FERMILAB-UPC-141

Effects of Normal Multipole Components in ES/D Dipoles

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1. INTRODUCTION

Program TEVLAT (1) is used to investigate the effects of normal 4- through 38-pole components in the fields of the ES/D dipoles. Use of the normal 4-, 6-, and 8-pole correction elements to cancel the 0-th harmonic component of these multipoles is studied. In none of the examples studied was more than 20% of the available correction strength needed for effective cancellation.

2. MAGNET SAMPLE

The magnet parameters used in this work are based on the measured parameters for a set of 16 "acceptable" magnets (2). The means and standard deviations of each of the multipole coefficients measured were used to define normal distributions from which the 4- through 12-pole coefficients for sets of 774 dipoles were selected at random. No correlations, either from magnet to magnet ("shuffling") or among multipoles within a single magnet, were included. Tables 1 and 2 summarize the properties of the measured data and of the generated magnet sets.

The results presented in this note are based on three different sets of dipole magnets. These sets will be called M1, M2, and M3 whenever it is necessary to distinguish them

The average values of the 14- through 30-pole coefficients attempts were made refine the current estimates, but no substantial improvements were obtained. The currents obtained from the simple estimates were therefore used throughout this note. The estimated trim currents are given in Table 4.

The first series of examples compare the results for the perfect reference machine (perfect dipoles and quadrupoles, no higher multipoles) with those obtained by including, one-by-one, quadrupole, sextupole and octopole terms in the dipoles and corresponding trim corrections. Results for magnet sets M1, M2 and M3 are shown in Figs. 1, 2 and 3 respectively. The corrections are seen to remove essentially all the momentum dependence of the tune induced by the error multipoles. (The effects of uncorrected multipole terms in the dipole fields have been illustrated in an earlier report (1).) However, all the examples show beta to be strongly dependent on momentum.

The rapid changes in beta as dp/p decreases toward -0.4% and the tune approaches 19.5 suggests that some part of the apparent momentum dependence may be attributable to the half-integer resonances. That this is in fact the case is strongly supported by the two following examples.

If the observed variations in beta are due to the tune approaching the half-integer resonance, systematically lowering the tune by adjusting the trim quads should reduce the change in beta at any momentum. Figure 4 shows the results obtained from magnet set M1 when the tune is lowered by 0.017 at dp/p=0. Comparing Fig. 4 to Fig. 1, the expected behaviour is seen.

As a second test, the trim sextupoles were used to set the chromaticity of the reference machine to zero and the calculations were repeated. The results for magnet set M1 are shown in Fig. 5. For the quadrupole and octopole cases, the same sextupole currents as for the reference machine were used. For the sextupole case, the trim currents were just the sums of the chromaticity-correcting currents determined for the linear machine and those estimated to cancel the 0-th harmonic of the error sextupole terms. In all cases, the chromaticity is essentially zero and the momentum dependence of the betas is very much reduced. This strongly supports the assumption that the observed momentum dependence of the betas may be largely attributed to the half-integer resonance.

To simplify interpretation of the following examples, the chromaticity is always set to zero near dp/p=0.

Figure 6a shows results for the basic linear machine with the design 10-pole term included. Figure 6b shows the corresponding result using the random 10-pole distribution from magnet set M1. As shown in Tables 1 and 2 the mean of the

REFERENCES

1. A. D. Russell, UPC-124
2. These data were provided by S. Ohnuma, Dec., 1979.
3. Tevatron Design Report, May, 1979.
4. T. L. Collins, TM-797.

	M1	M2	M3
4-pole	−0.848±1.560	−0.848±1.599	−0.846±1.540
6-pole	−0.572±2.746	−0.505±2.774	−0.626±2.913
8-pole	−0.317±0.832	−0.352±0.860	0.368±0.852
10-pole	0.959±1.777	1.068±1.726	1.158±1.747
12-pole	−0.190±0.396	−0.193±0.396	−0.186±0.402

Table 2. Means and standard deviations of the randomly distributed normal multipole coefficients for the three sets of 774 dipoles. Units of 10**-4 in**-n.

	lower limit	upper limit
4-pole	0.059	0.00058
6-pole	0.028	0.0084
8-pole	0.033	0.0047
10-pole	0.069	0.326
12-pole	(<0.0001)	(<10**-6)

Table 3. Probabilities that the normally distributed multipole coefficients are outside the ranges defined by the nominal selection criteria stated in the Design Report. The 12-pole estimates are based on assumed limits of ±2 units.

FIGURES

Fig. 1. Normal 4-, 6-, and 8-pole terms added to perfect linear machine. Magnet set M1. No chromaticity correction.

Fig. 2. Normal 4-, 6-, and 8-pole terms added to perfect linear machine. Magnet set M2. No chromaticity correction.

Fig. 3. Normal 4-, 6-, and 8-pole terms added to perfect linear machine. Magnet set M3. No chromaticity correction.

Fig. 4. Normal 4-, 6-, and 8-pole terms added to perfect linear machine. Magnet set M1. No chromaticity correction. Trim quads used to lower both tunes by 0.017. Compare to Fig. 1.

Fig. 5. Normal 4-, 6-, and 8-pole terms added to perfect linear machine. Magnet set M1. Chromaticity of reference (linear) machine set to zero. Momentum dependence of beta is much reduced compared to Fig. 1.

Fig. 6. Reference machine includes decapole term in dipoles, as specified in Design Report. Compared to decapole, 12-pole, and combined decapole and M12-pole from magnet set M1.

Fig. 7a. Decapole term from magnet set M1 reduced by factor of 10.

Fig. 7b. Combined 14- through 38-poles from magnet set M1.

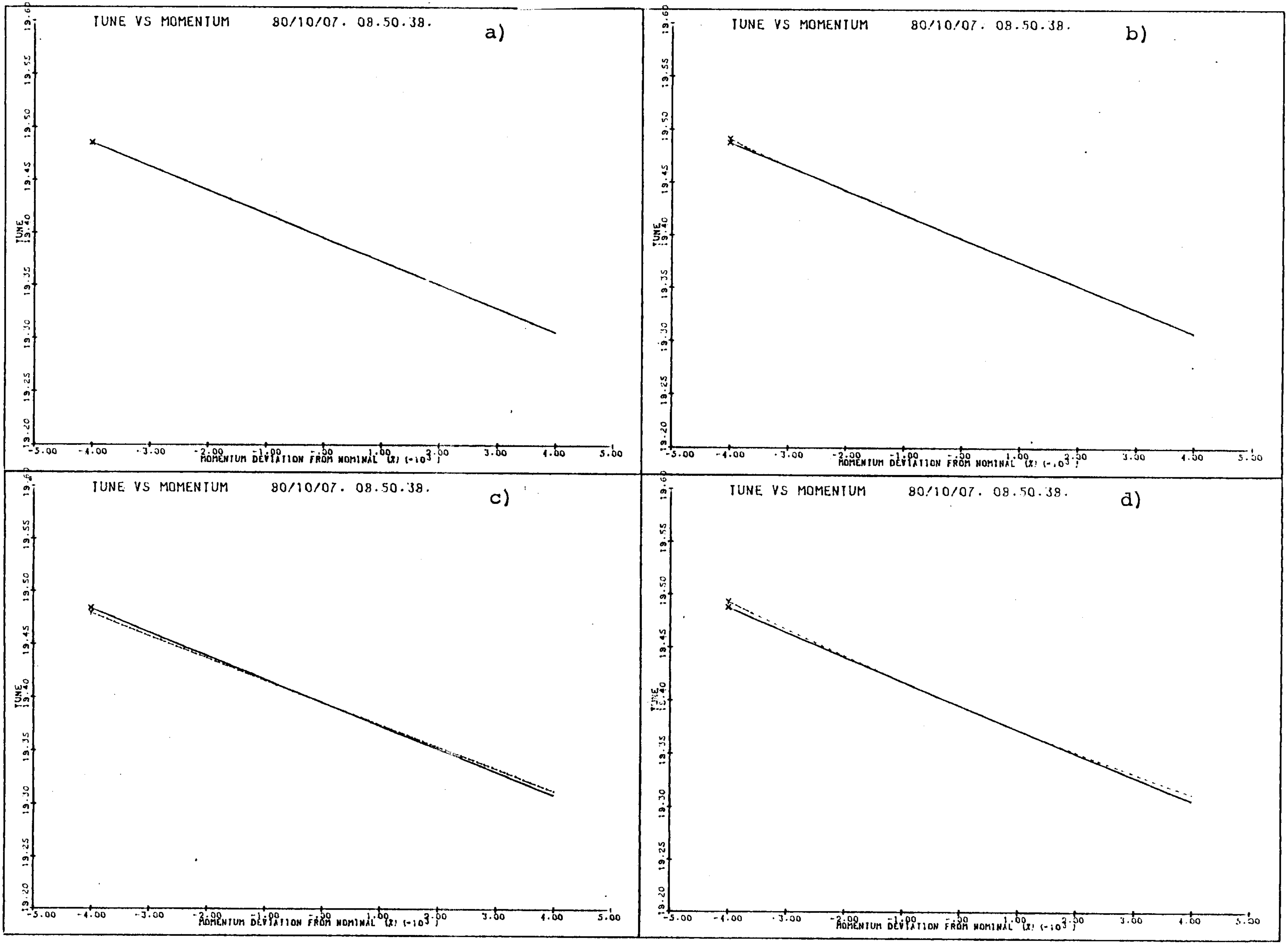
Fig. 7c. All multipoles included. Decapole reduced by factor 10. Magnet set M1.

Fig. 7d. All multipoles included. Magnet set M1.

Figs. 7e-7h. Betas corresponding to Figs. 7a-7d. The jump at dp/p=-0.004 in Fig. 7g is due to tune having passed through 19.5 between dp/p=-0.0036 and -0.004.

Figs. 8 - 10. Tune, Courant-Snyder functions, and momentum dispersion functions for magnet sets M1, M2, and M3 respectively. All multipoles are included and chromaticity is set to zero near dp/p=0.

Fig. 1.



TUNE VS MOMENTUM 80/10/07. 08.50.38.
a)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (×10³)
TUNE VS MOMENTUM 80/10/07. 08.50.38.
b)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (×10³)
TUNE VS MOMENTUM 80/10/07. 08.50.38.
c)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (×10³)
TUNE VS MOMENTUM 80/10/07. 08.50.38.
d)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (×10³)

Fig. 2.

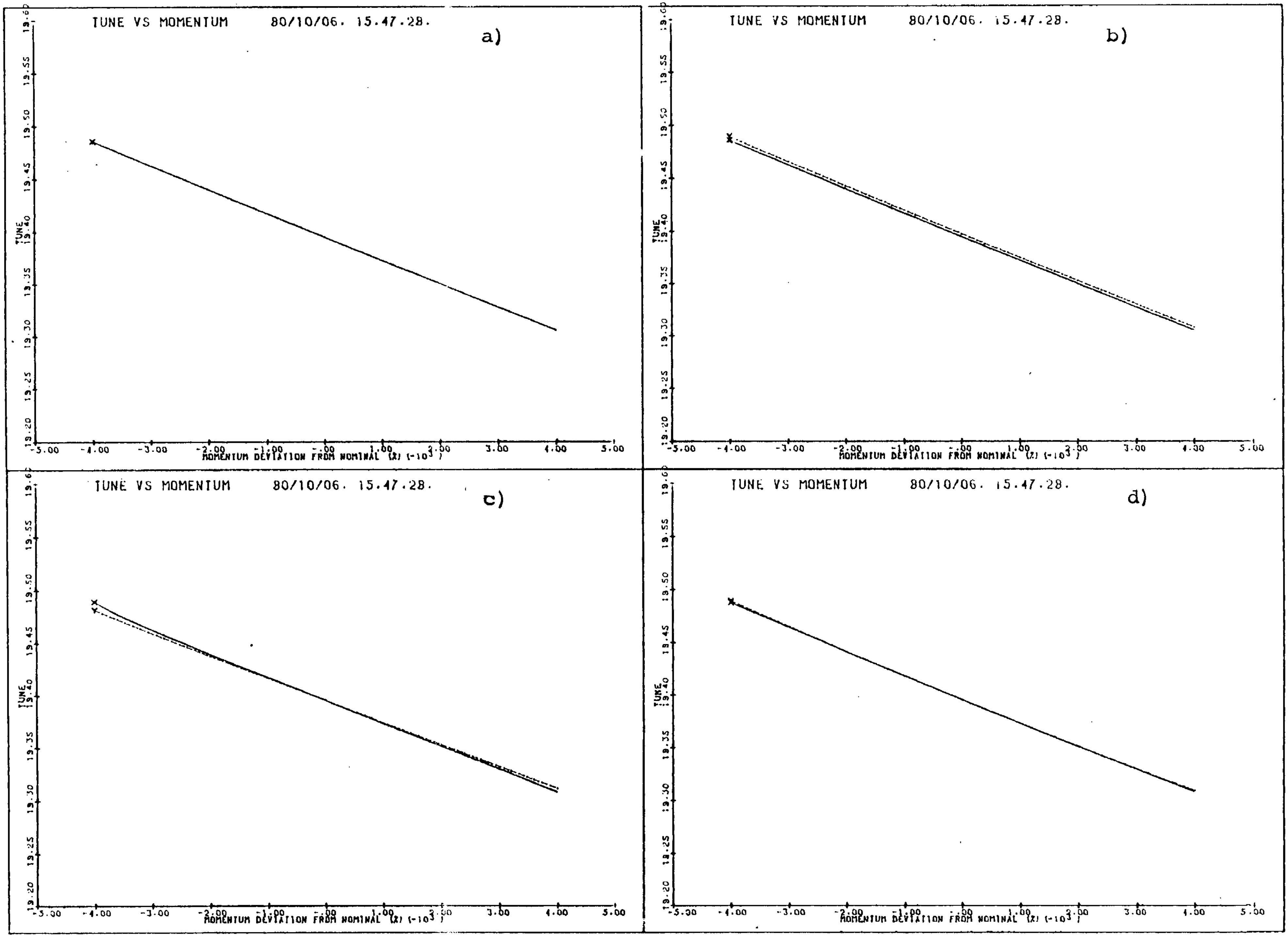

TUNE VS MOMENTUM 80/10/06. 15.47.28.
a)
b)
c)
d)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (·10³)
19.20
19.25
19.30
19.35
19.40
19.45
19.50
19.55
19.60
-5.00
-4.00
-3.00
-2.00
-1.00
.00
1.00
2.00
3.00
4.00
5.00

Fig. 3.

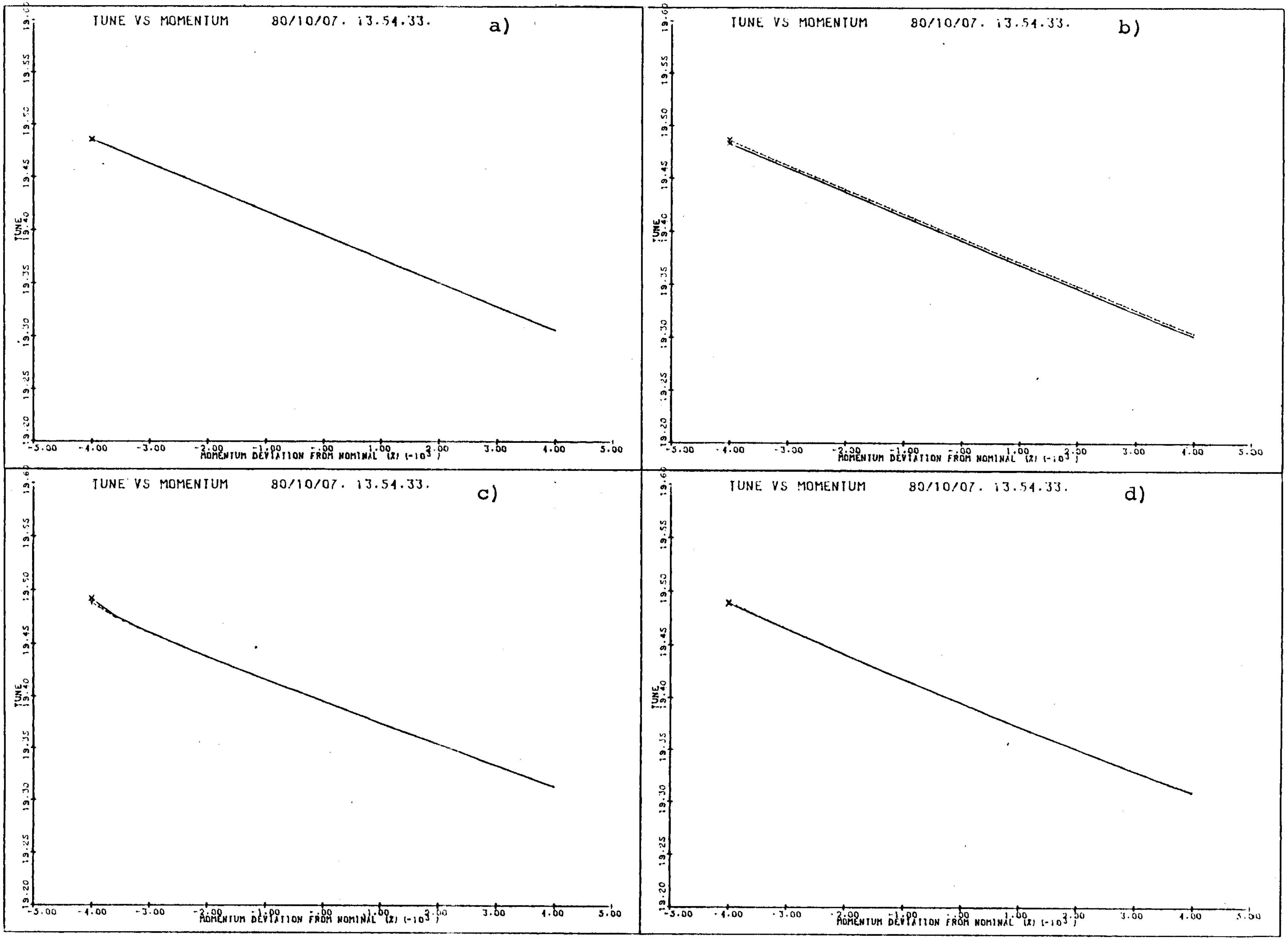

TUNE VS MOMENTUM 80/10/07. 13.54.33.
a)
b)
c)
d)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (·10^{3})
19.20
19.25
19.30
19.35
19.40
19.45
19.50
19.55
19.60
-5.00
-4.00
-3.00
-2.00
-1.00
.00
1.00
2.00
3.00
4.00
5.00

Fig. 4.

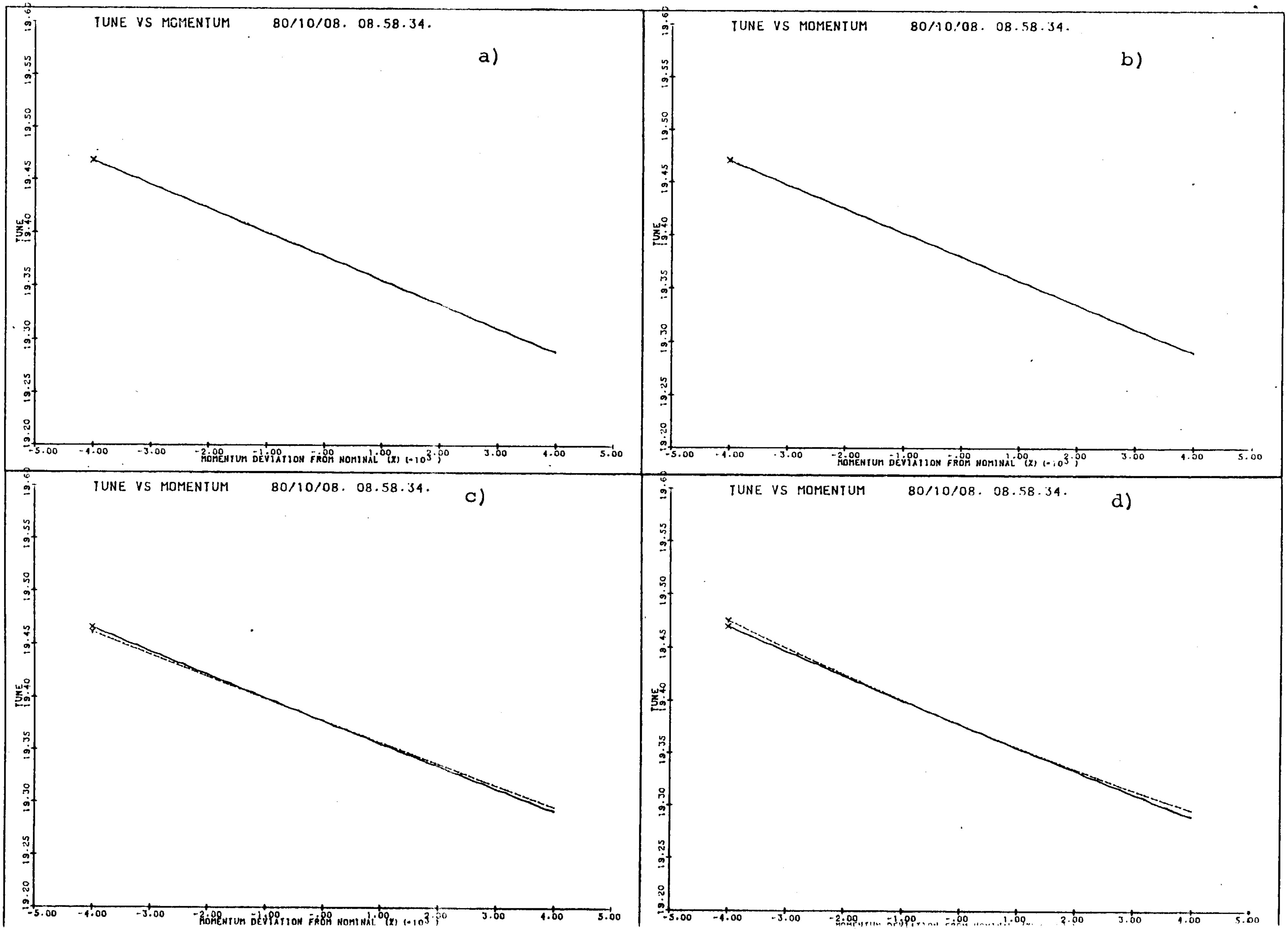
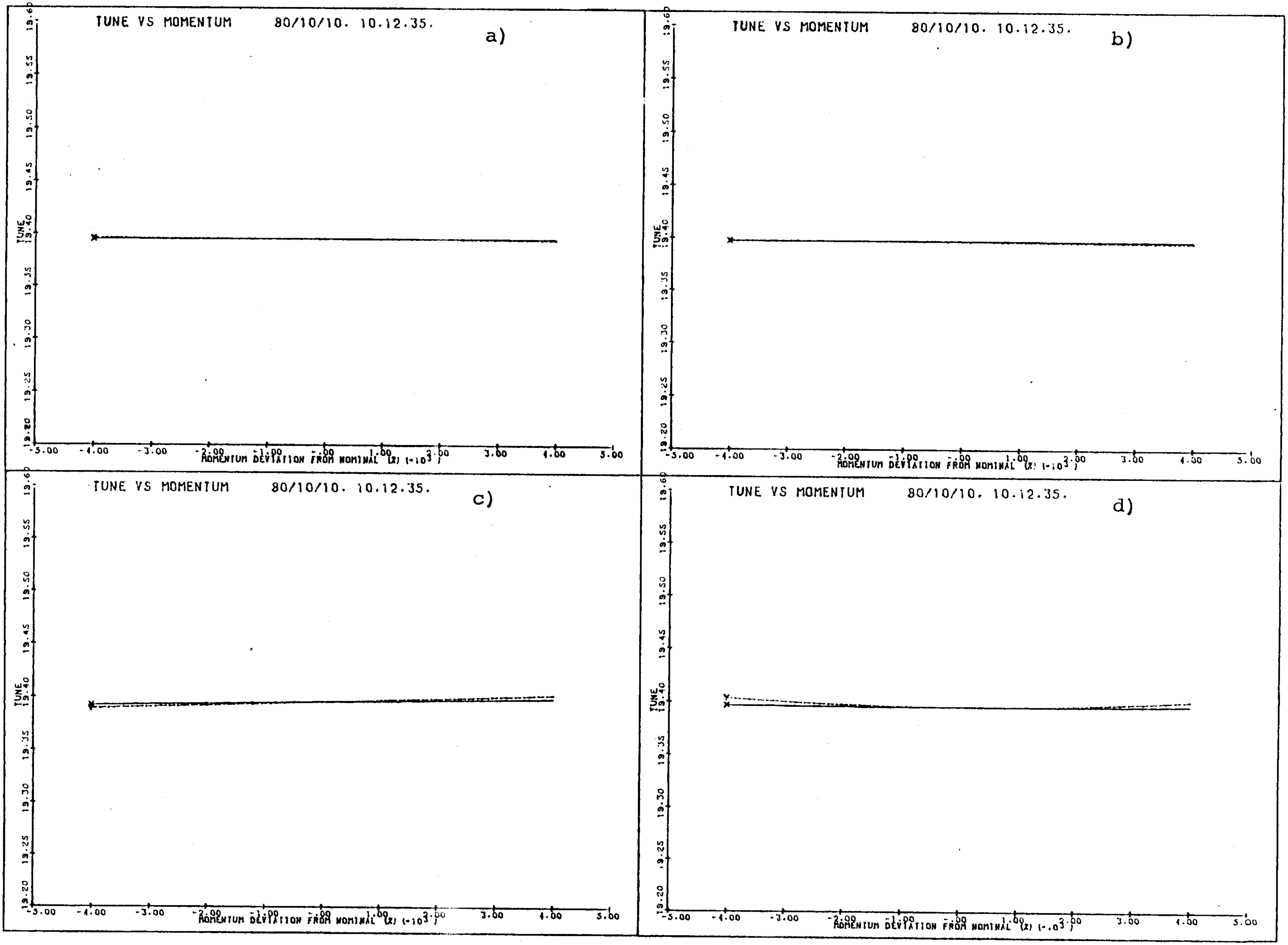
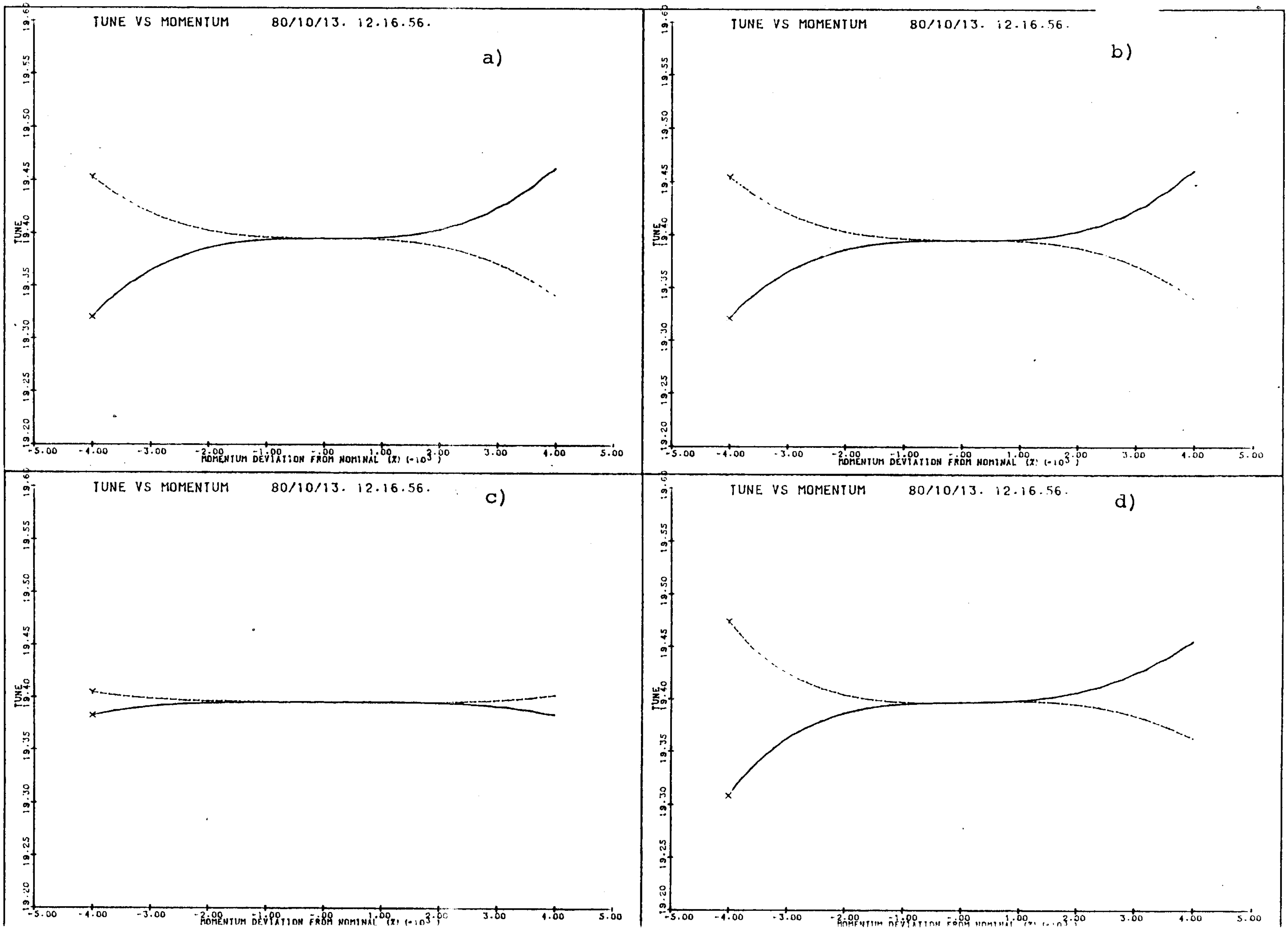

TUNE VS MOMENTUM 80/10/08. 08.58.34.
a)
b)
c)
d)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (×10³)
19.20
19.25
19.30
19.35
19.40
19.45
19.50
19.55
-5.00
-4.00
-3.00
-2.00
-1.00
-.00
1.00
2.00
3.00
4.00
5.00

Fig. 5.



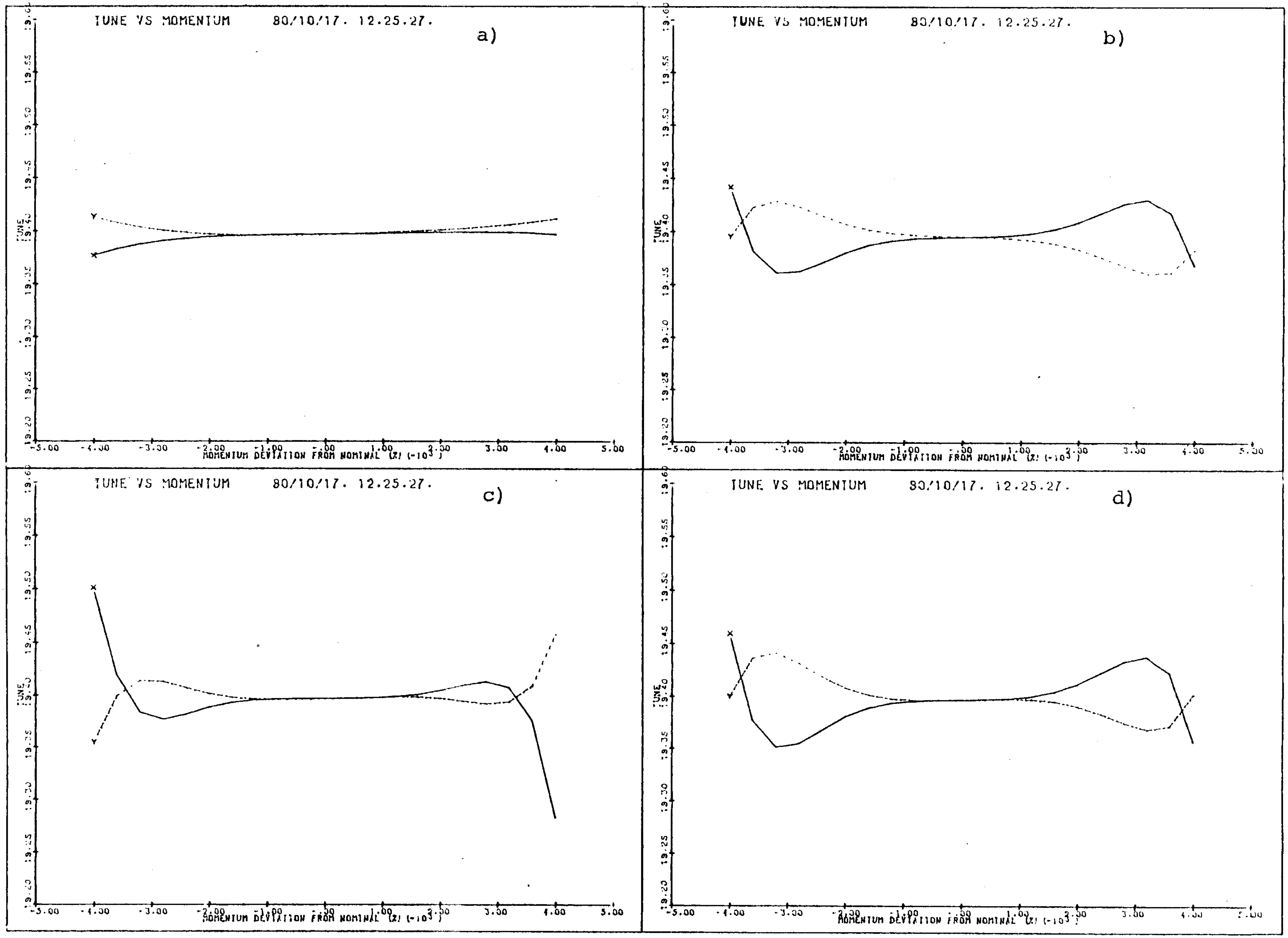
TUNE VS MOMENTUM 80/10/10. 10.12.35.
a)
b)
c)
d)
TUNE
19.20
19.25
19.30
19.35
19.40
19.45
19.50
19.55
19.60
-5.00
-4.00
-3.00
-2.00
-1.00
-.00
1.00
2.00
3.00
4.00
5.00
MOMENTUM DEVIATION FROM NOMINAL (%) (*10^3)

Fig. 6.



TUNE VS MOMENTUM 80/10/13. 12.16.56.
a)
b)
c)
d)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (*10^3)
19.20
19.25
19.30
19.35
19.40
19.45
19.50
19.55
19.60
-5.00
-4.00
-3.00
-2.00
-1.00
.00
1.00
2.00
3.00
4.00
5.00

Fig. 7.


TUNE VS MOMENTUM 80/10/17. 12.25.27.
a)
b)
c)
d)
TUNE
MOMENTUM DEVIATION FROM NOMINAL (%) (*10^3)

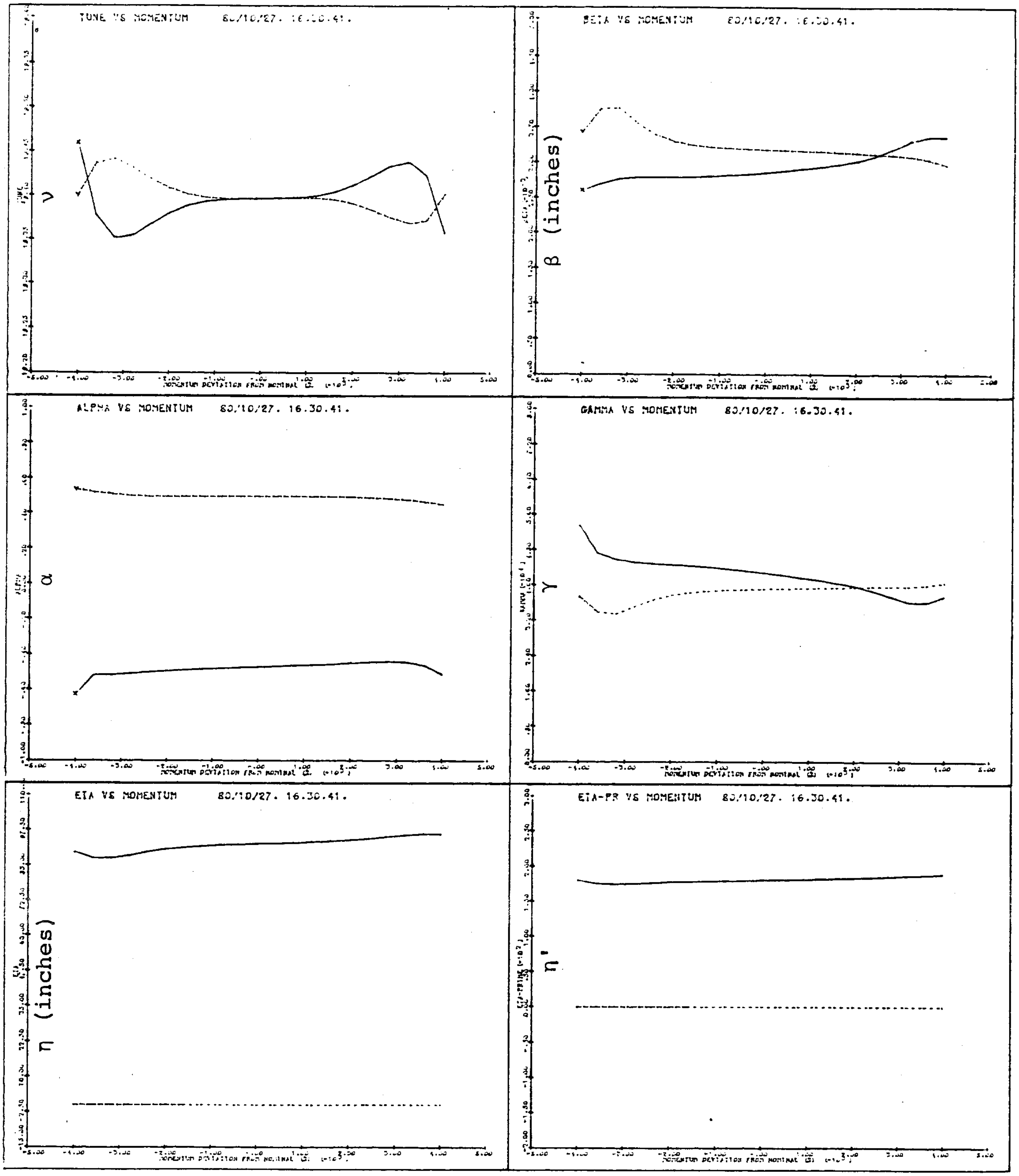


Fig. 8. Magnet set M1.

Scales: ν - 19.2 to 19.6
β - 0 to 3000
α - -1 to 1
γ - 0 to 0.0008
η - -15 to 110
η'- -0.02 to 0.03

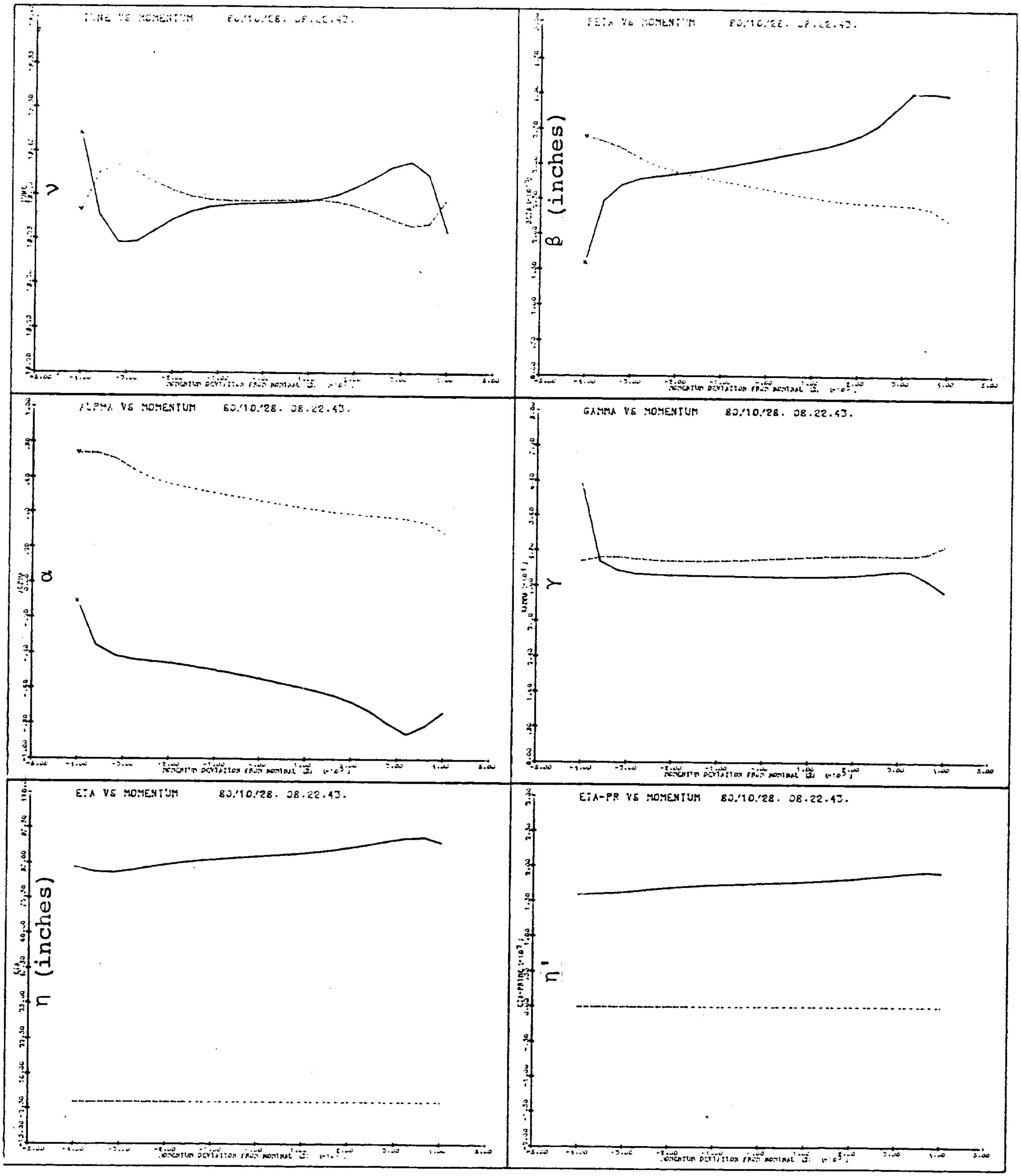


Fig. 10. Magnet set M3

Scales: ν - 19.2 to 19.6
β - 0 to 3000
α - -1 to 1
γ - 0 to 0.0008
η - -15 to 110
η'- -0.02 to 0.03