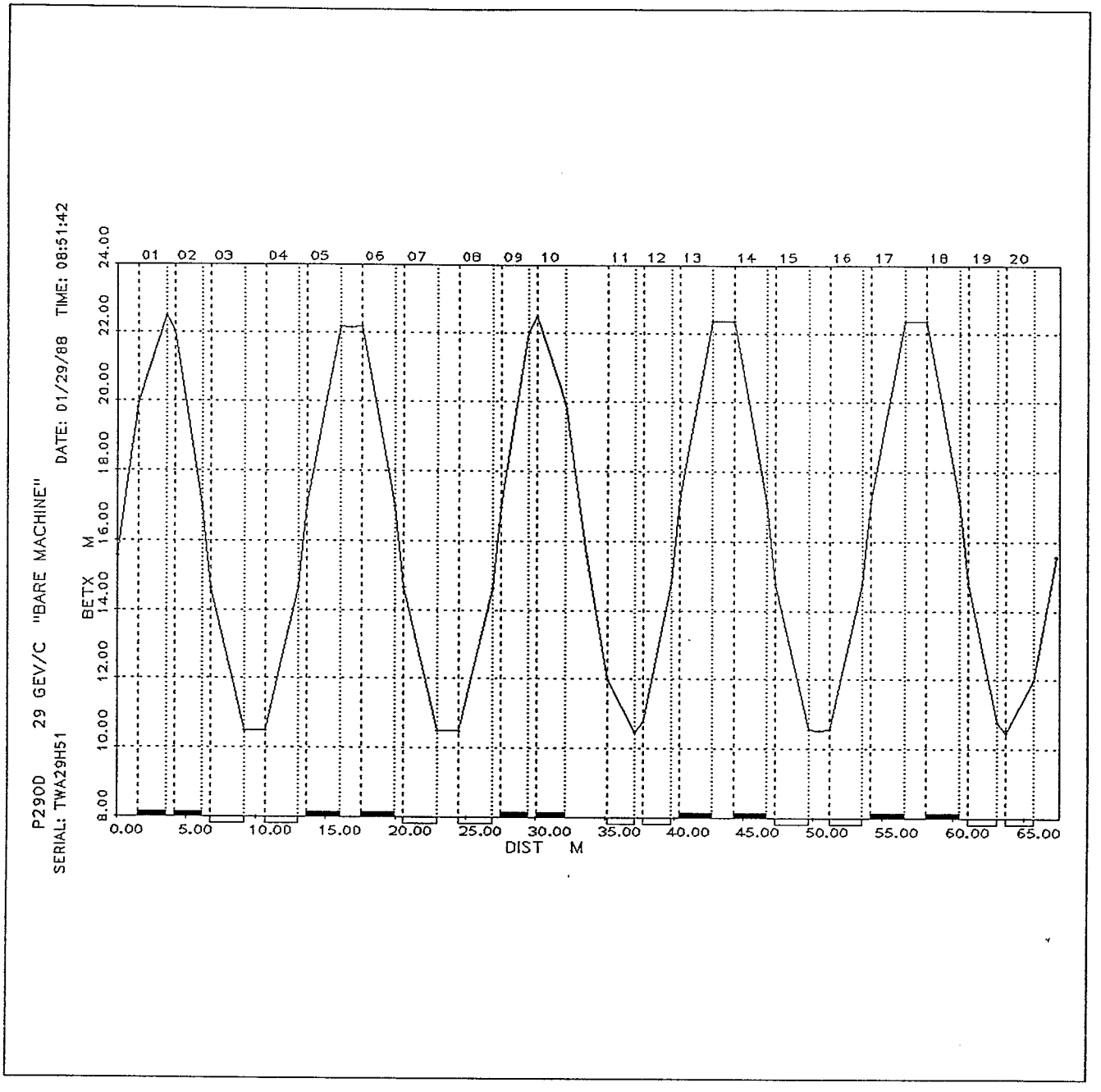

Figure 14. Courant-Snyder Parameter Beta-x (in meters) for the D. C. "Bare" Machine (main magnets only) at 29 GeV/c, given for one superperiod.

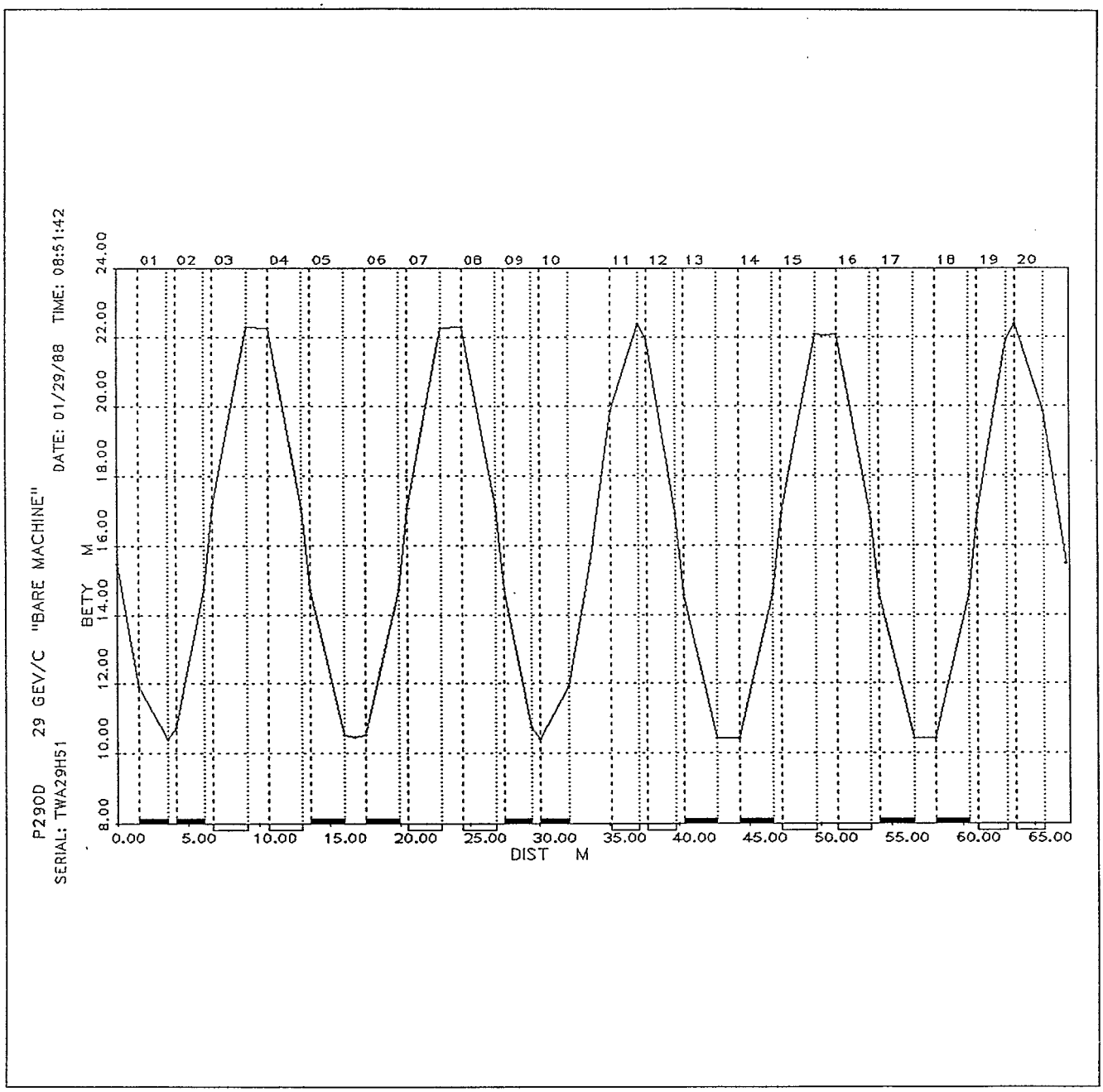

Figure 15. Courant-Snyder Parameter Beta-y (in meters) for the D. C. "Bare" Machine (main magnets only) at 29 GeV/c, given for one superperiod.

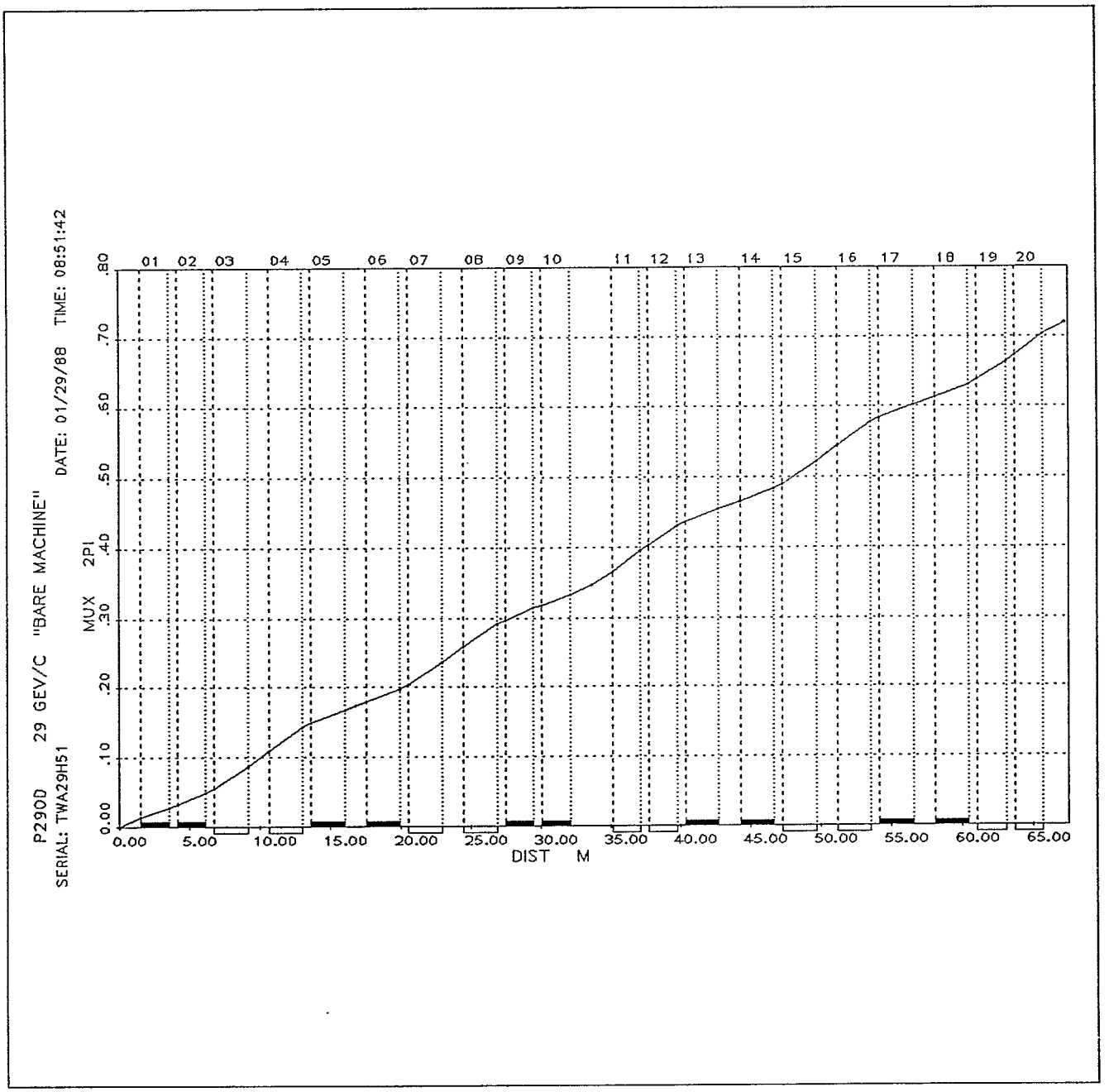

Figure 16. Phase Function Mu-x (in units of 2*pi radians) for the D. C. "Bare" Machine (main magnets only) at 29 GeV/c, given for one superperiod.

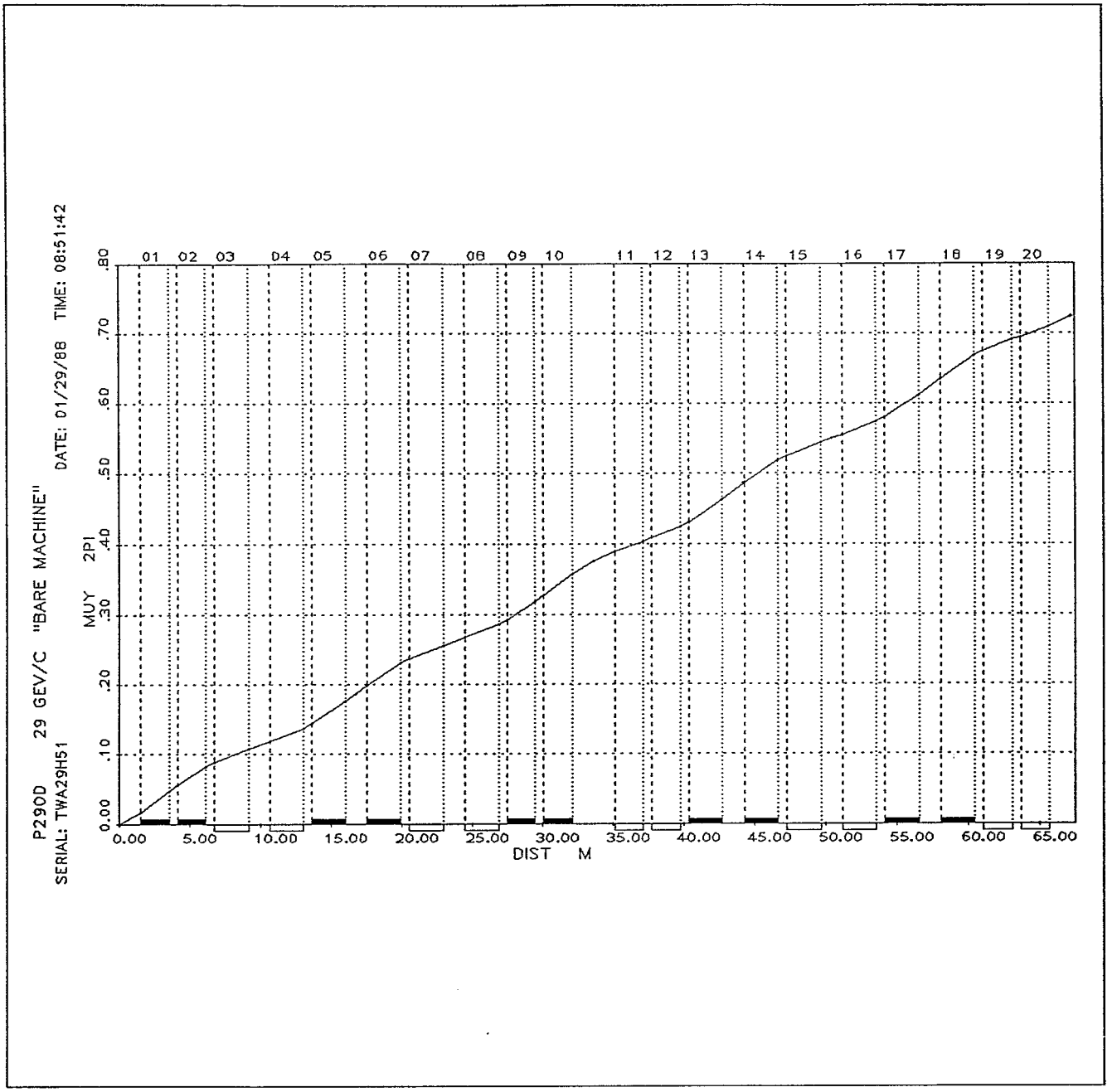

Figure 17. Phase Function Mu-y (in units of 2*pi radians) for the D. C. "Bare" Machine (main magnets only) at 29 GeV/c, given for one superperiod.

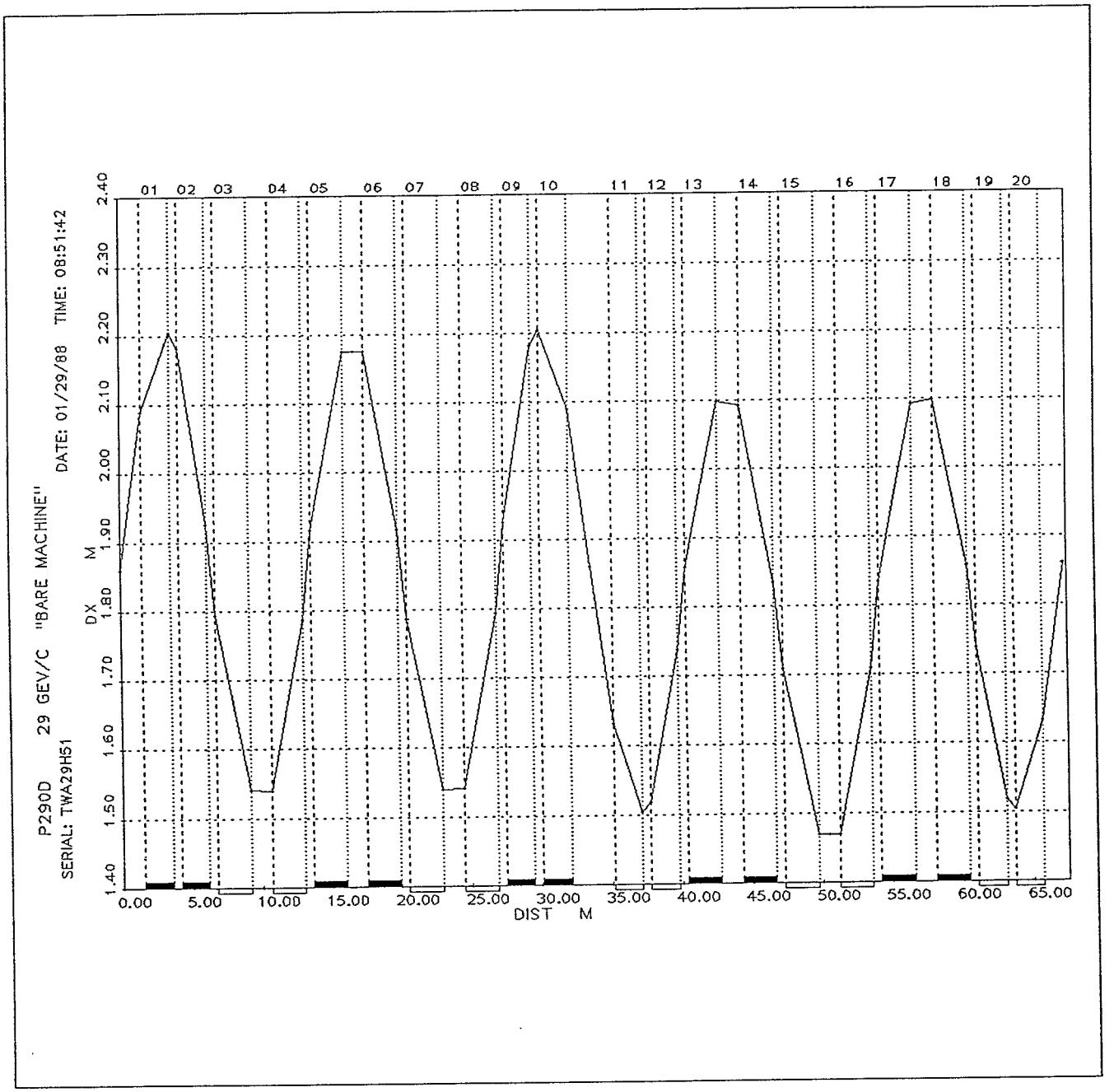

Figure 18. Dispersion Function dx (in meters) for the D. C. "Bare" Machine (main magnets only) at 29 GeV/c, given for one superperiod.

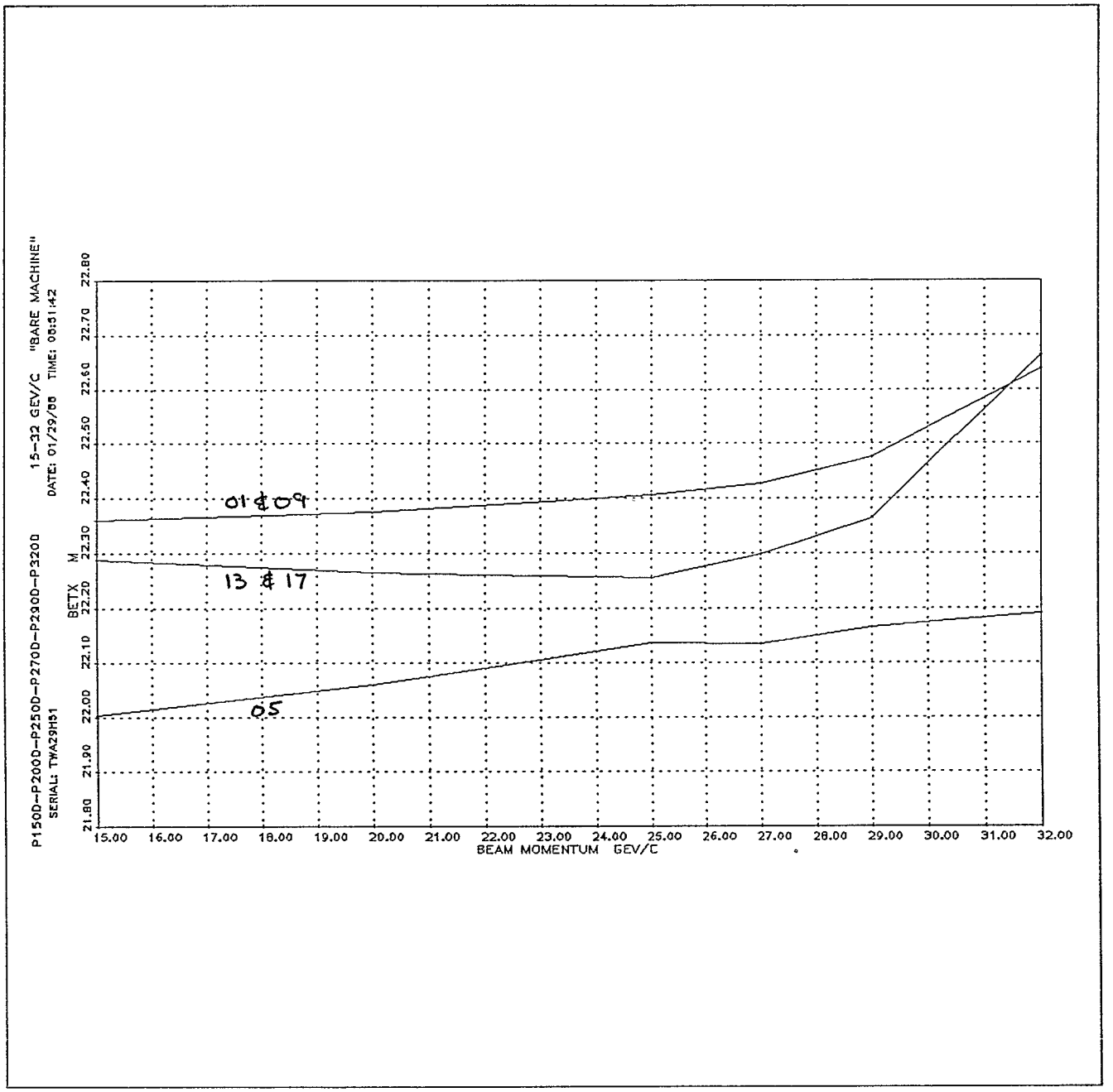

Figure 19. Energy Dependence of the Maxima in Beta-x (in meters) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 1.) The several maxima are labelled by the machine section in which they occur.

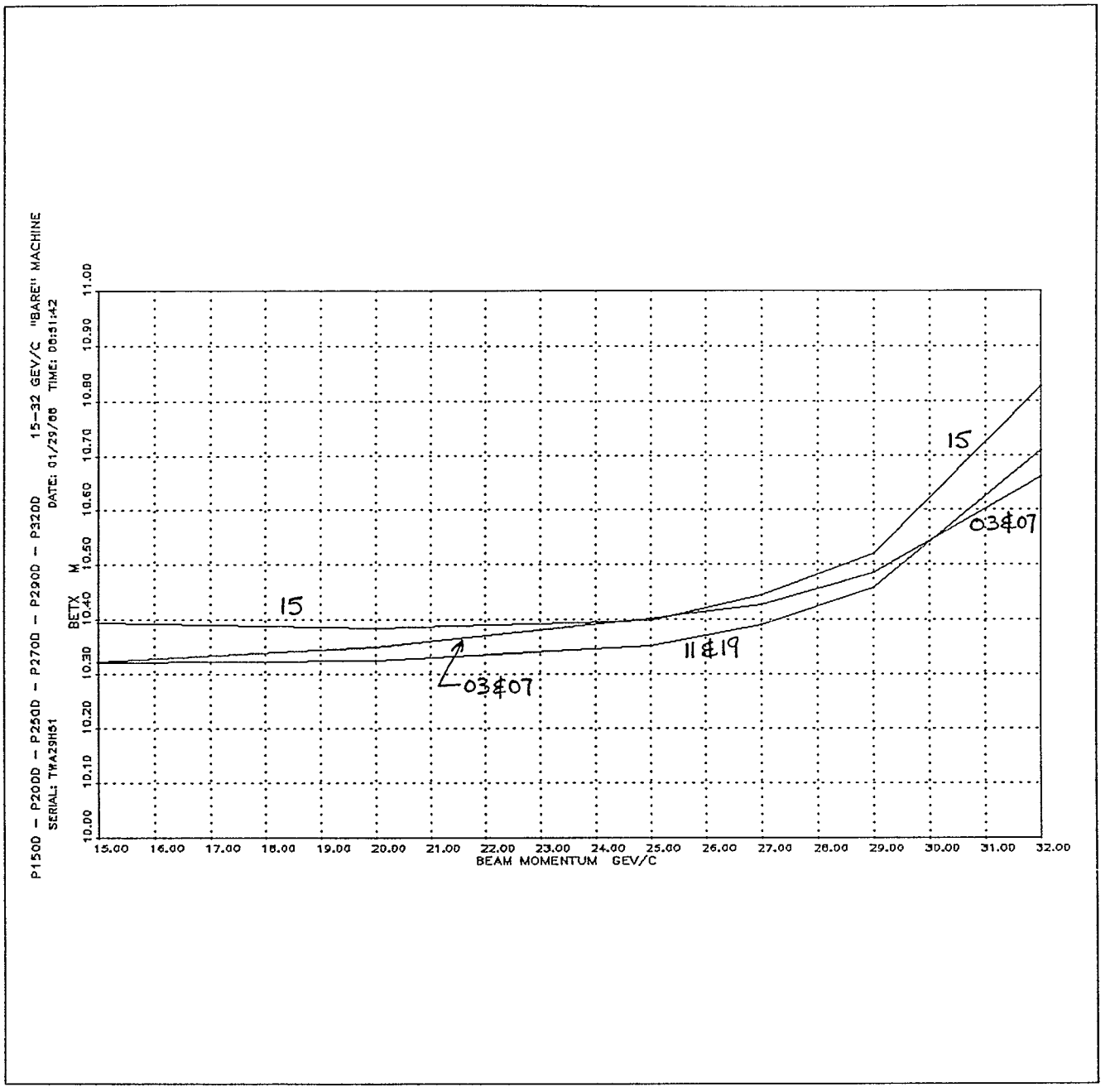

Figure 20. Energy Dependence of the Minima in Beta-x (in meters) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 1.) The several minima are labelled by the machine section in which they occur.

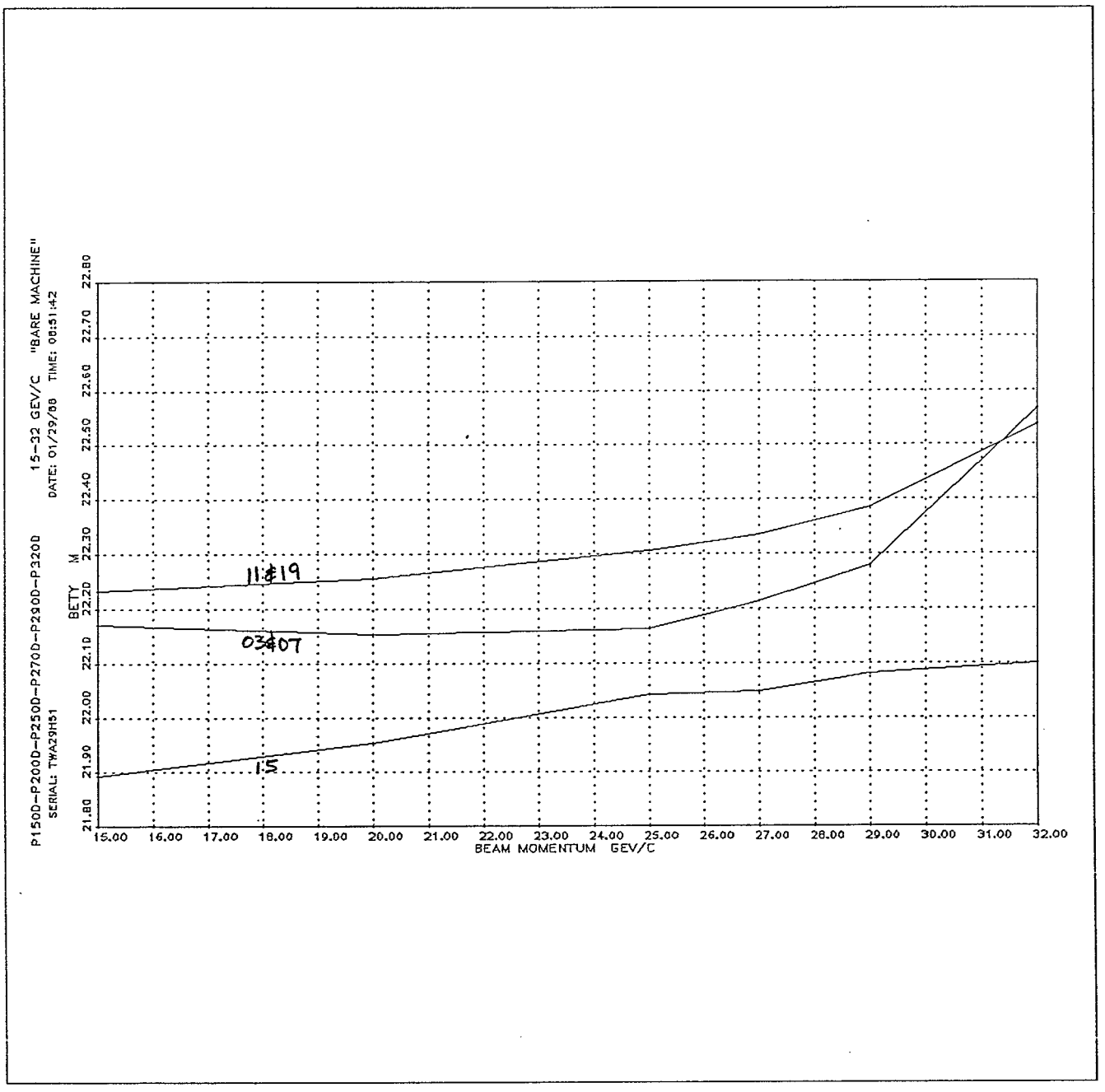

Figure 21. Energy Dependence of the Maxima in Beta-y (in meters) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 2.) The several maxima are labelled by the machine section in which they occur.

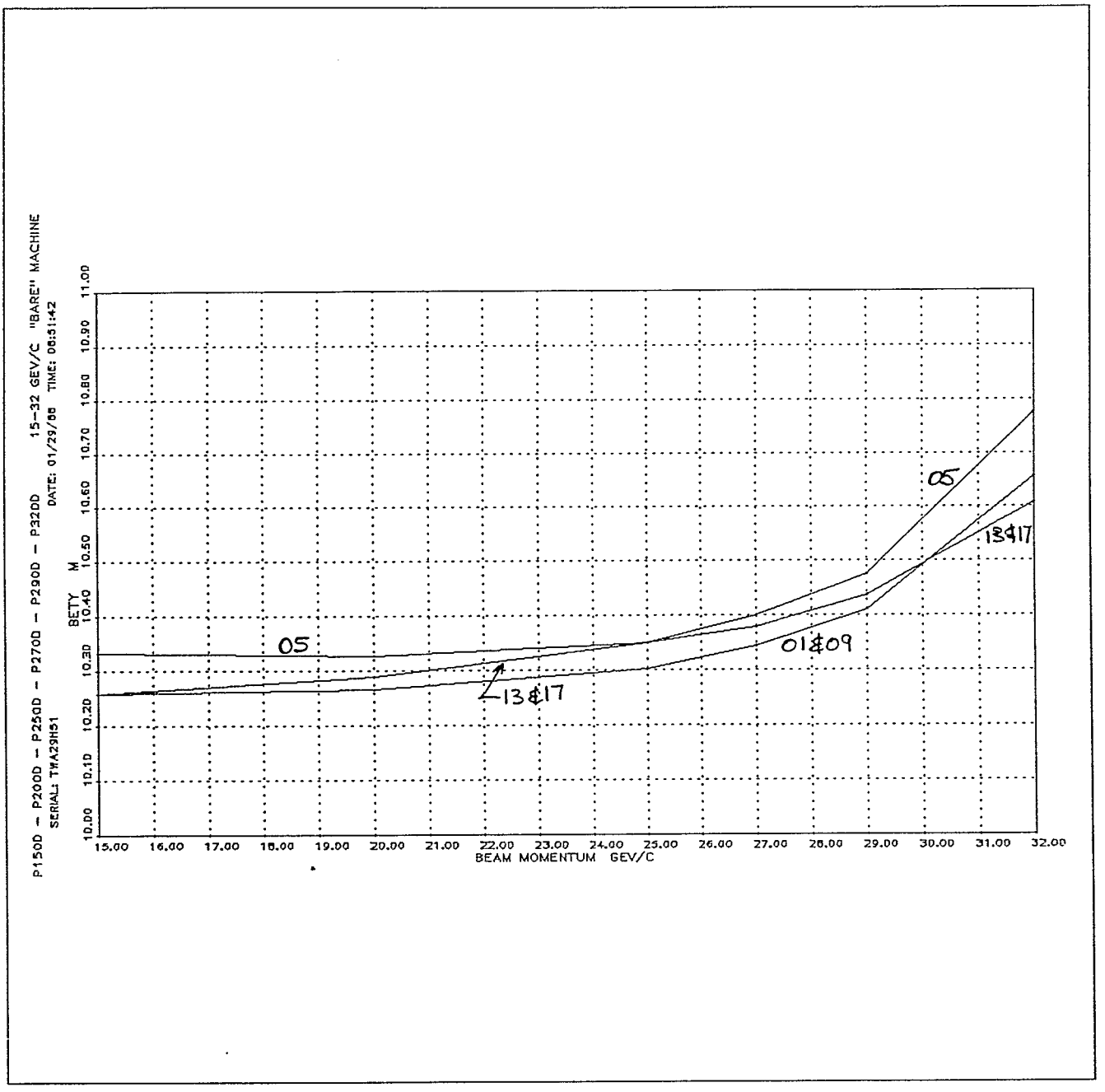

Figure 22. Energy Dependence of the Minima in Beta-y (in meters) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 2.) The several minima are labelled by the machine section in which they occur.

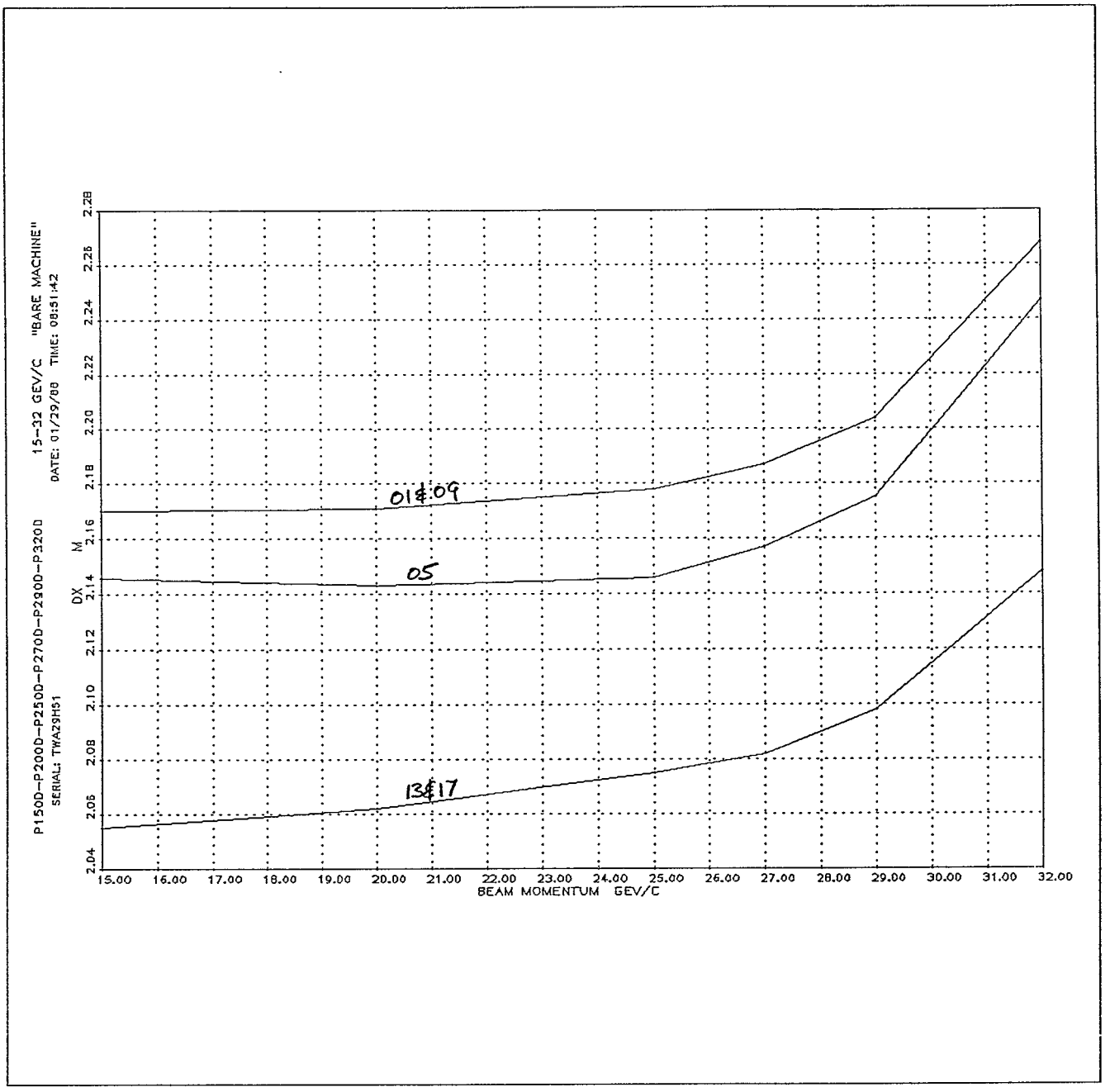

Figure 23. Energy Dependence of the Maxima in Dispersion (in meters) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 7.) The several maxima are labelled by the machine section in which they occur.

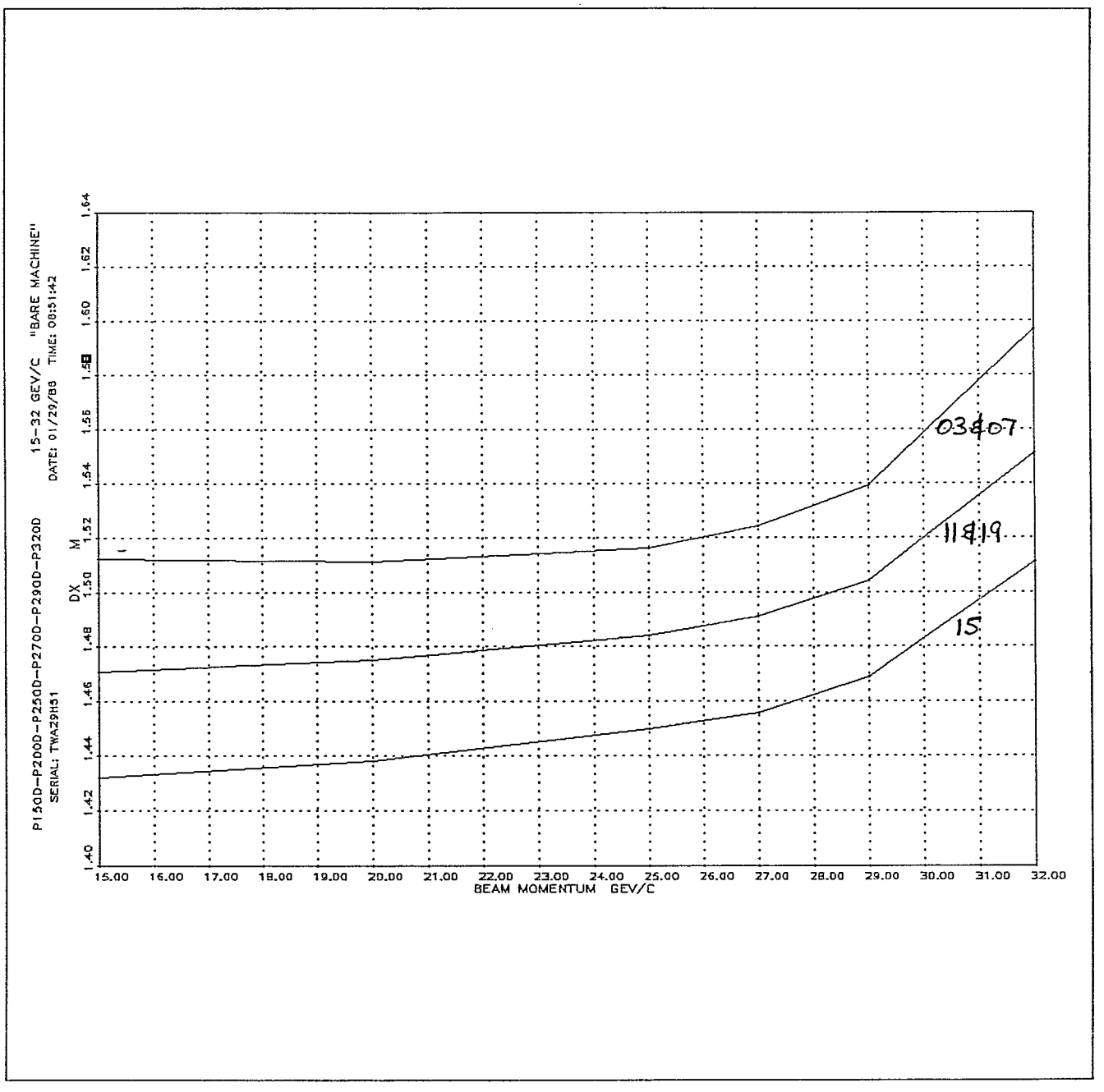

Figure 24. Energy Dependence of the Minima in Dispersion (in meters) for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 7.) The several minima are labelled by the machine section in which they occur.

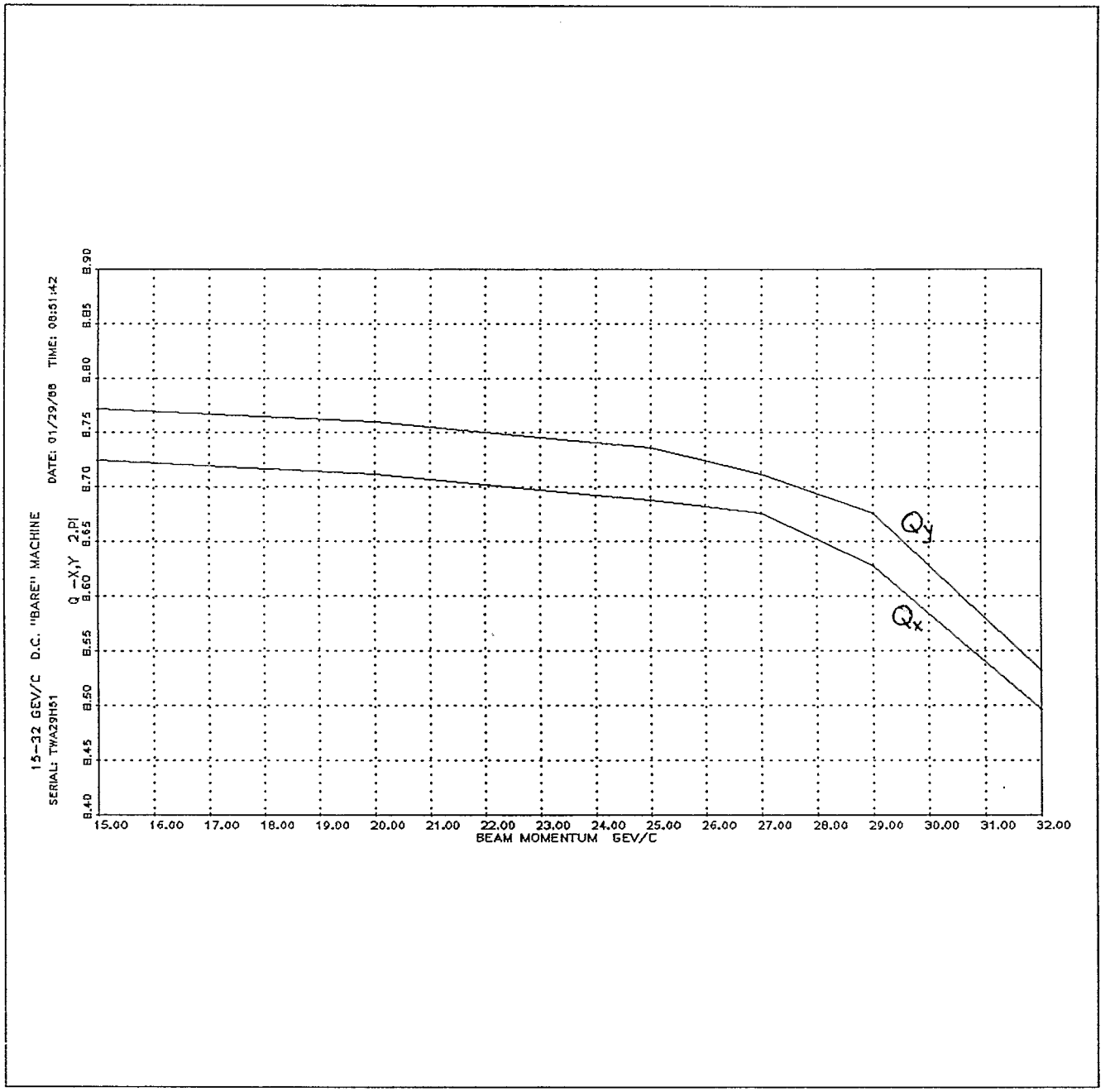

Figure 25. Energy Dependence of the Horizontal Tune, Q-x, and Vertical Tune, Q-y, for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c. (Corresponds to Figure 5.) These tunes are exactly 12 times the respective values of Mu at the end of one superperiod.

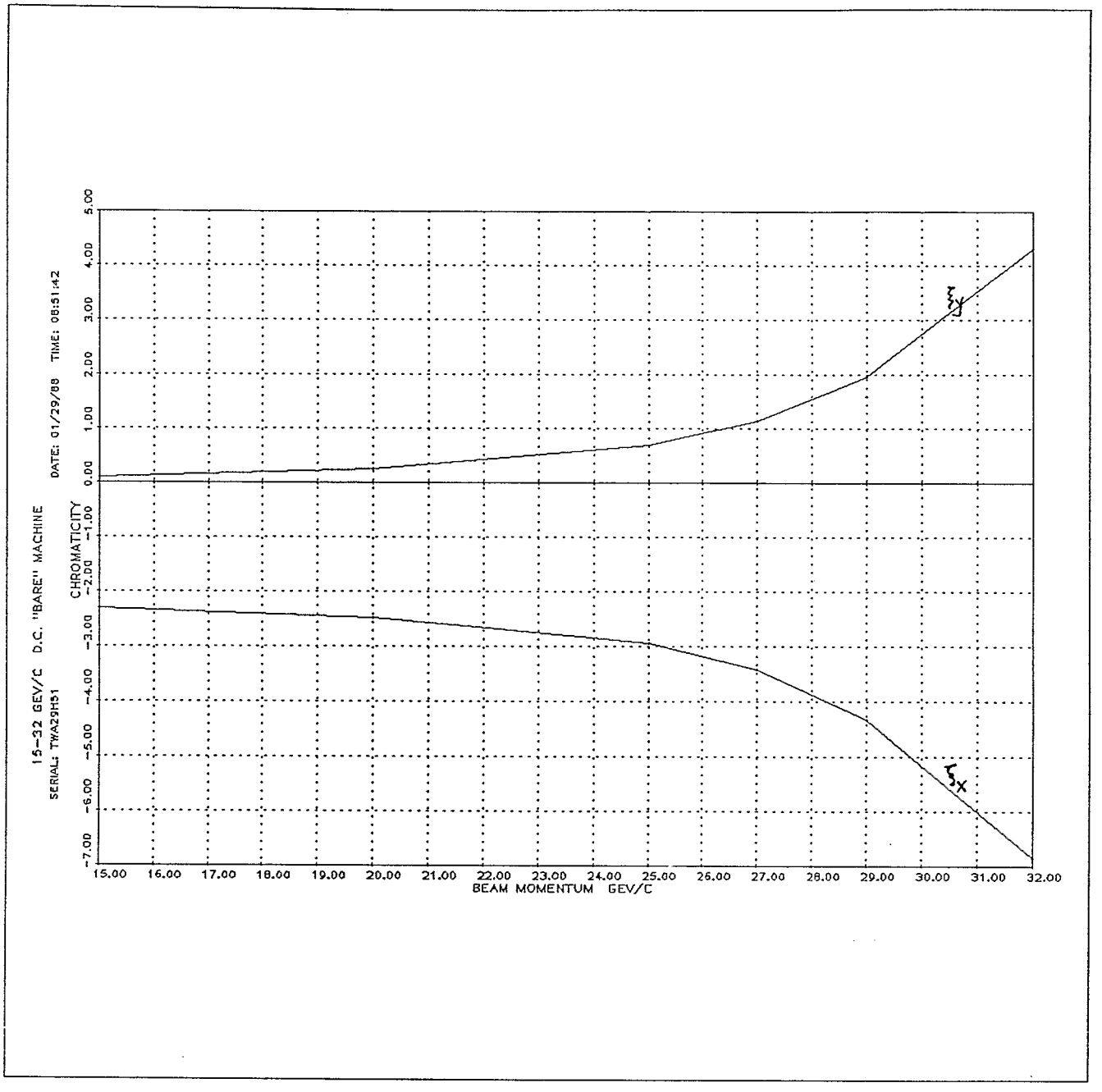

Figure 26. Energy Dependence of the Horizontal and Vertical Chromaticity for the D. C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c.
Chromaticity, Xi = Q'/Q, where Q' = p dQ/dp.
Note that the average of the Horizontal and Vertical Tunes is approximately -1.0, the "natural" tune of the machine.

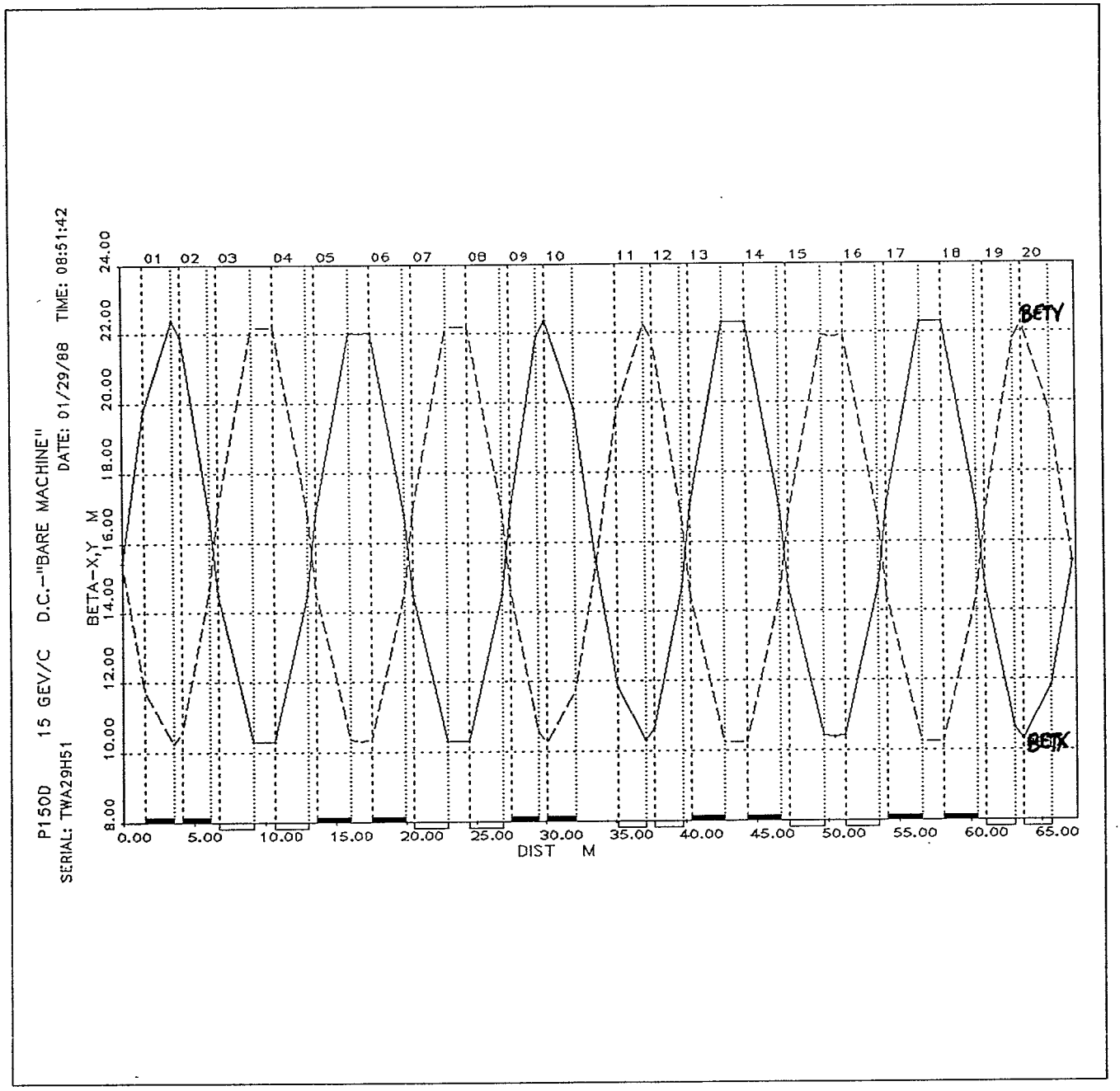

Figure 27. Courant-Snyder Parameters Beta-x and Beta-y (in meters) for the D.C. "Bare" Machine (main magnets only) at 15 GeV/c, shown on the same plot.

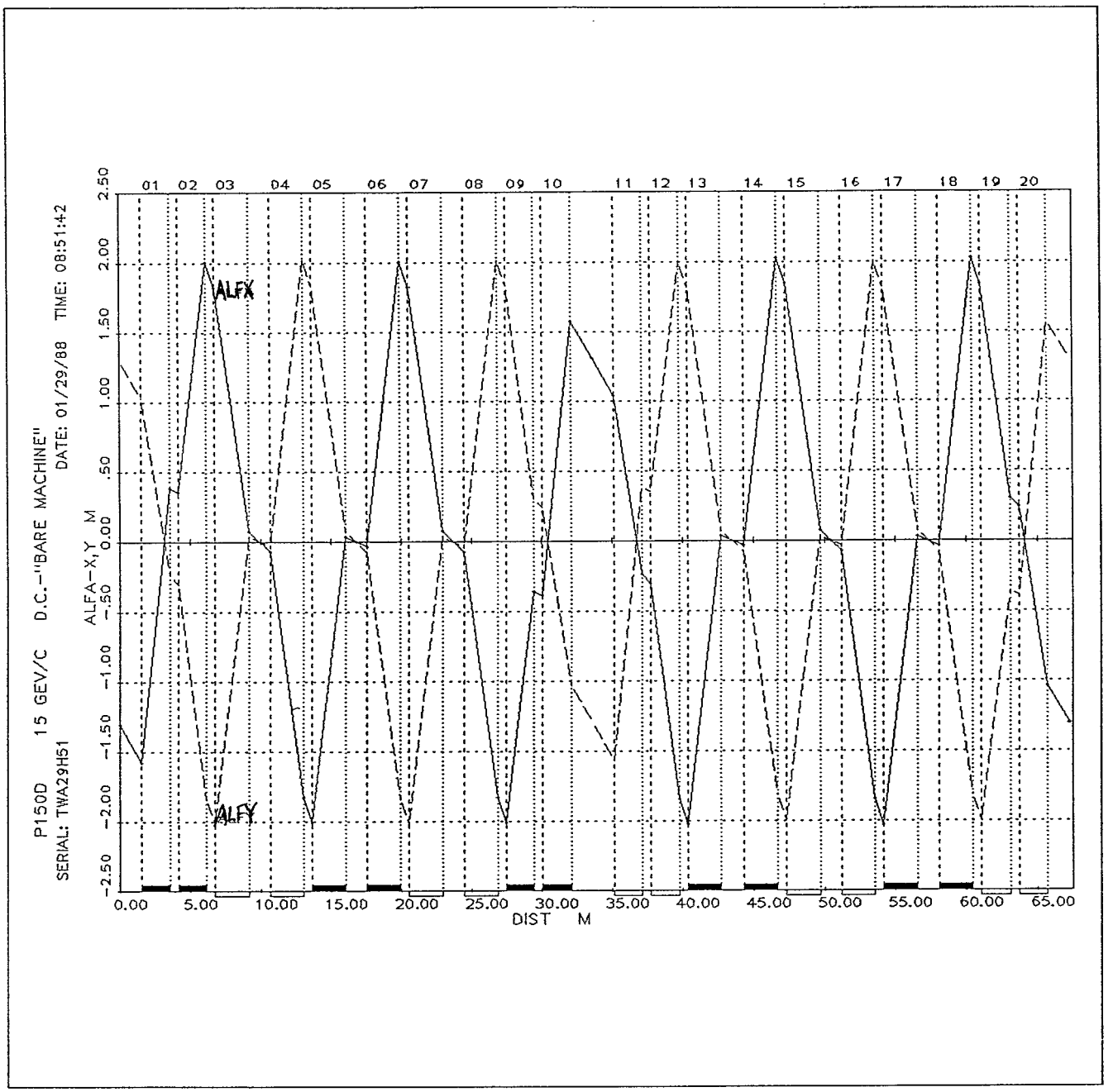

Figure 28. Courant-Snyder Parameters Alpha-x and Alpha-y (dimensionless) for the D.C. "Bare" Machine (main magnets only) at 15 GeV/c, shown on the same plot. Note that Alpha always has a negative slope in a straight section.

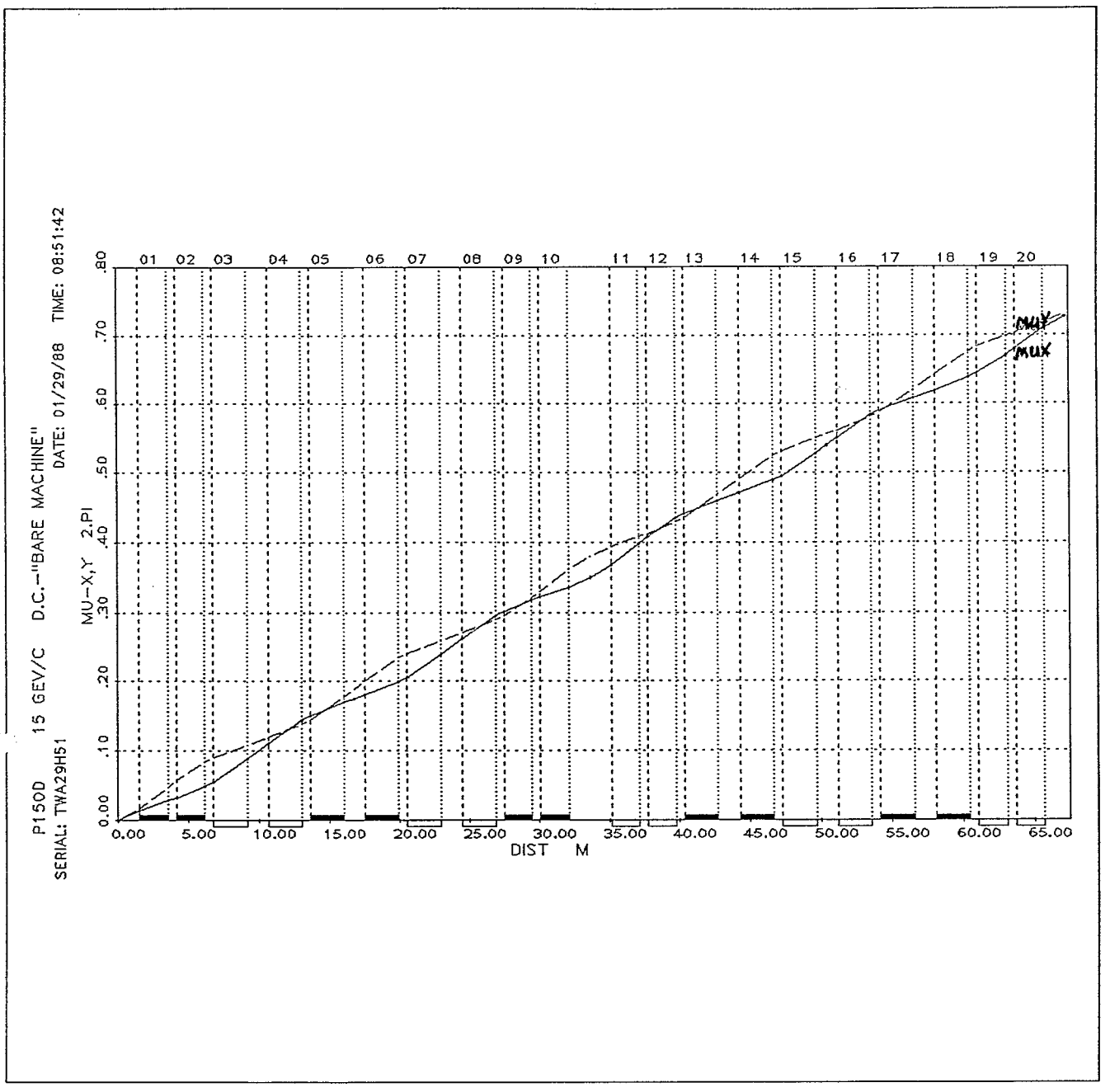

Figure 29. Phase Functions Mu-x and Mu-y (in units of 2*pi radians) for the D.C."Bare" Machine (main magnets only) at 15 GeV/c, shown on the same plot. Note that only phase advance is meaningful. A different choice of zero-point would result in an upward or downward displacement of Mu-x relative to Mu-y.

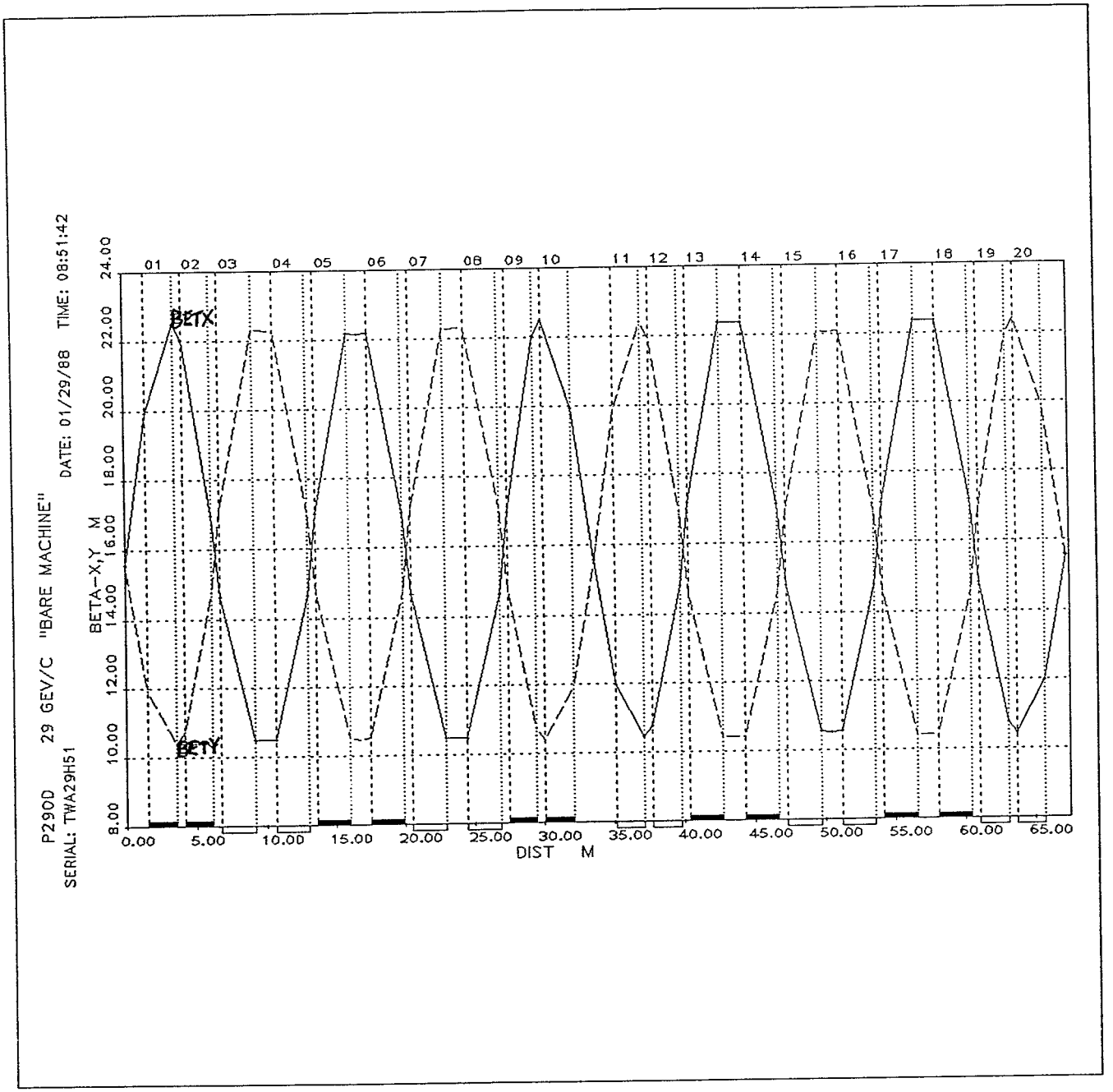

Figure 30. Courant-Snyder Parameters Beta-x and Beta-y (in meters) for the D.C. "Bare" Machine (main magnets only) at 29 GeV/c, shown on the same plot.

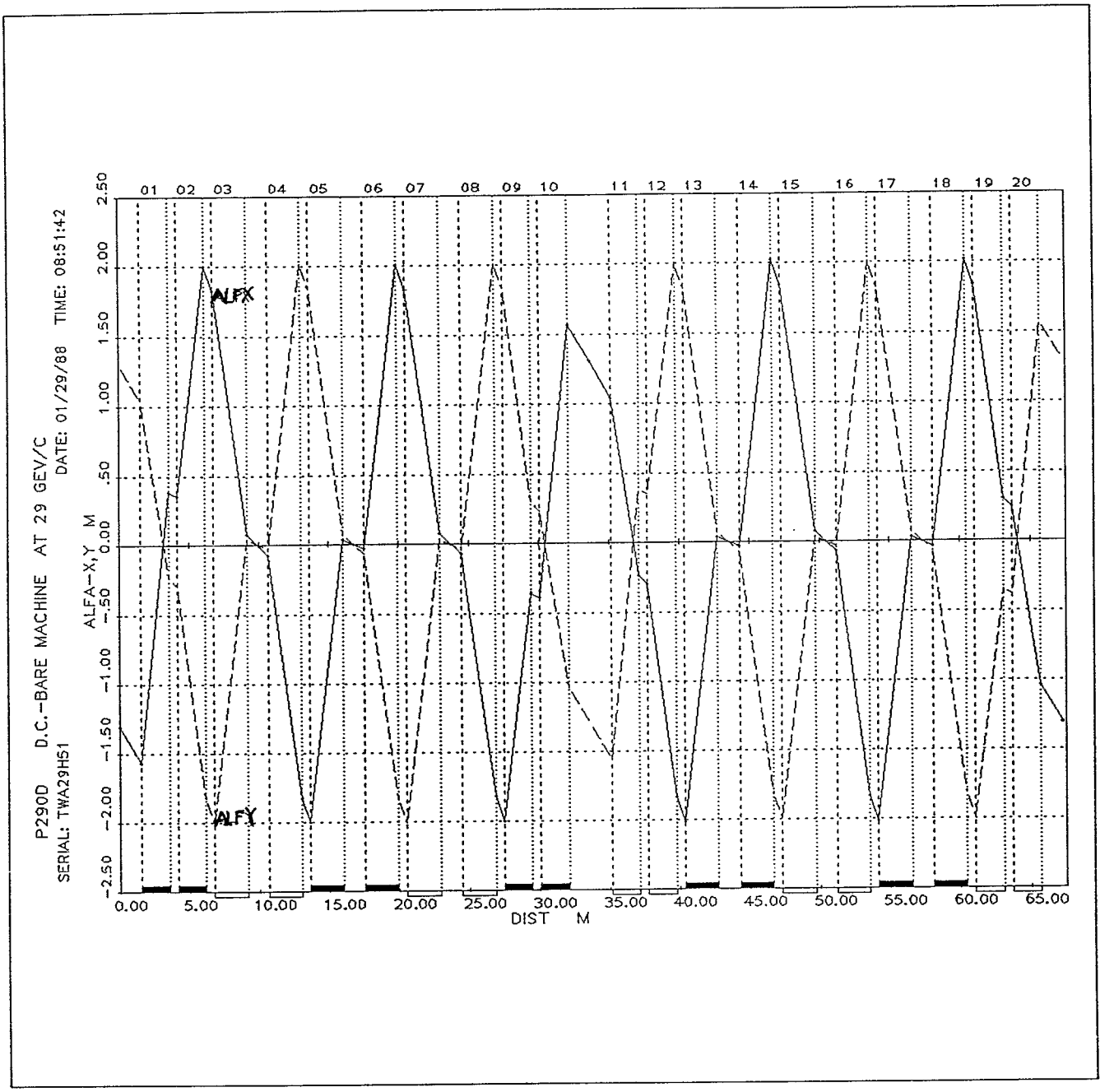

Figure 31. Courant-Snyder Parameters Alpha-x and Alpha-y (dimensionless) for the D.C. "Bare" Machine (main magnets only) at 29 GeV/c, shown on the same plot. Note that Alpha always has a negative slope in a straight section.

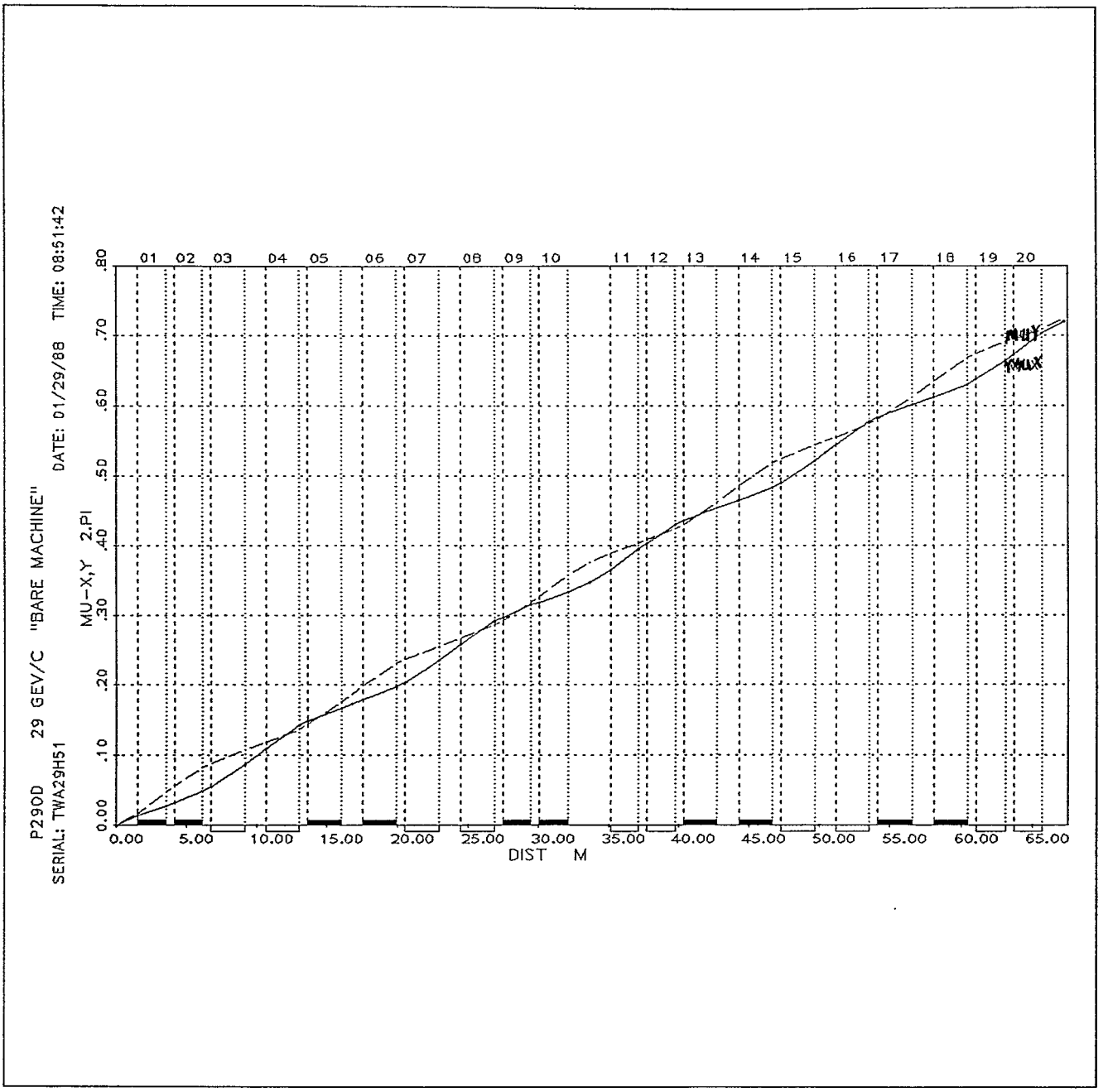

Figure 32. Phase Functions Mu-x and Mu-y (in units of 2*pi radians) for the D.C."Bare" Machine (main magnets only) at 29 GeV/c, shown on the same plot. Note that only phase advance is meaningful. A different choice of zero-point would result in an upward or downward displacement of Mu-x relative to Mu-y.

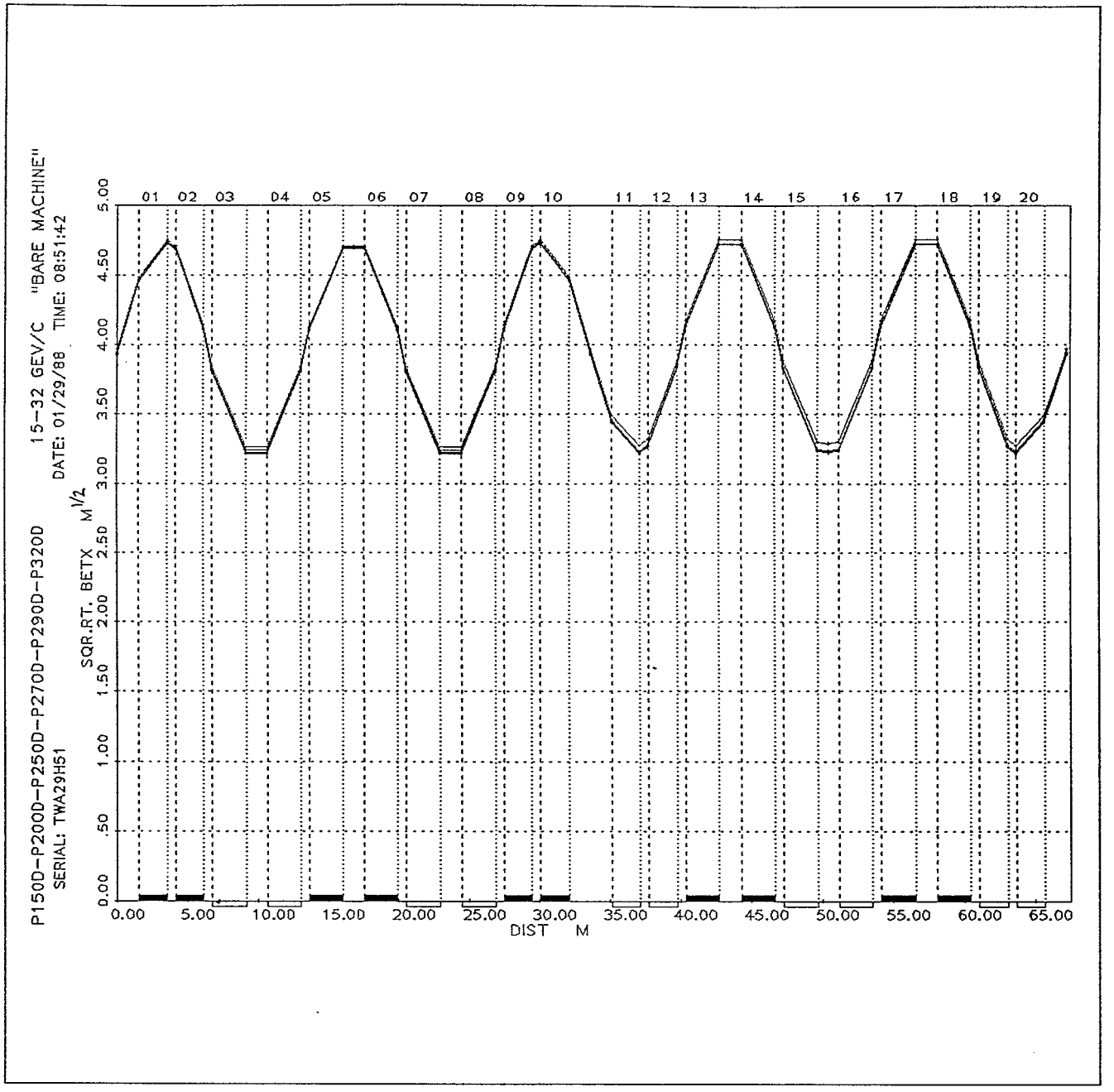

Figure 33. Courant-Snyder Parameter Beta-x shown on a square root scale for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod. (Corresponds to Figure 1 which has a linear scale.)

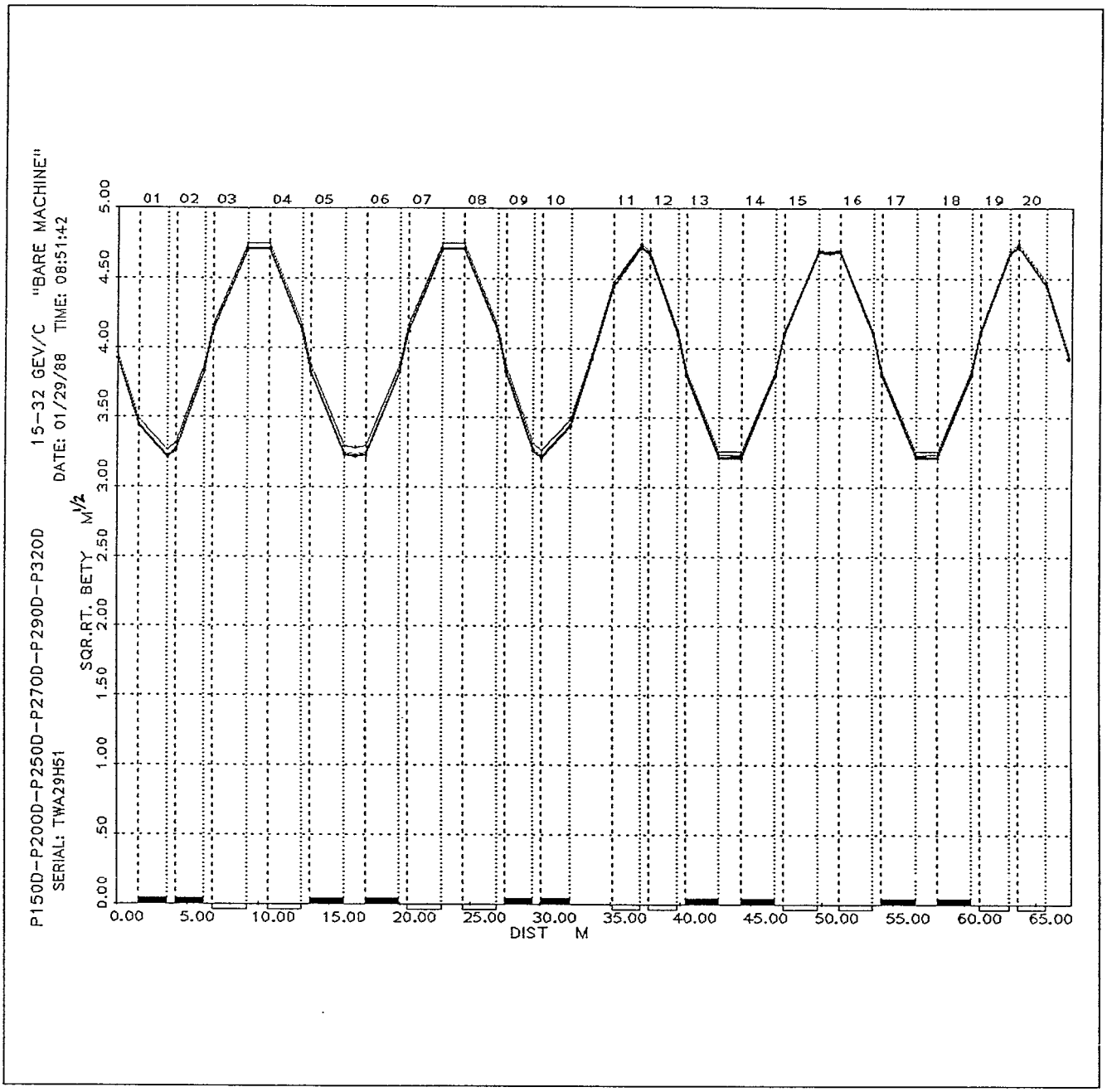

Figure 34. Courant-Snyder Parameter Beta-y shown on a square root scale for the D.C. "Bare" Machine (main magnets only) at high fields: 15-32 GeV/c, given for one superperiod. (Corresponds to Figure 2 which has a linear scale.)

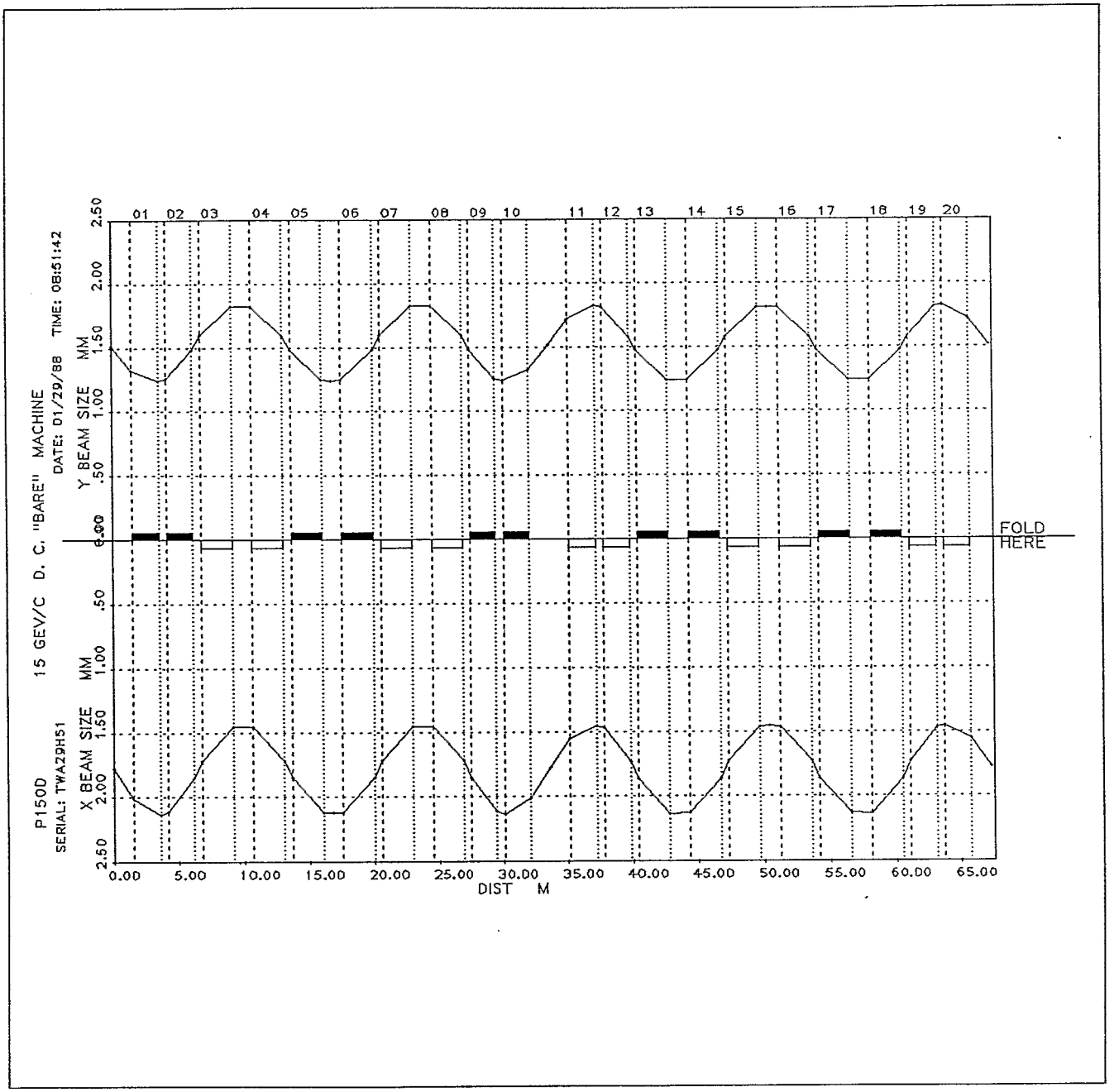

Figure 35. Beam Sizes (in mm) of the D. C. "Bare" Machine at 15 GeV/c, given for one superperiod. The y-direction (with scale increasing upward) appears in the upper half of the panel, while the x-direction (with scale increasing downward) is shown in the lower half of the panel.

[On folding the paper horizontally along the zero-line of the vertical axis, holding the two parts at right angles gives an approximate three-dimensional view of the transverse beam sizes.]