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Preliminary Design Parameters of 6 GeV Storage Ring Lattice for Synchrotron Light Source

Introduction

In this note, we describe a design of lattice, which is by no means optimized for the ultimate performance, but these parameters can be used for the starting point of other design efforts. Assumptions and features used in this design are:

1. 32 periods which is reasonably high periodicity for chromaticity corrections.

2. Achromatic bending cell which enables us to make all straight sections to be dispersion free.

3. Twiss parameters at dispersion area are the same for all cells to make undulator straight section can be tuned to wiggler straight section and vice versa.

4. No attempt is made to extract the photon beam from bending magnets, and when this feature is added, the lattice design may have to be changed in order to provide the photon beam channel.

5. Natural emittance in the horizontal plane is made as small as possible in the range of 10^{-8}m radians. This value can be optimized later by judicious choice of the Twiss parameters through the bending magnets.

6. The bending magnet should have parallel edges in order to simplify its construction. This assumption implies that there is vertical focussing from the edge.

7. The beta functions at the straight section should be tunable so that various configurations of the insertion devices should be accommodated.

Lattice

Amongst several of the series of lattice structure studied, we describe one series, which is representive of all others. In order to show the capability of adjusting the beta functions at the straight section, we describe, at first, all wiggler lattice, which requires smaller beta functions for both planes at the wiggler.

Figure 1 shows the Twiss functions of one period of this lattice which is 24 m long. Table 1 describes lengths and strengths (MKS unit) of the lattice elements. Table 2 shows the Twiss parameters along the lattice. The values are calculated at mid-point and at the end point of each element. The eta function shown in Fig. 1 has a magnification factor of ten and displaced by

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ten in order to show the details. In Fig. 1, the insertion straight section is shown in the middle of the figure, and in order to describe sextupoles for chromaticity corrections, the same lattice in a different element sequence is in Fig. 2.

Computer code, PATRICIA, is used to investigate the chromaticity corrections and dynamic aperture study. Natural chromaticity, defined to be $\xi = d\nu/^{dp}/p$, of this lattice is -122.3 in the horizontal plane, and is -41.4 in the vertical plane assuming linear lattice with no sextupole contributions from any element. With the arrangement of two family sextupoles (one SF and two SD's per period) shown in Fig. 2, the chromaticity can be adjusted to zero. Integrated strength of sextupoles are SD = $-6.12/m^2$ and SF = $2.9/m^2$. Figure 3 shows the non-integral part of the tune variations as a function of $\Delta p/p$. Figure 4 shows the variations of the beta functions with respect to $\Delta p/p$. Table 3 shows other pertinent parameters of this lattice.

Tunability of the beta functions at the insertion straight section is demonstrated in Fig. 5. What is done in this figure is that while keeping the Twiss parameters of the end point of the lattice shown in Fig. 1 (wiggler lattice) constant, the strengths of QD3, QF2 and QD1 are changed to make a high beta insertion straight section which is required for undulators. In doing so, the QD1 is turned off in order to make the straight-section length long. To distinguish this undulator period from the wiggler period, the new setting of QD3 and QF2 are renamed to be QD6 and QF7 as shown in Fig. 6. Table 4 shows length and strength of this lattice elements in the MKS units. The Twiss parameters along the lattice is shown in Table 5.

Natural chromaticities of this lattice are: $\xi x = -66.7$ and $\xi y = -22.2$ under the similar assumption as described previously. Using integrated sextupole strengths of SD = $-3.95/m^2$ and SF = $1.63/m^2$, these chromaticities can be made zero with sextupole arrangements similar to that described previously. The tune variations and the beta function variations at the center of insertion straight section are shown in Figs. 7 and 8. Table 3 shows other pertinent parameters of this lattice.

Remarks

1. It should be noted here that the trade off between the length and the strength of quadrupoles has not been performed, therefore the straight-section lengths of 3 m for the wiggler and 5.9 m for the undulator can be made longer by 10 cm or so by readjusting these parameters.

2. As noted earlier, the Twiss parameters at the mid-point of the wiggler period are the same as those of the undulator period, two periods can be combined to make a sixteen-period machine consisting of one wiggler cell and one undulator cell in each period. However, there should be a word of caution which is to be careful about resultant tune of the machine which may turn out to be at an undesirable working point. If this happens, then we must readjust the insertion quadrapoles, i.e. QD1, QF2, QD3 for the wiggler cell, and QD6, QF7 for the undulator cell, while the Twiss parameters at the midpoints of each cell are

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kept the same. At present, the method used for this tuning is somewhat tedious, but we must devise an easier method. This technique must involve finding of the working point as well as dynamic aperture search.

3. As stated earlier, the lattice parameter described here is one series of many. An example of variation of lattice is shown in Fig. 6. Without changing magnet locations, many variations of the lattice setting can be made.

4. Photon beam path originating in the insertion device has been studied with this lattice, and there appears to be no difficulties in extracting ±8 mr beam from the insertion point. However transporting the bending magnet photon beam may face some difficulties due the placement of the sextupoles. To alleviate this, we may have to change the placements of elements or to devise very narrow sextupoles in order to accommodate ±8 mr beam.

5. This note may serve as the starting point of tooling up the design study, however, we must be prepared to change the layout as we progress toward the final layout.

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MATCHED FUNCTIONS FOR 32 PERIOD(S)

TOTAL LENGTH= 768.00 METERS, TOTAL BEND= 360.0000 DEGREES

BETAX= 20.841 METERS ALPHAX= 0.000 NUX= 32+9.2694 = 41.2694

BETAY= 2.530 METERS ALPHAY= 0.000 NUY= 19.2515

ETAX = 0.465 METERS ETA'X = 0.000 TRGAMMA= 50.3331

BEAM RIGIDITY=20.0139 X,Y EMITT=.01100 ,.00110 PI CM-MR,DPP=.00100

ELEMENTS: 20 ELEMENT DEFINITIONS

NAM	TYPE	VAR	LEN,ANG	B,B'	N,GAP
L1	DRFT	0.0	1.5000	0.0000	0.000
L2	DRFT	0.0	.50000	0.0000	0.000
L3	DRFT	0.0	.30000	0.0000	0.000
L4	DRFT	0.0	2.9000	0.0000	0.000
L5	DRFT	0.0	.20000	0.0000	0.000
L6	DRFT	0.0	.10000	0.0000	0.000
L7	DRFT	0.0	.65000	0.0000	0.000
L8	DRFT	0.0	2.4000	0.0000	0.000
SD	DRFT	0.0	.40000	0.0000	0.000
M	BEND	0.0	2.9500	.66605	0.000
QD1	QUAD	1.2	.70000	-4.292	0.000
QF2	QUAD	2.2	1.0000	18.385	0.000
QD3	QUAD	0.0	.70000	-17.64	0.000
QD4	QUAD	0.0	.70000	-7.499	0.000
QF5	QUAD	0.0	.70000	10.863	0.000
QD6	QUAD	1.2	.70000	-11.90	0.000
QF7	QUAD	2.2	1.0000	8.8800	0.000
LX	DRFT	0.0	.75000	0.0000	0.000
E	EDGE	0.0	2.8125	.66605	0.000
LM	DRFT	0.0	.85000	0.0000	0.000

LATTICE: 18 ELEMENTS: LX QF5 L2 QD4 LM E M E L7 QD3 L3 QF2 L6 SD L5 QD1 L1 RFL

PERIODS 32 | FIT: NU X =9.270,NU Y =19.23,

COMMANDS: BEAM, ELEMENTS, LATTICE, PERIODS, FIT, TRANSPOR, INSERT, MATRIX, GO, CYCLE, GRAPH, ITERATE, HELP, SAVE, RECALL, QUIT, NEW CASE, PRINT

TABLE I

ELEM	LTH (M)	SUM L (M)	BETAX (M)	ALPHAX	ETAX (M)	ETA'X (RAD)	PSIX (DEG)	X (CM)	BETAY (M)	ALPHAY	PSIY (DEG)	Y (CM)
	0.00	0.00	20.84	0.00	0.47	0.00	0.0	.198	2.53	0.00	0.0	.017
LX	0.38	0.38	20.85	-0.02	0.47	0.00	1.0	.198	2.59	-0.15	8.4	.017
LX	0.38	0.75	20.87	-0.04	0.47	0.00	2.1	.198	2.75	-0.30	16.5	.017
QF5	0.35	1.10	19.54	3.74	0.45	-0.09	3.0	.192	3.21	-1.03	23.4	.019
QF5	0.35	1.45	15.86	6.55	0.40	-0.17	4.2	.173	4.26	-2.04	28.9	.022
L2	0.25	1.70	12.75	5.86	0.36	-0.17	5.2	.155	5.35	-2.34	31.9	.024
L2	0.25	1.95	10.00	5.17	0.32	-0.17	6.4	.137	6.60	-2.64	34.3	.027
QD4	0.35	2.30	7.08	3.30	0.27	-0.13	8.8	.115	8.24	-1.98	37.0	.030
QD4	0.35	2.65	5.24	2.04	0.23	-0.10	12.2	.099	9.28	-0.95	39.2	.032
LM	0.43	3.08	3.68	1.62	0.19	-0.10	17.7	.082	10.13	-1.04	41.8	.033
LM	0.43	3.50	2.48	1.20	0.14	-0.10	25.8	.067	11.05	-1.13	44.1	.035
E	0.00	3.50	2.48	1.20	0.14	-0.10	25.8	.067	11.05	-1.11	44.1	.035
M	1.48	4.98	1.08	-0.25	0.04	-0.05	90.0	.038	14.76	-1.41	50.7	.040
M	1.48	6.45	3.95	-1.69	0.00	0.00	135.6	.066	19.35	-1.70	55.7	.046
E	0.00	6.45	3.95	-1.70	0.00	0.00	135.6	.066	19.35	-1.67	55.7	.046
L7	0.33	6.78	5.15	-2.02	0.00	0.00	139.7	.075	20.46	-1.74	56.6	.047
L7	0.33	7.10	6.57	-2.34	0.00	0.00	142.9	.085	21.61	-1.80	57.5	.049
QD3	0.35	7.45	9.19	-5.41	0.00	0.00	145.6	.101	20.55	4.71	58.5	.048
QD3	0.35	7.80	14.71	-10.91	0.00	0.00	147.3	.127	15.48	9.26	59.6	.041
L3	0.15	7.95	18.16	-12.13	0.00	0.00	147.8	.141	12.83	8.42	60.2	.038
L3	0.15	8.10	21.98	-13.36	0.00	0.00	148.3	.156	10.43	7.58	60.9	.034
QF2	0.50	8.60	30.60	-2.54	0.00	0.00	149.3	.183	5.73	2.52	64.8	.025
QF2	0.50	9.10	26.32	10.44	0.00	-0.00	150.3	.170	4.57	-0.03	70.6	.022
L6	0.05	9.15	25.29	10.23	0.00	-0.00	150.4	.167	4.57	-0.04	71.2	.022
L6	0.05	9.20	24.27	10.02	0.00	-0.00	150.5	.163	4.58	-0.05	71.8	.022
SD	0.20	9.40	20.43	9.18	0.00	-0.00	151.0	.150	4.61	-0.09	74.3	.023
SD	0.20	9.60	16.93	8.35	0.00	-0.00	151.7	.136	4.65	-0.13	76.8	.023
L5	0.10	9.70	15.30	7.93	0.00	-0.00	152.0	.130	4.68	-0.16	78.0	.023
L5	0.10	9.80	13.75	7.51	0.00	-0.00	152.4	.123	4.71	-0.18	79.3	.023
QD1	0.35	10.15	9.28	5.37	0.00	-0.00	154.2	.101	4.74	0.10	83.5	.023
QD1	0.35	10.50	6.10	3.80	0.00	-0.00	156.9	.082	4.57	0.37	87.8	.022
L1	0.75	11.25	1.82	1.90	-.00	-0.00	169.9	.045	4.15	0.19	97.7	.021
L1	0.75	12.00	0.39	0.00	-.00	-0.00	232.1	.021	4.01	-0.00	108.3	.021
L1	0.75	12.75	1.82	-1.90	-.00	-0.00	294.4	.045	4.15	-0.19	118.9	.021
L1	0.75	13.50	6.10	-3.80	-.00	-0.00	307.4	.082	4.57	-0.37	128.8	.022
QD1	0.35	13.85	9.28	-5.37	-.00	-0.00	310.1	.101	4.74	-0.10	133.1	.023
QD1	0.35	14.20	13.75	-7.51	-.00	-0.00	311.8	.123	4.71	0.18	137.3	.023
L5	0.10	14.30	15.30	-7.93	-.00	-0.00	312.2	.130	4.68	0.16	138.5	.023
L5	0.10	14.40	16.93	-8.35	-.00	-0.00	312.6	.136	4.65	0.13	139.8	.023
SD	0.20	14.60	20.43	-9.18	-.00	-0.00	313.2	.150	4.61	0.09	142.2	.023
SD	0.20	14.80	24.27	-10.02	-.00	-0.00	313.7	.163	4.58	0.05	144.7	.022
L6	0.05	14.85	25.29	-10.23	-.00	-0.00	313.8	.167	4.57	0.04	145.4	.022
L6	0.05	14.90	26.32	-10.44	-.00	-0.00	314.0	.170	4.57	0.03	146.0	.022
QF2	0.50	15.40	30.60	2.54	-.00	0.00	314.9	.183	5.73	-2.52	151.8	.025
QF2	0.50	15.90	21.98	13.36	-.00	0.00	316.0	.156	10.43	-7.58	155.7	.034
L3	0.15	16.05	18.16	12.13	-.00	0.00	316.4	.141	12.83	-8.42	156.4	.038
L3	0.15	16.20	14.71	10.91	-.00	0.00	316.9	.127	15.48	-9.26	157.0	.041
QD3	0.35	16.55	9.19	5.41	-.00	0.00	318.7	.101	20.55	-4.71	158.1	.048
QD3	0.35	16.90	6.57	2.34	-.00	0.00	321.3	.085	21.61	1.80	159.1	.049
L7	0.33	17.23	5.15	2.02	-.00	0.00	324.5	.075	20.46	1.74	159.9	.047
L7	0.33	17.55	3.95	1.70	-.00	0.00	328.7	.066	19.35	1.67	160.9	.046
E	0.00	17.55	3.95	1.69	-.00	0.00	328.7	.066	19.35	1.70	160.9	.046
M	1.48	19.03	1.08	0.25	0.04	0.05	374.3	.038	14.76	1.41	165.9	.040
M	1.48	20.50	2.48	-1.20	0.14	0.10	438.5	.067	11.05	1.11	172.5	.035
E	0.00	20.50	2.48	-1.20	0.14	0.10	438.5	.067	11.05	1.13	172.5	.035
LM	0.43	20.93	3.68	-1.62	0.19	0.10	446.5	.082	10.13	1.04	174.8	.033
LM	0.43	21.35	5.24	-2.04	0.23	0.10	452.1	.099	9.28	0.95	177.3	.032
QD4	0.35	21.70	7.08	-3.30	0.27	0.13	455.4	.115	8.24	1.98	179.6	.030
QD4	0.35	22.05	10.00	-5.16	0.32	0.17	457.8	.137	6.60	2.64	182.3	.027
L2	0.25	22.30	12.75	-5.86	0.36	0.17	459.1	.155	5.35	2.34	184.7	.024
L2	0.25	22.55	15.85	-6.55	0.40	0.17	460.1	.173	4.26	2.04	187.7	.022
QF5	0.35	22.90	19.54	-3.74	0.45	0.09	461.2	.192	3.21	1.03	193.2	.019
QF5	0.35	23.25	20.87	0.04	0.47	-0.00	462.2	.198	2.75	0.30	200.1	.017
LX	0.38	23.63	20.85	0.02	0.47	-0.00	463.2	.198	2.59	0.15	208.1	.017
LX	0.38	24.00	20.84	-0.00	0.47	-0.00	464.3	.198	2.53	-0.00	216.6	.017
ELEM	LTH	SUM L	BETAX	ALPHAX	ETAX	ETA'X	PSIX	X	BETAY	ALPHAY	PSIY	Y

TABLE 2

TABLE 3

Momentum Compaction Factor	3.96×10^{-4}
Horizontal Natural Emittance (m)	$2.3 \times 10^{-4} \times E(GeV)^2$
Energy Spread (%)	$0.0156 \times E(GeV)$
Transition Gamma	50.233
Energy Loss per Turn	3.82 MeV
<Beta x> for all W	9.8 m
<Beta y> for all W	9.7 m
rf Voltage	4.4 MV
rf Phase (degree)	61
Synchrotron Frequency	2.1 KHz
Synchrotron Damping Time	4 msec
Betatron Damping Time	8 msec
Bunch Length (I = 0)	8.3 mm
<Beta x> for all U	14.9 m
<Beta y> for all U	10.8 m

MATCHED FUNCTIONS FOR 32 PERIOD(S)

TOTAL LENGTH= 768.00 METERS, TOTAL BEND= 360.0000 DEGREES

BETAX=	20.839 METERS	ALPHAX=	0.000	NUX=	27.7759
BETAY=	2.538 METERS	ALPHAY=	-0.000	NUY=	15.7374
ETAX =	0.465 METERS	ETA'X =	-0.000	TRGAMMA=	50.3319

BEAM RIGIDITY=20.0139 X,Y EMITT=.01100 ,.00110 PI CM-MR,DPP=.00100

ELEMENTS: 20 ELEMENT DEFINITIONS

NAM	TYPE	VAR	LEN,ANG	B,B'	N,GAP
L1	DRFT	0.0	1.5000	0.0000	0.000
L2	DRFT	0.0	.50000	0.0000	0.000
L3	DRFT	0.0	.30000	0.0000	0.000
L4	DRFT	0.0	2.9000	0.0000	0.000
L5	DRFT	0.0	.20000	0.0000	0.000
L6	DRFT	0.0	.10000	0.0000	0.000
L7	DRFT	0.0	.65000	0.0000	0.000
L8	DRFT	0.0	2.4000	0.0000	0.000
SD	DRFT	0.0	.40000	0.0000	0.000
M	BEND	0.0	2.9500	.66605	0.000
QD1	QUAD	0.0	.70000	-.0000	0.000
QF2	QUAD	2.2	1.0000	9.0204	0.000
QD3	QUAD	1.2	.70000	-12.62	0.000
QD4	QUAD	0.0	.70000	-7.499	0.000
QF5	QUAD	0.0	.70000	10.863	0.000
QD6	QUAD	1.2	.70000	-11.90	0.000
QF7	QUAD	2.2	1.0000	8.8800	0.000
LX	DRFT	0.0	.75000	9.0000	0.000
E	EDGE	0.0	2.8125	.66605	0.000
LM	DRFT	0.0	.85000	0.0000	0.000

LATTICE: 18 ELEMENTS: LX QF5 L2 QD4 LM E M E L7 QD3 L3 QF2 L6 SD L5 QD1 L1 RFL

PERIODS 32 | FIT: TALFAX =0.000,TALFAY =0.000,

COMMANDS: BEAM, ELEMENTS, LATTICE, PERIODS, FIT, TRANSPOR, INSERT, MATRIX, GO, CYCLE, GRAPH, ITERATE, HELP, SAVE, RECALL, QUIT, NEW CASE, PRINT

TABLE 4

ELEM	LTH (M)	SUM L (M)	BETAX (M)	ALPHAX	ETAX (M)	ETA'X (RAD)	PSIX (DEG)	X (CM)	BETAY (M)	ALPHAY	PSIY (DEG)	Y (CM)
	0.00	0.00	20.84	0.00	0.47	-0.00	0.0	.198	2.54	-0.00	0.0	.017
LX	0.38	0.38	20.85	-0.02	0.47	-0.00	1.0	.198	2.59	-0.15	8.4	.017
LX	0.38	0.75	20.87	-0.04	0.47	-0.00	2.1	.198	2.76	-0.30	16.5	.017
QF5	0.35	1.10	19.54	3.74	0.45	-0.09	3.0	.192	3.21	-1.03	23.3	.019
QF5	0.35	1.45	15.86	6.55	0.40	-0.17	4.2	.173	4.26	-2.04	28.8	.022
L2	0.25	1.70	12.75	5.86	0.36	-0.17	5.2	.155	5.36	-2.34	31.8	.024
L2	0.25	1.95	10.00	5.17	0.32	-0.17	6.4	.137	6.60	-2.64	34.2	.027
QD4	0.35	2.30	7.08	3.30	0.27	-0.13	8.8	.115	8.25	-1.98	36.9	.030
QD4	0.35	2.65	5.24	2.04	0.23	-0.10	12.2	.099	9.29	-0.95	39.2	.032
LM	0.43	3.08	3.68	1.62	0.19	-0.10	17.7	.082	10.13	-1.04	41.7	.033
LM	0.43	3.50	2.48	1.20	0.14	-0.10	25.8	.067	11.05	-1.13	44.0	.035
E	0.00	3.50	2.48	1.20	0.14	-0.10	25.8	.067	11.05	-1.11	44.0	.035
M	1.48	4.98	1.08	-0.25	0.04	-0.05	90.0	.038	14.76	-1.40	50.6	.040
M	1.48	6.45	3.95	-1.69	0.00	0.00	135.6	.066	19.33	-1.70	55.6	.046
E	0.00	6.45	3.95	-1.70	0.00	0.00	135.6	.066	19.33	-1.67	55.6	.046
L7	0.33	6.78	5.15	-2.02	0.00	0.00	139.7	.075	20.44	-1.73	56.6	.047
L7	0.33	7.10	6.57	-2.34	0.00	0.00	142.9	.085	21.59	-1.80	57.4	.049
QD6	0.35	7.45	8.94	-4.60	0.00	0.00	145.6	.099	21.18	2.93	58.4	.048
QD6	0.35	7.80	13.35	-8.32	0.00	0.00	147.4	.121	17.69	6.78	59.4	.044
L3	0.15	7.95	15.97	-9.11	0.00	0.00	148.0	.133	15.71	6.38	59.9	.042
L3	0.15	8.10	18.82	-9.90	0.00	0.00	148.5	.144	13.86	5.98	60.5	.039
QF7	0.50	8.60	27.22	-6.26	0.00	0.00	149.8	.173	9.73	2.59	63.0	.033
QF7	0.50	9.10	30.42	0.10	0.00	0.00	150.7	.183	8.28	0.41	66.3	.030
L4	1.45	10.55	30.21	0.05	0.00	0.00	153.5	.182	7.39	0.20	76.9	.029
L4	1.45	12.00	30.14	0.00	0.00	0.00	156.2	.182	7.09	0.00	88.5	.028
L4	1.45	13.45	30.21	-0.05	0.00	0.00	159.0	.182	7.39	-0.20	100.1	.029
L4	1.45	14.90	30.42	-0.10	0.00	0.00	161.7	.183	8.28	-0.41	110.7	.030
QF7	0.50	15.40	27.22	6.26	0.00	-0.00	162.7	.173	9.72	-2.59	114.0	.033
QF7	0.50	15.90	18.82	9.90	0.00	-0.00	164.0	.144	13.85	-5.98	116.5	.039
L3	0.15	16.05	15.97	9.11	0.00	-0.00	164.4	.133	15.70	-6.38	117.1	.042
L3	0.15	16.20	13.35	8.32	0.00	-0.00	165.0	.121	17.68	-6.77	117.6	.044
QD6	0.35	16.55	8.94	4.60	0.00	-0.00	166.9	.099	21.16	-2.93	118.6	.048
QD6	0.35	16.90	6.57	2.34	0.00	-0.00	169.5	.085	21.57	1.80	119.6	.049
L7	0.33	17.23	5.15	2.02	0.00	-0.00	172.7	.075	20.43	1.73	120.4	.047
L7	0.33	17.55	3.95	1.70	0.00	-0.00	176.9	.066	19.32	1.67	121.4	.046
E	0.00	17.55	3.95	1.69	0.00	-0.00	176.9	.066	19.32	1.70	121.4	.046
M	1.48	19.03	1.08	0.25	0.04	0.05	222.5	.038	14.74	1.40	126.4	.040
M	1.48	20.50	2.48	-1.20	0.14	0.10	286.7	.067	11.04	1.11	133.0	.035
E	0.00	20.50	2.48	-1.20	0.14	0.10	286.7	.067	11.04	1.12	133.0	.035
LM	0.43	20.93	3.69	-1.62	0.19	0.10	294.8	.082	10.12	1.04	135.3	.033
LM	0.43	21.35	5.24	-2.04	0.23	0.10	300.3	.099	9.28	0.95	137.8	.032
QD4	0.35	21.70	7.08	-3.30	0.27	0.13	303.6	.115	8.24	1.97	140.1	.030
QD4	0.35	22.05	10.00	-5.17	0.32	0.17	306.0	.137	6.60	2.64	142.8	.027
L2	0.25	22.30	12.76	-5.86	0.36	0.17	307.3	.155	5.35	2.34	145.2	.024
L2	0.25	22.55	15.86	-6.55	0.40	0.17	308.3	.173	4.26	2.04	148.2	.022
QF5	0.35	22.90	19.54	-3.74	0.45	0.09	309.4	.192	3.21	1.03	153.7	.019
QF5	0.35	23.25	20.87	0.04	0.47	-0.00	310.4	.198	2.76	0.30	160.6	.017
LX	0.38	23.63	20.85	0.02	0.47	-0.00	311.4	.198	2.59	0.15	168.6	.017
LX	0.38	24.00	20.84	-0.00	0.47	-0.00	312.5	.198	2.54	-0.00	177.0	.017

ELEM	LTH (M)	SUM L (M)	BETAX (M)	ALPHAX	ETAX (M)	ETA'X (RAD)	PSIX (DEG)	X (CM)	BETAY (M)	ALPHAY	PSIY (DEG)	Y (CM)

AVERAGE Bx AND By 14.87078 10.83353

TABLE 5

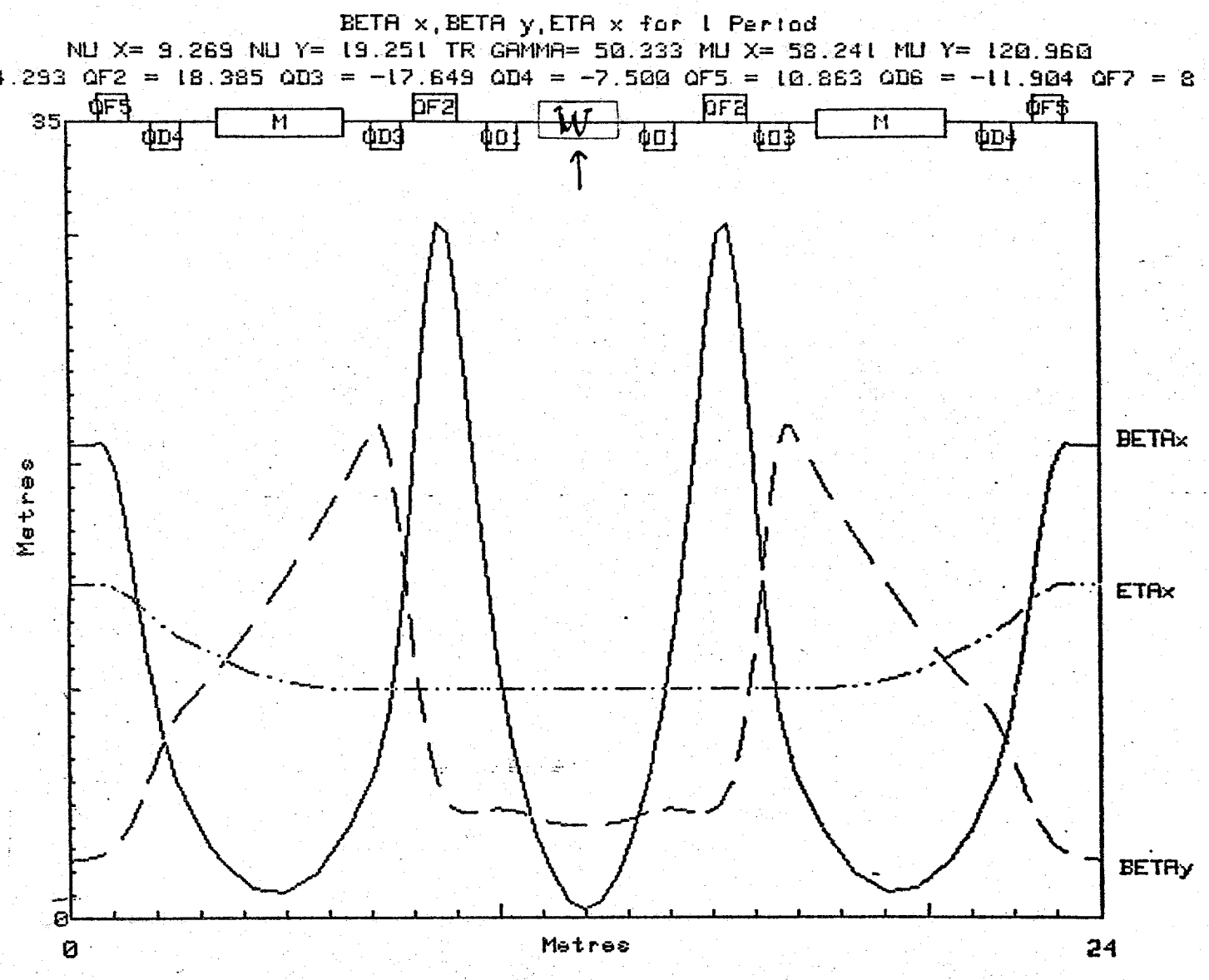

BETA x,BETA y,ETA x for 1 Period
NU X= 9.269 NU Y= 19.251 TR GAMMA= 50.333 MU X= 58.241 MU Y= 120.960
4.293 QF2 = 18.385 QD3 = -17.649 QD4 = -7.500 QF5 = 10.863 QD6 = -11.904 QF7 = 8
QF5
QD4
M
QD3
QF2
QD1
W
QD1
QF2
QD3
M
QD4
QF5
35
0
Metres
BETAx
ETAx
BETAy
0
Metres
24

Figure 1

ETA STARTING SCALE FACTORS MULT AND ADD 10.00000 10.00000

MATCHED FUNCTIONS FOR 32 PERIOD(S)

TOTAL LENGTH= 768.00 METERS, TOTAL BEND= 360.0000 DEGREES

BETAX=	0.394 METERS	ALPHAX=	0.000	NUX=	9.2694
BETAY=	4.011 METERS	ALPHAY=	0.000	NUY=	19.2514
ETAX =	-0.000 METERS	ETA'X =	-0.000	TRGAMMA=	50.3334

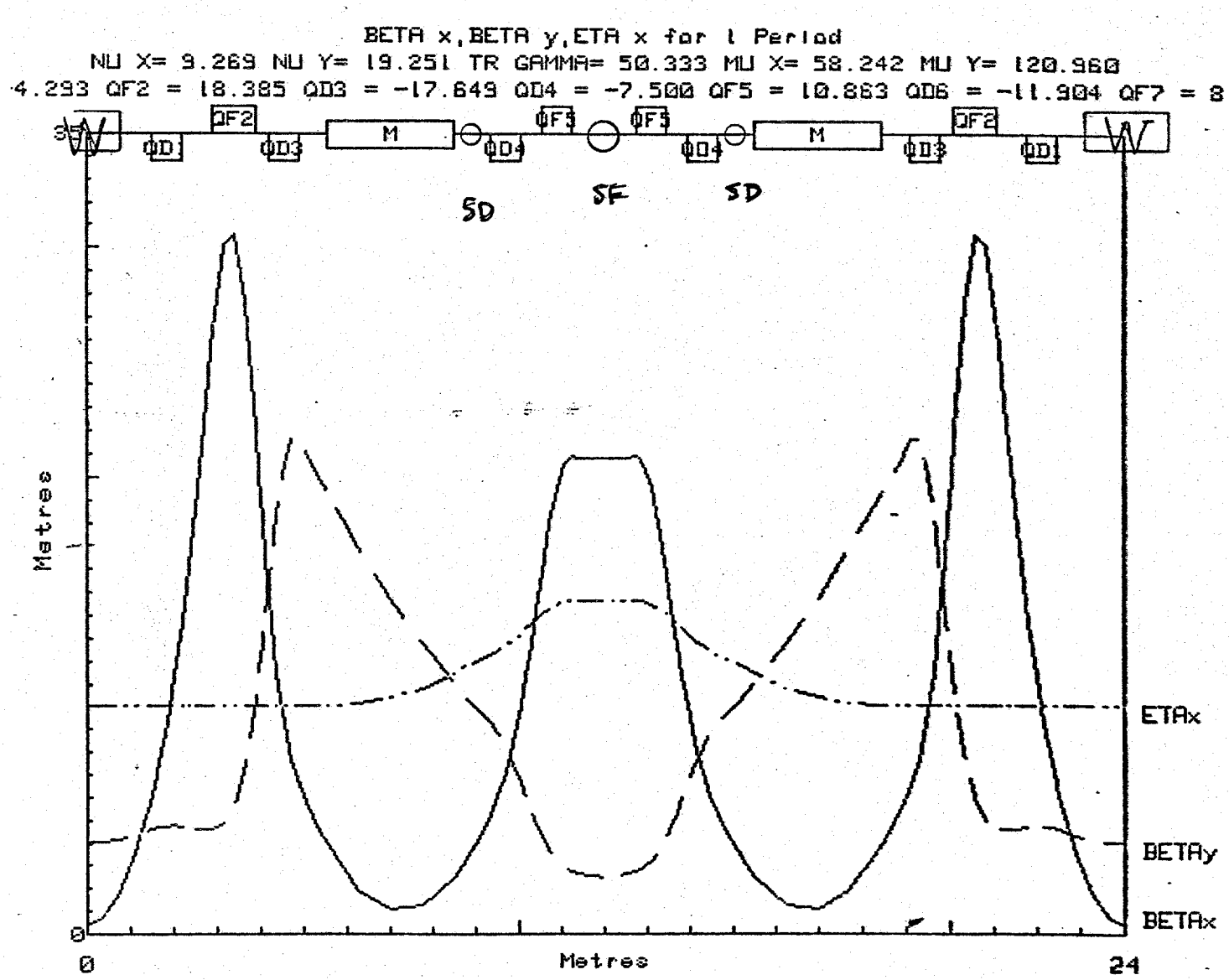
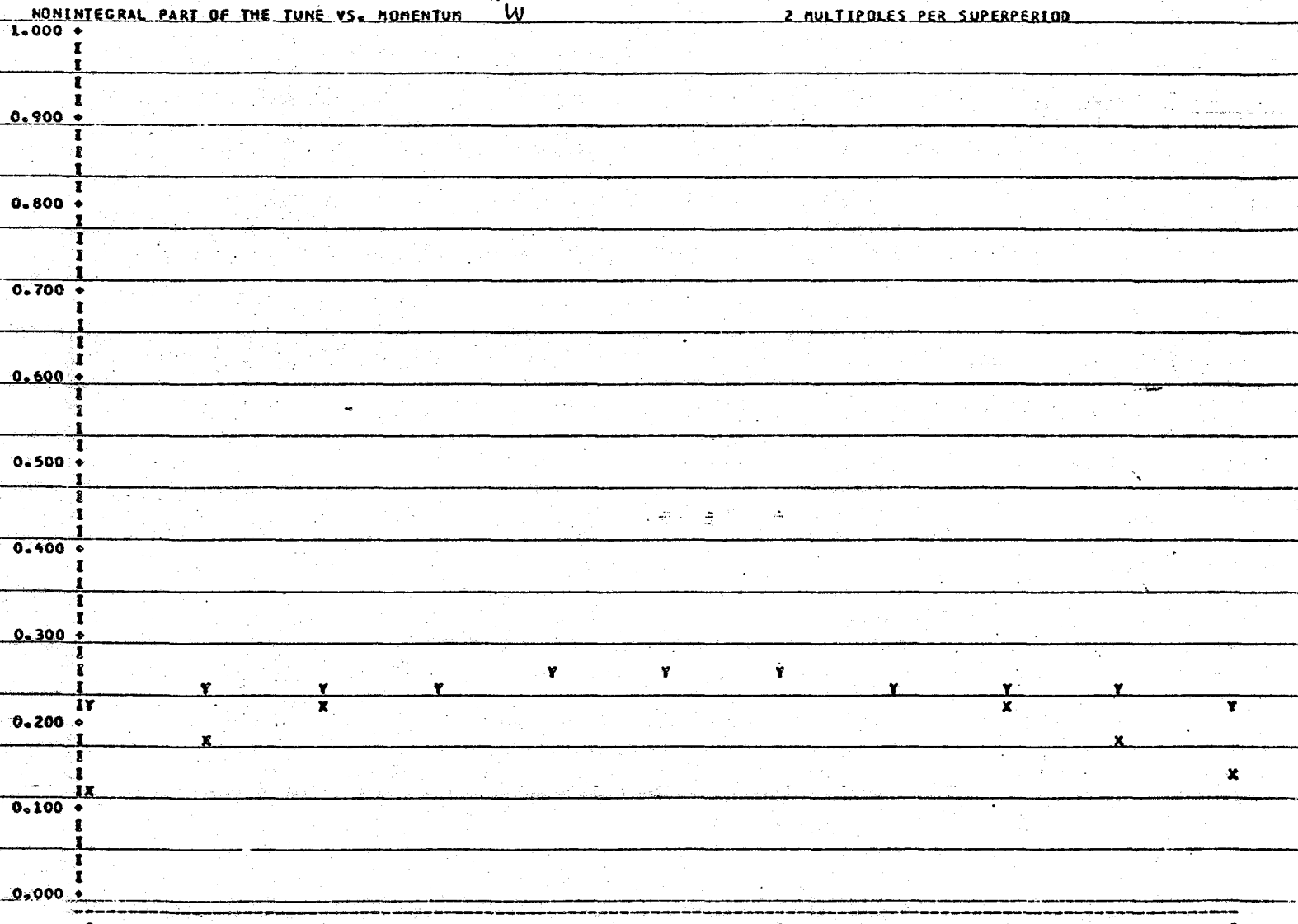


Figure 2

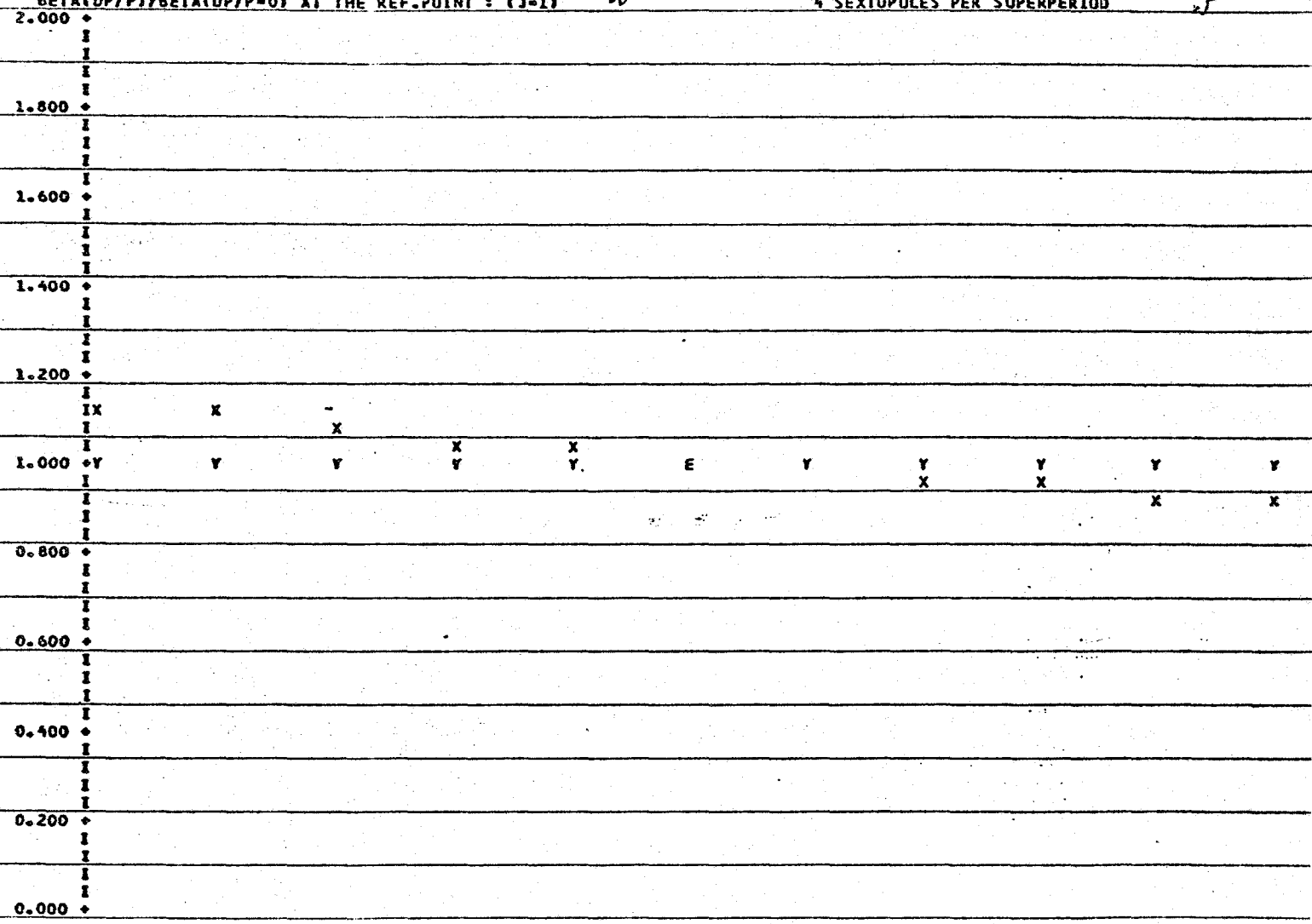
NONINTEGRAL PART OF THE TUNE VS. MOMENTUM "W" 2 MULTIPOLES PER SUPERPERIOD



NUEX	0.1144	0.1719	0.2156	0.2460	0.2637	0.2694	0.2635	0.2467	0.2196	0.1826	0.1363
NUEY	0.2211	0.2329	0.2415	0.2474	0.2506	0.2515	0.2502	0.2469	0.2416	0.2347	0.2261

Fig 3

BETA(DP/P)/BETA(DP/P=0) AT THE REF.POINT : (J=1) "W" 4 SEXTUPOLES PER SUPERPERIOD



BETXO	0.4488	0.4353	0.4233	0.4126	0.4030	0.3945	0.3868	0.3800	0.3739	0.3684	0.3635
BETYO	3.9655	3.9734	3.9819	3.9910	4.0007	4.0109	4.0216	4.0328	4.0445	4.0566	4.0692
ETAXO	-0.0063	-0.0049	-0.0036	-0.0023	-0.0011	0.0000	0.0011	0.0021	0.0031	0.0040	0.0050
ETAYO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Figure 4

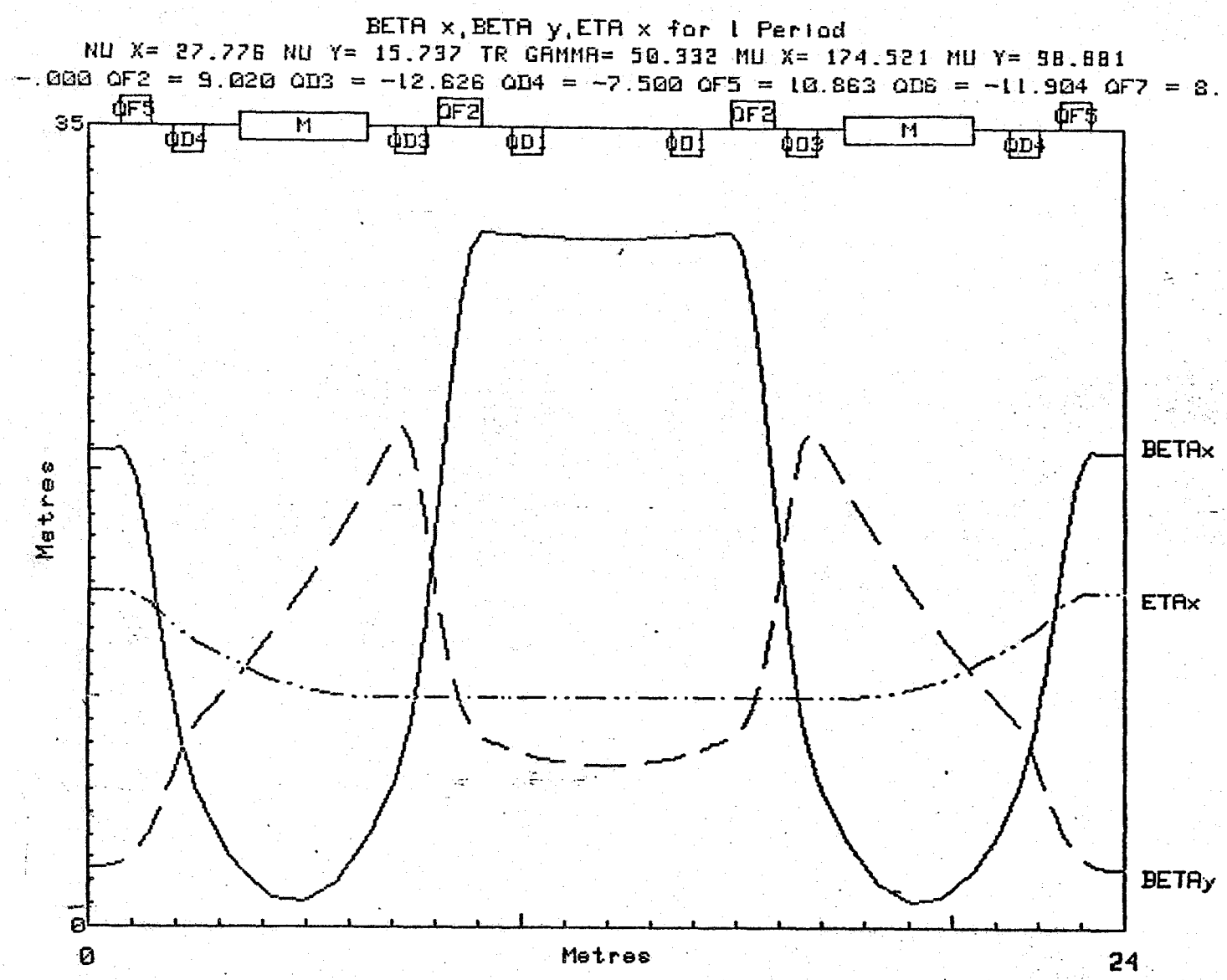

BETA x,BETA y,ETA x for 1 Period
NU X= 27.776 NU Y= 15.737 TR GAMMA= 50.332 MU X= 174.521 MU Y= 98.881
-.000 QF2 = 9.020 QD3 = -12.626 QD4 = -7.500 QF5 = 10.863 QD6 = -11.904 QF7 = 8.
QF5
QD4
M
QD3
QF2
QD1
QD1
QF2
QD3
M
QD4
QF5
35
0
Metres
BETAx
ETAx
BETAy
0
Metres
24

Figure 5

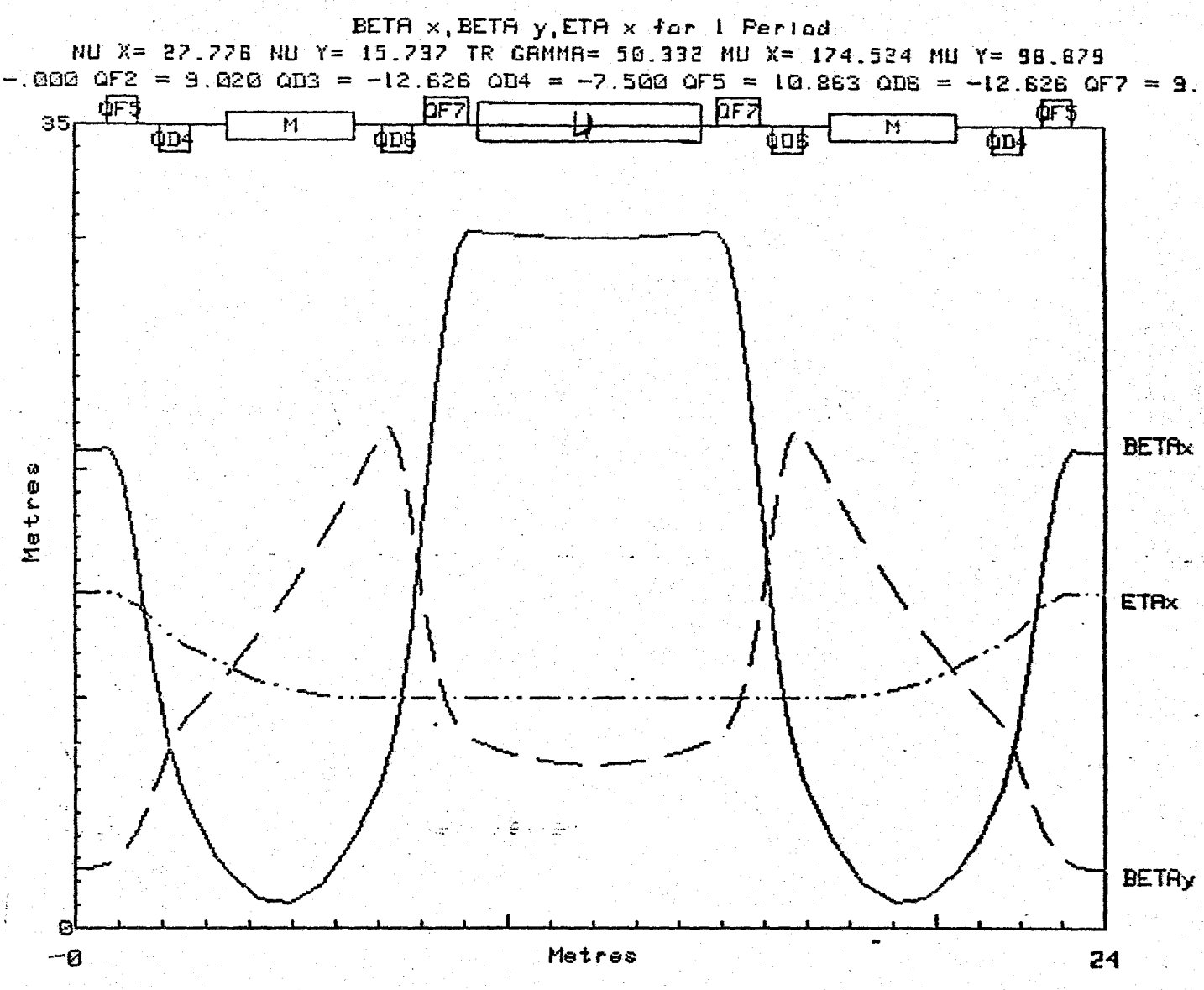
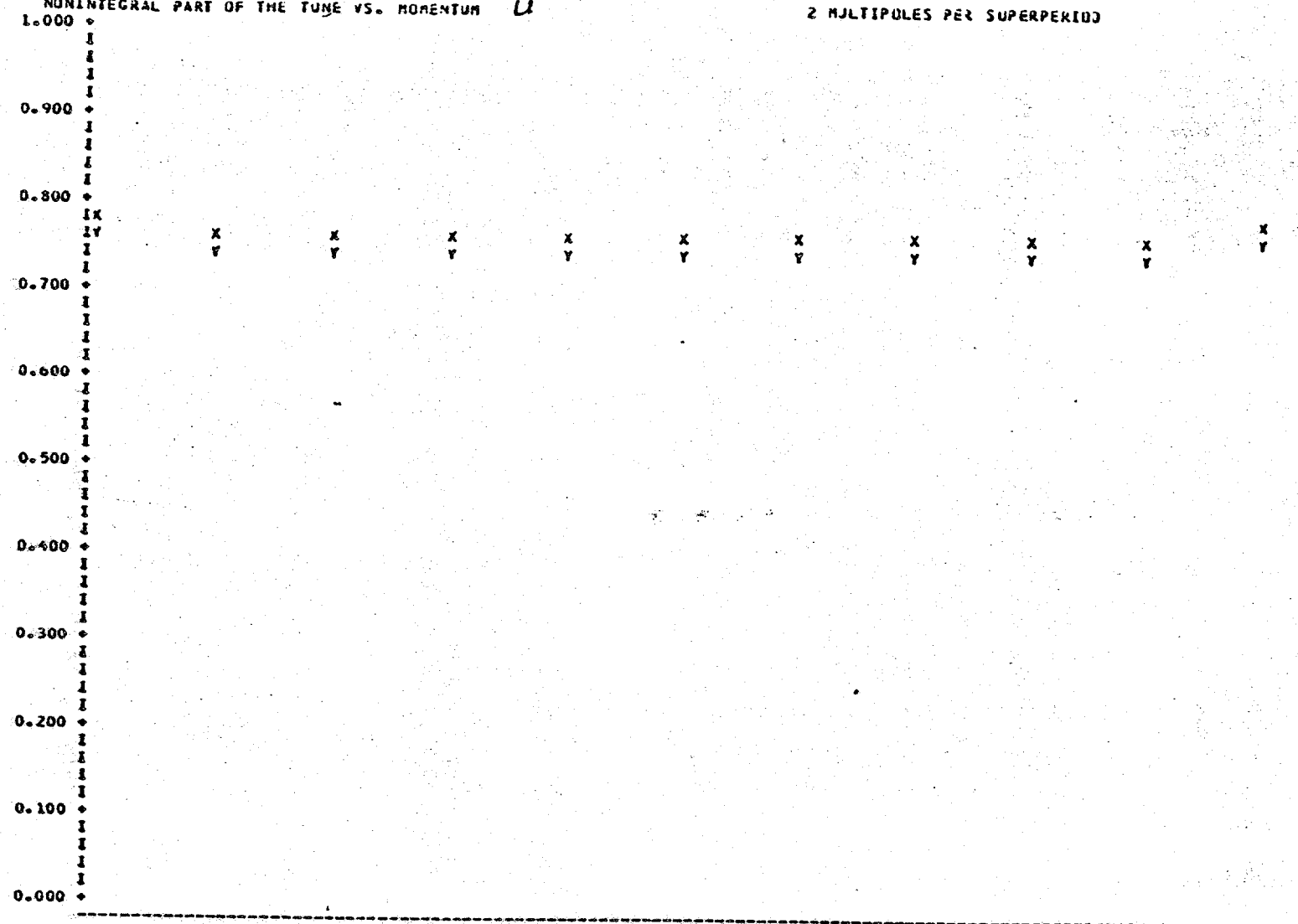

BETA x,BETA y,ETA x for 1 Period
NU X= 27.776 NU Y= 15.737 TR GAMMA= 50.332 MU X= 174.524 MU Y= 98.879
-.000 QF2 = 9.020 QD3 = -12.626 QD4 = -7.500 QF5 = 10.863 QD6 = -12.626 QF7 = 9.
QF5
QD4
M
QD6
QF7
L
QF7
QD6
M
QD4
QF5
35
0
Metres
BETAx
ETAx
BETAy
-0
Metres
24

Figure 6

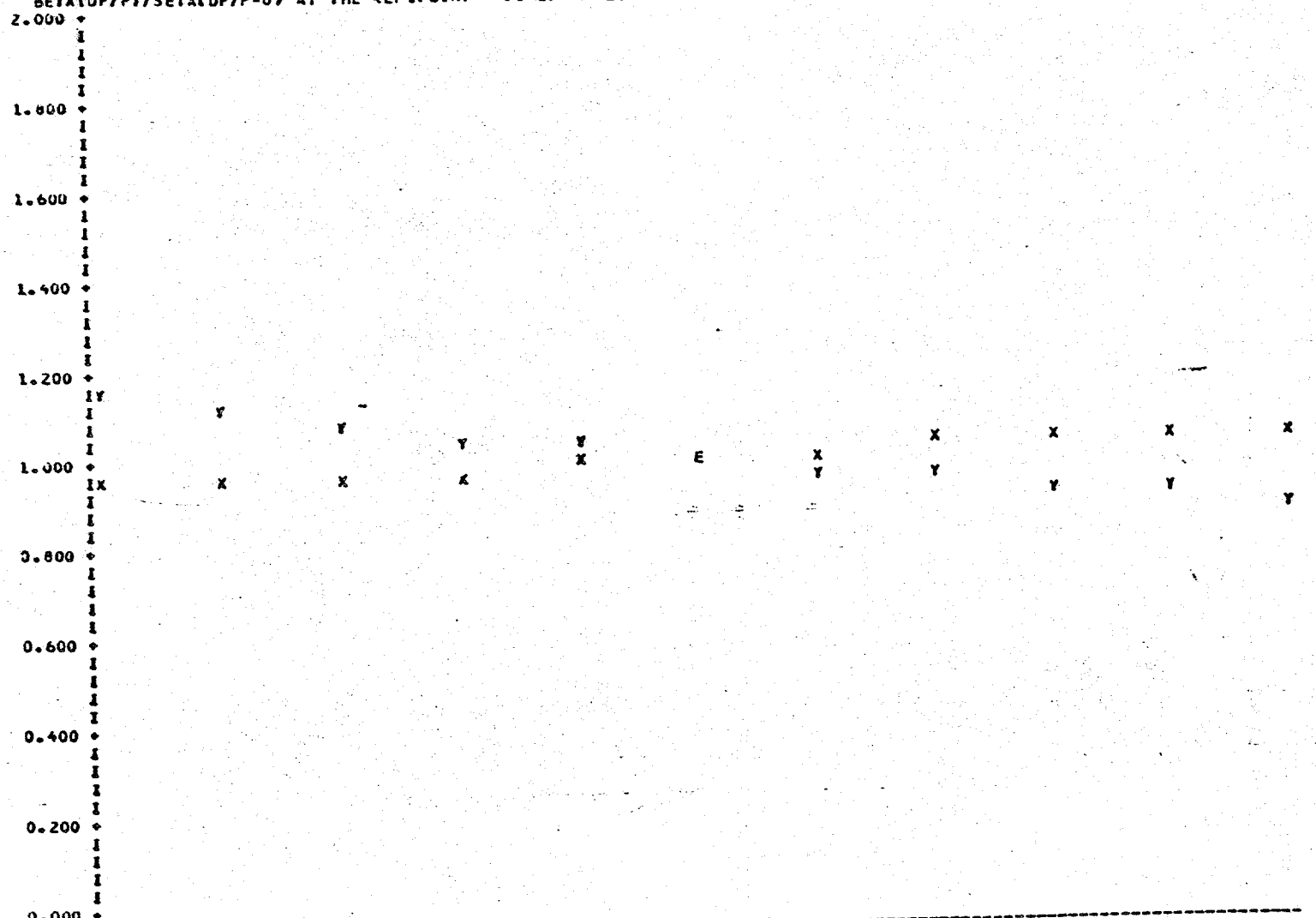
NONINTEGRAL PART OF THE TUNE VS. MOMENTUM "U" 2 MULTIPOLES PER SUPERPERIOD



NUEX	0.7740	0.7694	0.7658	0.7634	0.7620	0.7615	0.7620	0.7633	0.7654	0.7683	0.7723
NUEY	0.7537	0.7493	0.7460	0.7436	0.7422	0.7417	0.7420	0.7431	0.7450	0.7476	0.7509

Figure 7

BETA(DP/P)/BETA(DP/P=0) AT THE REF.POINT = (J=1) "U" 4 SEXTUPOLES PER SUPERPERIOD U



ETX0	28.6526	28.9149	29.1891	29.4751	29.7728	30.0820	30.4026	30.7346	31.0777	31.4318	31.7969
ETY0	8.3168	8.0578	7.8230	7.6076	7.4076	7.2199	7.0419	6.8716	6.7073	6.5473	6.3903
TAX0	0.0181	0.0145	0.0109	0.0072	0.0036	0.0000	-0.0036	-0.0072	-0.0109	-0.0145	-0.0181
TAY0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Figure B