BNL-104070-2014-TECH

AGS.SN193;BNL-104070-2014-IR

Measurement of Twiss Parameters and Emittance in the U line

J. F. Ryan

December 1985

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

12/10/85 Number 193

AGS Studies Report

Date(s) 11/5/85 Time(s) 0800-1100

Experimenter(s) J. Ryan and R. Thern

Reported by R. Thern

Subject Measurement of Twiss Parameters and Emittance in the U Line

Observations and Conclusion

The emittance and Twiss parameters of the extracted beam in the U line at H13 were determined by measuring the beam size in the SEM at U56 while varying the strengths of quads UQ1 and UQ2. This SEM is placed downstream of the 4.25 degree bend and UQ3, just before the beam line leaves the main ring enclosure. Since UQ3 is relatively weak and is immediately upstream of the SEM, varying it has essentially no effect on the beam size at the SEM; its effect, however, is included in the analysis.

Before the studies began, the machine was operating FEB at an intensity of 15 TP. At ths intensity, the SEM would overflow when the beam was focused with a waist at the SEM and essentially all the signal was in one wire. As there is no gain control for the SEM, the beam was reduced to about 4.5 TP so the SEM would not overflow even at the waist. In retrospect, this was probably not really necessary, since the profiles with all the signal in one wire are not usable anayway.

The SEM data were collected with the program MSEM, which was modified from an old program CPROM to be somewhat easier to run. A file containing ten profiles was written for each set of quad settings.

The SEM profiles were analyzed to find their widths with the program MSEMO, which was modified from WENGC. Several profiles are shown in Figures 1-4. The program uses the same routine as the IPM programs to find the width and mean of the profiles. The profiles have a varying baseline which was not cured by the null subtraction. The IPM statistics routine can accommodate this background if it is uniform, but it appears that there are also asymmetries, shoulders, and other ills which keep the width determination from being precise. In addition, the width determination fails completely for very narrow profiles, so data with a sigma less than 30 mils (the wire spacing is 60 mils) were not used.

A table of transfer matrix values from H13 to the SEM for each set of quad settings was generated on an IBM-PC using a spreadsheet program; several of the values were checked against results from the QTUNE program, which can also generate the matrices. Both of these programs calculate the focusing strength of the quads from the datacon readback using the polynomial equation from the MAGNET program as shown in Appendix I. The parameters of the U-line--bend angles, drift lengths, etc.--are available through the QTUNE program.

For each data point (i.e., at each quad setting) the widths of the ten profiles were averaged to get one width, and an error bar assigned by taking the rms of the ten widths and adding 1.5 mils in quadrature to avoid any extremely small errors which would then dominate the fit. Note that this should overestimate the error--a statistician would divide by sqrt (n-1) or 3--but there are other problems here, such as size-dependent biases in the procedure that finds the width of the profile. In addition, data points with widths below 20 mils and above 300 mils were removed by assigning a large error, because the width calculation failed for profiles concentrated in one or two wires, or at the other extreme, so wide that the entire profile was not included in the SEM. Both of these problems could be at least partially fixed by using a more clever algorithm or lots of hand labor, but the analysis is satisfactory without these data points. Some of the data points with widths of 30-35 mils were also changed slightly (increased width and increased error) because the program appears to underestimate their width.

Finally, a least-squares fit was done for the Twiss parameters (alpha, beta, and gamma) and emittance which give the best agreement with the measured beam sizes. The method is outlined in Reference 1. All profiles were included in the fitting process, but some were effectively removed by assigning a large error bar as explained above. The chisquare for the vertical fit was 53 with 44 data points, and for the horizontal, 36 for 23 data points. Figure 5 shows, for a subset of the data with one quad constant, how the measured size varies with the other quad. Also shown is the size calculated using the Twiss parameters derived here.

The observed horizontal size is due partially to the momentum spread in the beam, since the momentum dispersion at the SEM is not zero. The calculation subtracts off (in quadrature) the size due to momentum spread before fitting for the betatron size. The momentum spread was not measured for this test; the value assumed here is ±0.12% for the full width (2). To show the sensitivity of the answers to this value, the analysis was also done assuming no momentum spread.

The results are shown in Table 1. Also shown are the "old" values which are used in several references to the U line (3-5). The old emittances shown are those used in the QTUNE program and are for higher intensity (8-9 TP) than measured here. Figures 6 and 7 show the phase space ellipses for these parameters. Figures 8 and 9 show the ellipses with the error bars from Table 1 added and subtracted from the alpha and beta. This is not a precise indication of the range of ellipse shapes and orientations because it does not take account of correlations in the errors of alpha, beta, and emittance.

References

1. J. Ryan, Accelerator Division Technical Note No. 198, Measuring a Beam Emittance Using Lienar Least-Square Analysis.

2. E. Raka, private communication.

3. FEB Operations Manual.

4. J. Ryan, AGS Division Technical Note No. 176, The U Line.

5. W.T. Weng, The New AGS Fast Extraction System, BNL 51310.

TABLE 1. Beam Parameters at H13 (at 4.5 TP)

		unit	ref. 4 value	this measurement value	this measurement error
Vertical:					
	alpha		0.9871	1.053	0.041
	beta	kiloinch	0.1455	0.3170	0.0068
		m	3.696	8.052	0.174
	emittance(rms)	in-mrad	0.0064	0.00331	0.00010
		mm-mrad	0.163	0.0841	0.0025
Horizontal: (assuming dp/d=.12%)					
	alpha		-5.67	-4.778	0.579
	beta	kiloinch	2.262	1.480	0.181
		m	57.46	37.59	4.60
	emittance(rms)	in-mrad	0.0064	0.00568	0.00058
		mm-mrad	0.163	0.143	0.015
Horizontal: (assuming dp/d=0 for illustration of effect only)					
	alpha			-3.967	0.303
	beta	kiloinch		1.352	0.104
		m		34.34	2.64
	emittance(rms)	in-mrad		0.00868	0.00052
		mm-mrad		0.220	0.013

Appendix I. Use of MAGNET program on PDP-10

```
.R R

ENTER "/H" FOR HELP
*MAGNET

                        5-Dec-85  09:43

 WELCOME TO THE AGS EXTRACTED BEAMS MAGNET DATA PROGRAM

COMMAND( HELP(H),CALC(C),MAGNET(M),NAMES(N),DATA(D),PBEAM(G),EXIT(E): M

GIVE THE EXTRACTED BEAM MAGNET NAME( CQ1,UP2)... UQ1

COMMAND (H,C,M,N,D,G,E) : D

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
                     POWER SUPPLY INFORMATION               QUAD
-----MAGNET------    --PRIMARY-----MAX-  -SECONDARY-     POLE RADIUS
NAME  KIND  GROUP   DDF  AMPS/DCN KAMPS DDF  AMPS/DCN      INCH
UQ1   QUAD  N3Q36 UQ1    0.6250   2.100                     1.50
 -     -     -     -     -     -     -     -     -     -     -     -     -     -

 EFF.LEN   KG/IN OR KG-IN POWER SERIES COEFF. FOR I IN KAMPS      MAX.MAG
 INCH       A0         A1         A2          A3          A4       KAMPS
 37.500  1.520E-02  4.477E+00  1.979E-01  4.738E-02 -9.160E-02   2.600
 ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

COMMAND (H,C,M,N,D,G,E) : M

GIVE THE EXTRACTED BEAM MAGNET NAME( CQ1,UP2)... UQ2

COMMAND (H,C,M,N,D,G,E) : D

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
                     POWER SUPPLY INFORMATION               QUAD
-----MAGNET------    --PRIMARY-----MAX-  -SECONDARY-     POLE RADIUS
NAME  KIND  GROUP   DDF  AMPS/DCN KAMPS DDF  AMPS/DCN      INCH
UQ2   QUAD  N3Q36 UQ2    0.6250   2.100                     1.50
 -     -     -     -     -     -     -     -     -     -     -     -     -     -

 EFF.LEN   KG/IN OR KG-IN POWER SERIES COEFF. FOR I IN KAMPS      MAX.MAG
 INCH       A0         A1         A2          A3          A4       KAMPS
 37.500  1.520E-02  4.477E+00  1.979E-01  4.738E-02 -9.160E-02   2.600
 ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

COMMAND (H,C,M,N,D,G,E) : E

END OF EXECUTION
CPU TIME: 0.54  ELAPSED TIME: 51.13
EXIT
```

Figure Captions

Figures 1 - 4	Typical SEM profiles. The points are the SEM data and the line is the Gaussian determined with the fitting routine from the IPM programs. Note the failure of the fit for the narrow profiles of Figure 2. Such data were not used.
Figure 5	Horizontal size at U53 SEM, as UQ2 is changed.
Figures 6 & 7	Phase space ellipses at H13, for parameters (γ, β and ε), from Ref. 4 and from this report.
Figures 8 & 9	Phase space ellipses at H13 for $\alpha \pm d\alpha$, $\beta \pm d\beta$ (with ε held constant). Correlations between the errors are not taken into account.

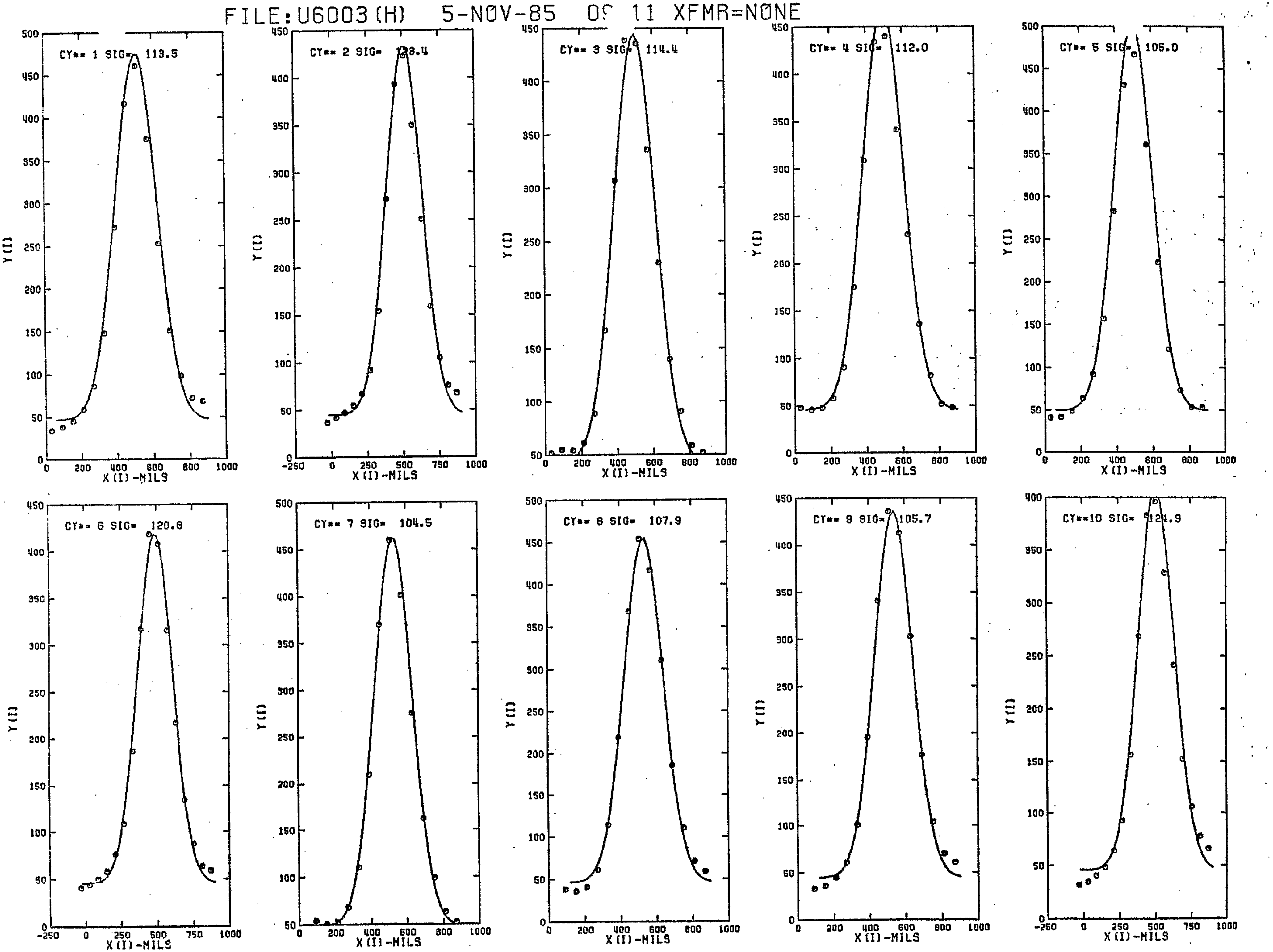

FILE:U6003(H) 5-NOV-85 OS 11 XFMR=NONE
CY*= 1 SIG= 113.5
CY*= 2 SIG= 123.4
CY*= 3 SIG= 114.4
CY*= 4 SIG= 112.0
CY*= 5 SIG= 105.0
CY*= 6 SIG= 120.6
CY*= 7 SIG= 104.5
CY*= 8 SIG= 107.9
CY*= 9 SIG= 105.7
CY*=10 SIG= 124.9
Y(I)
X(I)-MILS

Figure 1

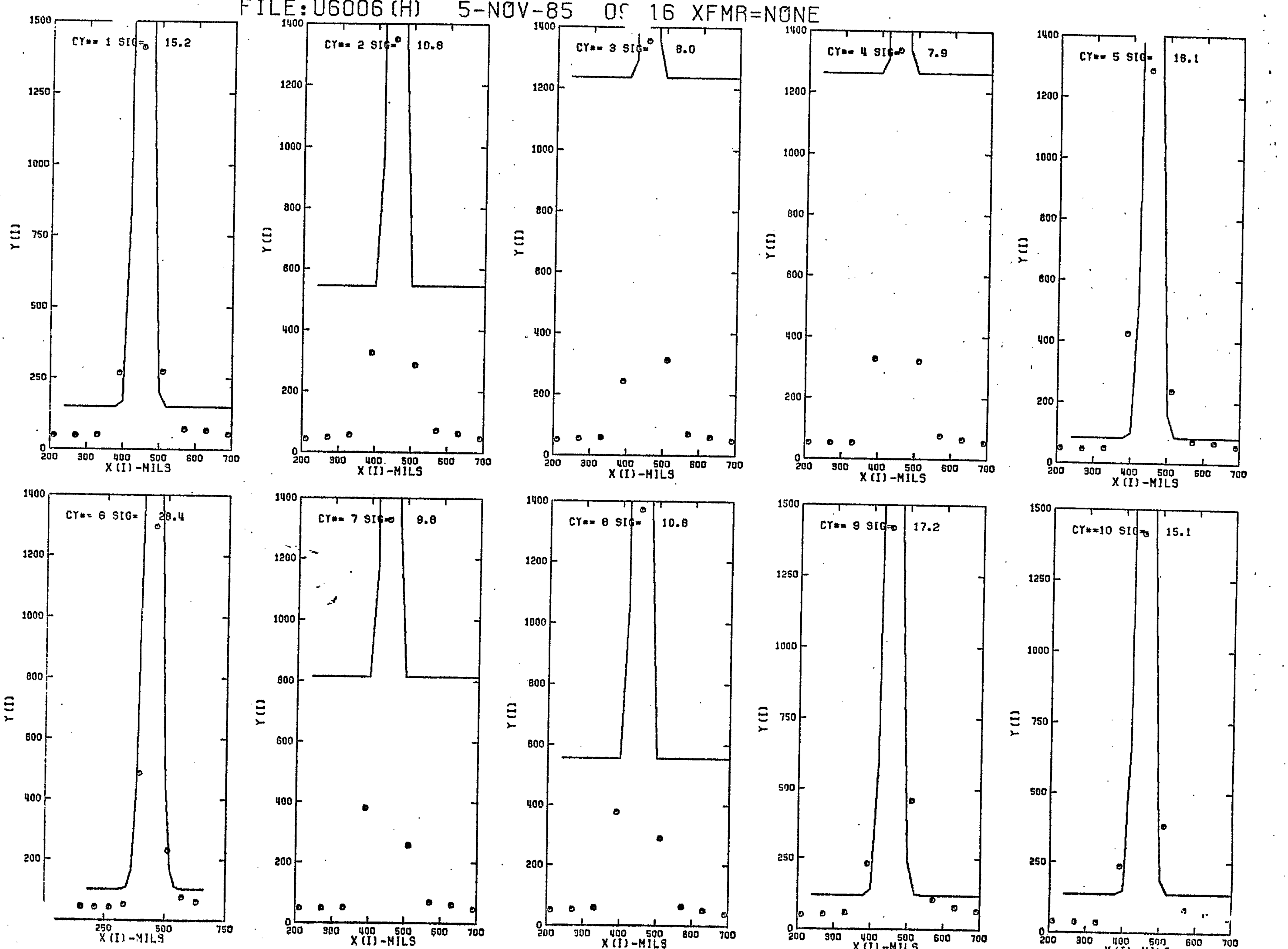

FILE:U6006(H) 5-NOV-85 OS 16 XFMR=NONE
CY*= 1 SIG= 15.2
CY*= 2 SIG= 10.8
CY*= 3 SIG= 8.0
CY*= 4 SIG= 7.9
CY*= 5 SIG= 16.1
CY*= 6 SIG= 28.4
CY*= 7 SIG= 9.8
CY*= 8 SIG= 10.8
CY*= 9 SIG= 17.2
CY*=10 SIG= 15.1
Y(I)
X(I)-MILS

Figure 2

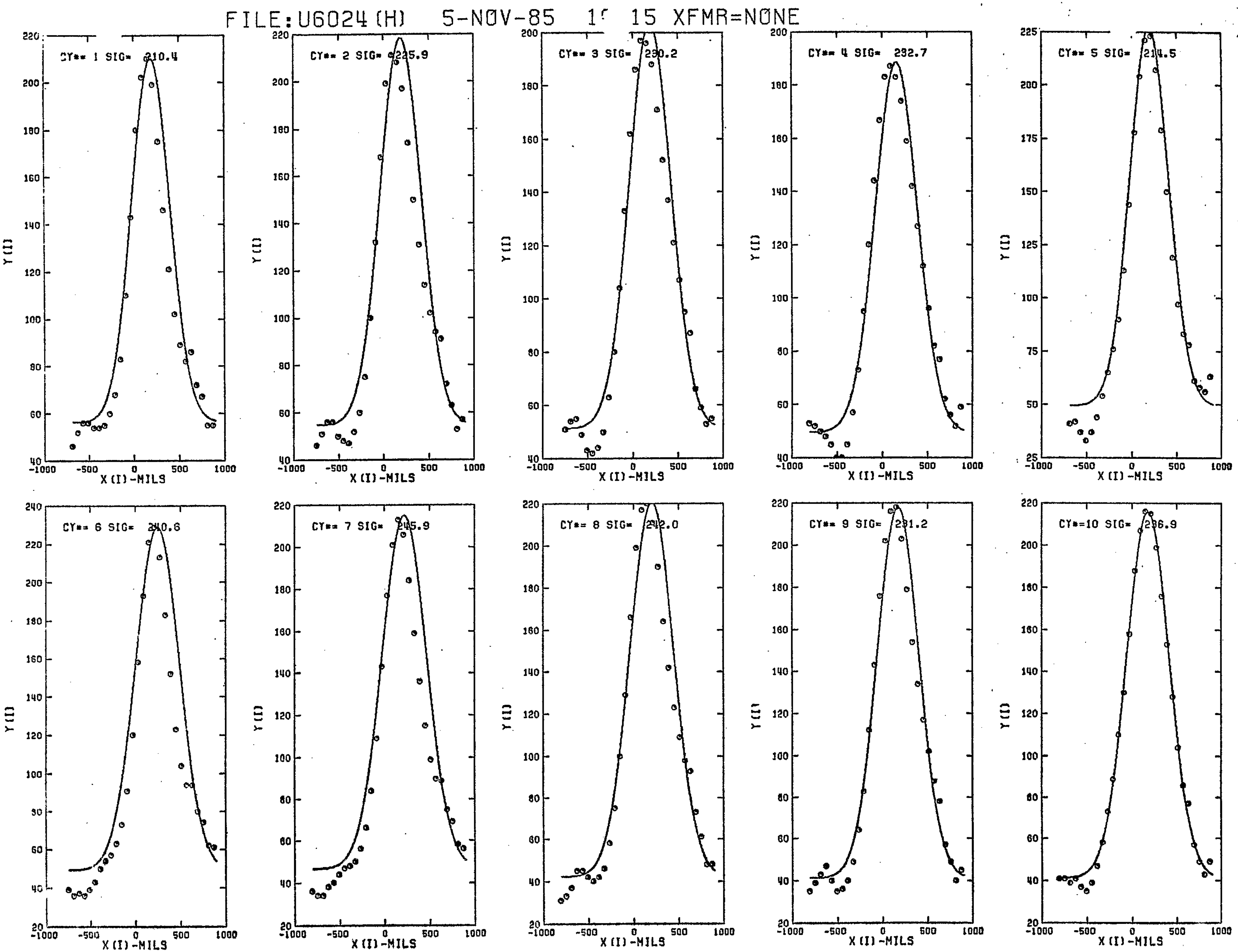

FILE:U6024(H)
5-NOV-85
XFMR=NONE
CY*= 1 SIG= 210.4
CY*= 2 SIG= 225.9
CY*= 3 SIG= 230.2
CY*= 4 SIG= 232.7
CY*= 5 SIG= 214.5
CY*= 6 SIG= 240.6
CY*= 7 SIG= 245.9
CY*= 8 SIG= 242.0
CY*= 9 SIG= 231.2
CY*=10 SIG= 236.9
Y(I)
X(I)-MILS

Figure 3

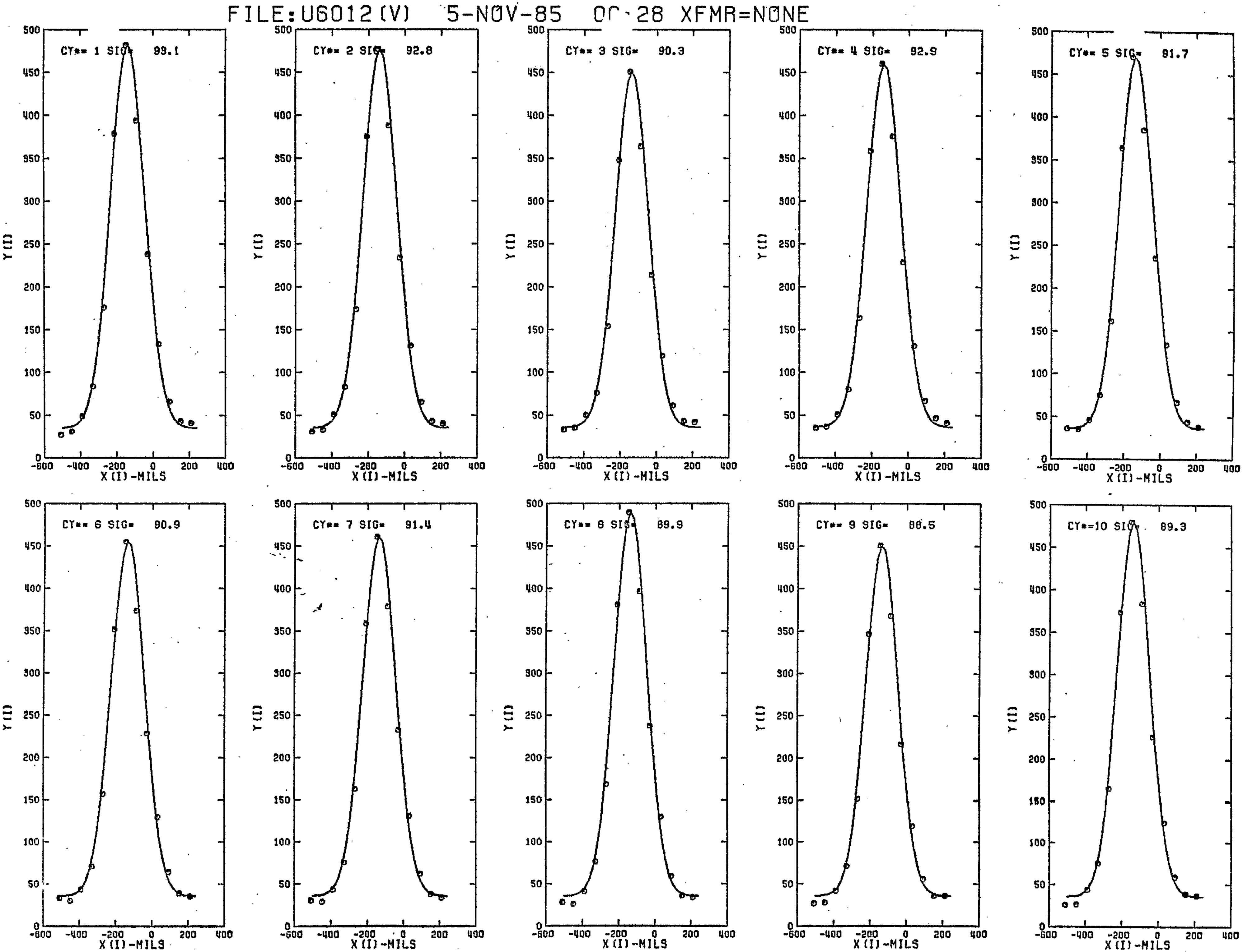
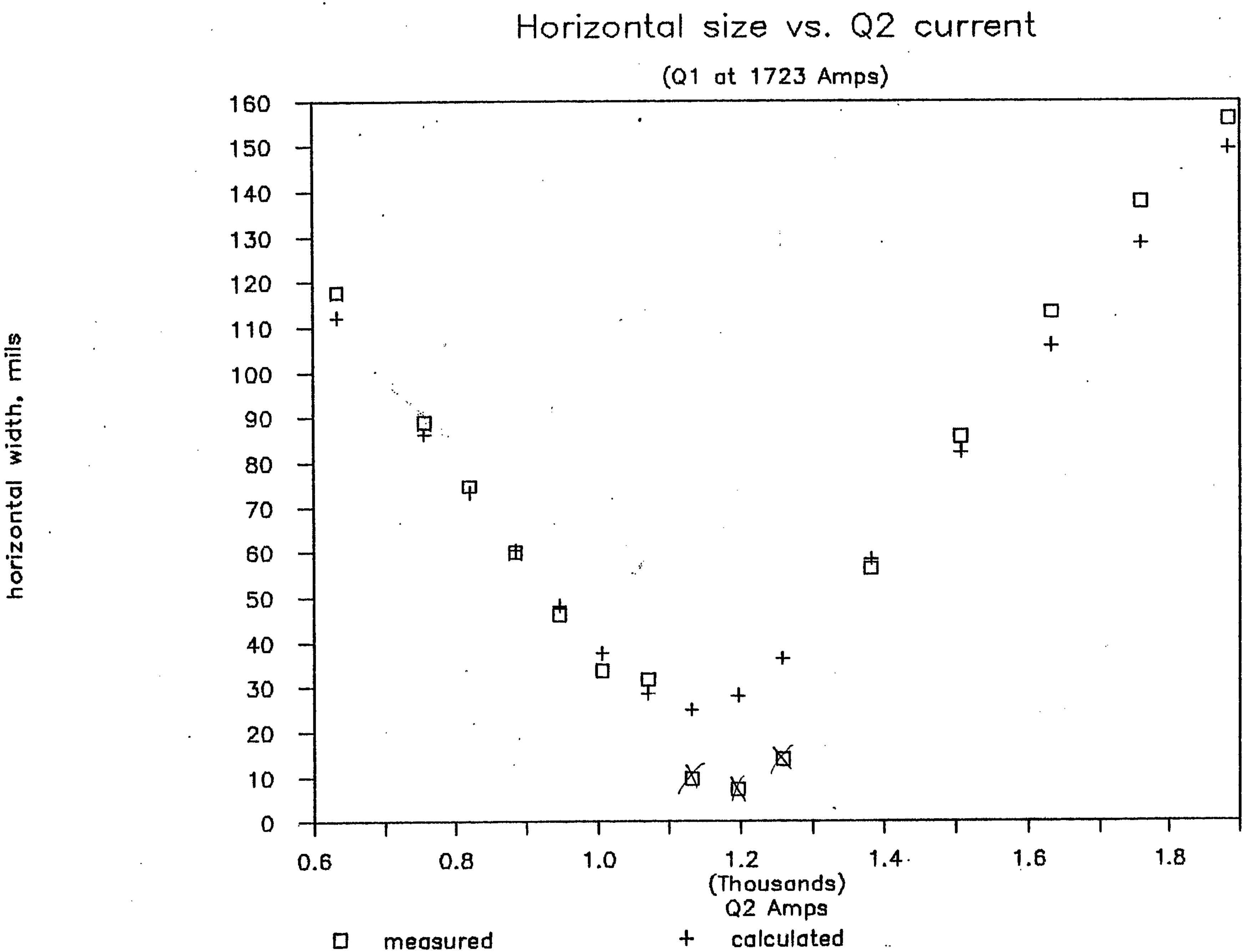
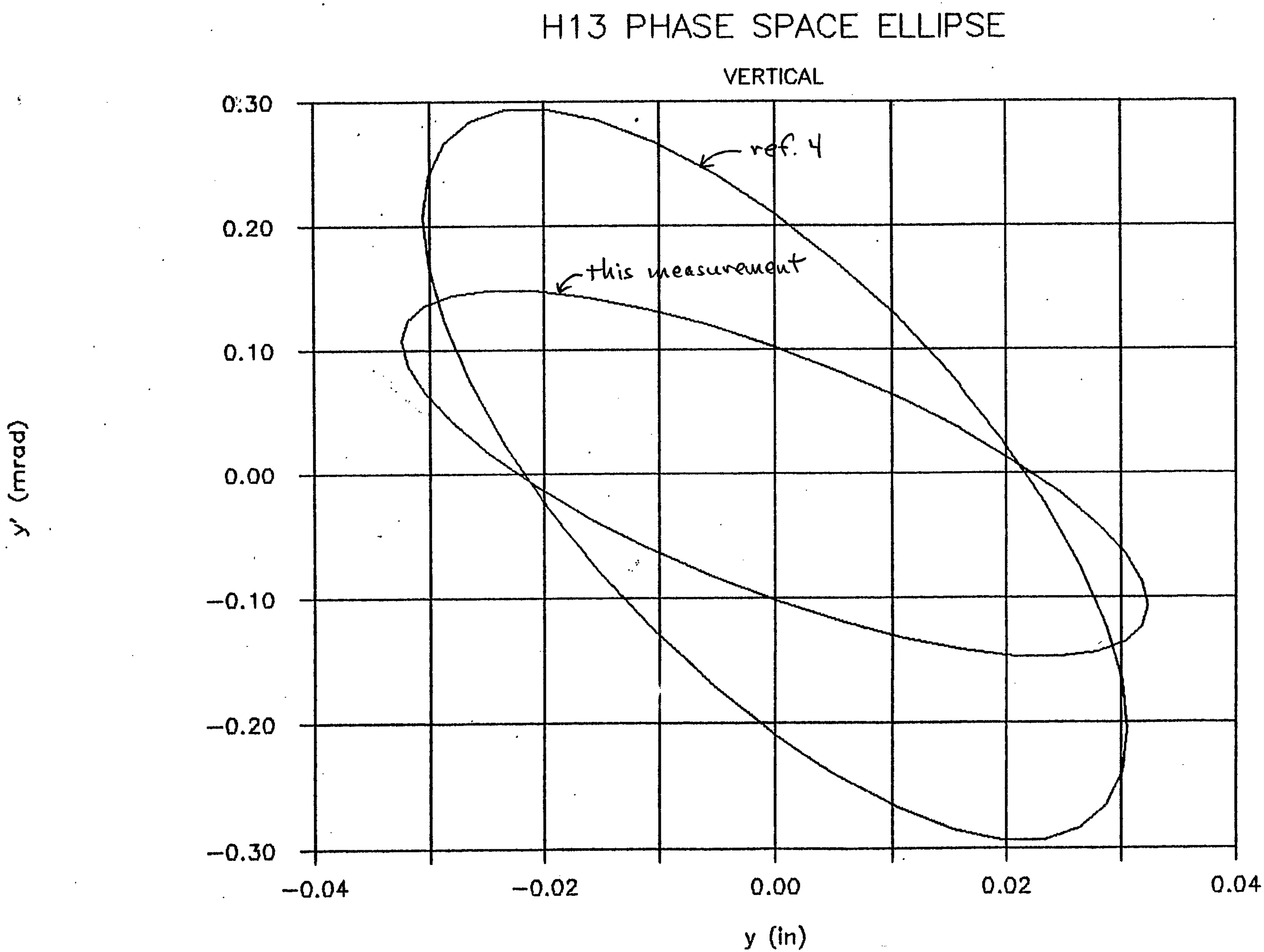

FILE:U6012(V) 5-NOV-85
XFMR=NONE
CY#= 1 SIG= 93.1
CY#= 2 SIG= 92.8
CY#= 3 SIG= 90.3
CY#= 4 SIG= 92.9
CY#= 5 SIG= 91.7
CY#= 6 SIG= 90.9
CY#= 7 SIG= 91.4
CY#= 8 SIG= 89.9
CY#= 9 SIG= 88.5
CY#=10 SIG= 89.3
Y(I)
X(I)-MILS

Figure 4



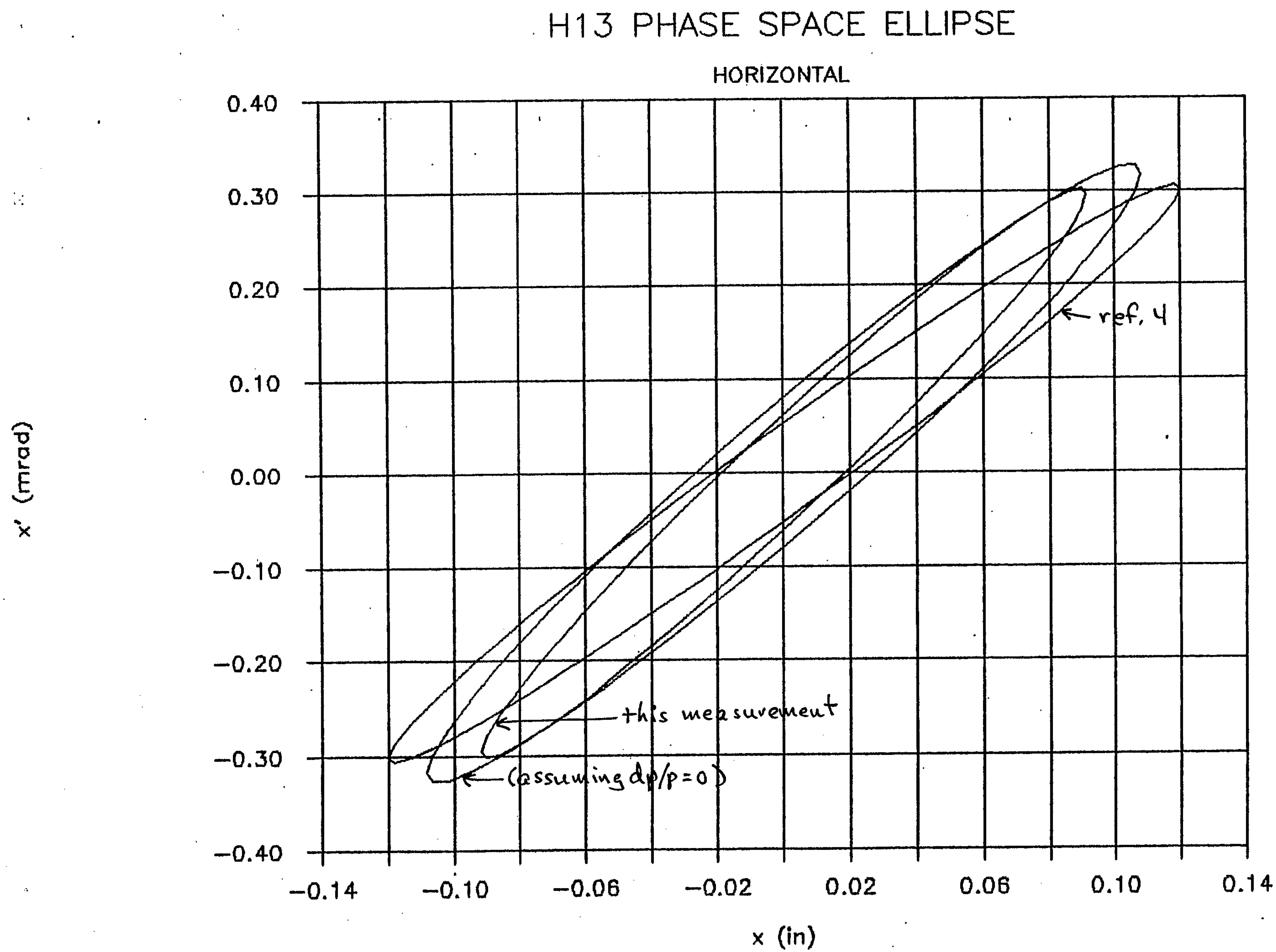
Horizontal size vs. Q2 current
(Q1 at 1723 Amps)
horizontal width, mils
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.6
0.8
1.0
1.2
1.4
1.6
1.8
(Thousands)
Q2 Amps
measured
calculated

Figure 5



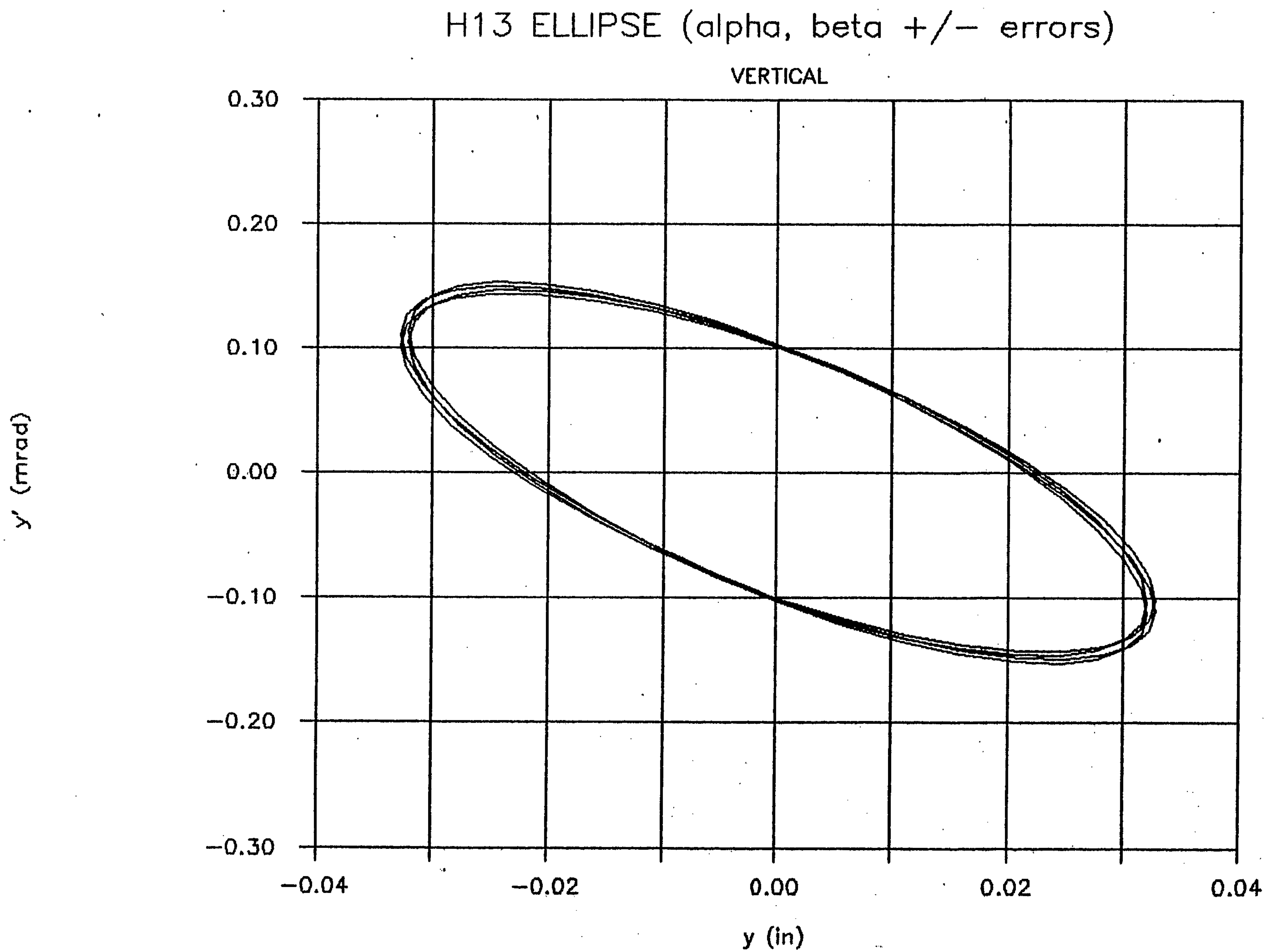
H13 PHASE SPACE ELLIPSE
VERTICAL
0.30
0.20
0.10
0.00
−0.10
−0.20
−0.30
y' (mrad)
−0.04
−0.02
0.00
0.02
0.04
y (in)
ref. 4
this measurement

Figure 6



H13 PHASE SPACE ELLIPSE
HORIZONTAL
0.40
0.30
0.20
0.10
0.00
−0.10
−0.20
−0.30
−0.40
−0.14
−0.10
−0.06
−0.02
0.02
0.06
0.10
0.14
x' (mrad)
x (in)
ref, 4
this measurement
(assuming dp/p=0)

Figure 7



H13 ELLIPSE (alpha, beta +/- errors)
VERTICAL
0.30
0.20
0.10
0.00
−0.10
−0.20
−0.30
y' (mrad)
−0.04
−0.02
0.00
0.02
0.04
y (in)

Figure 8

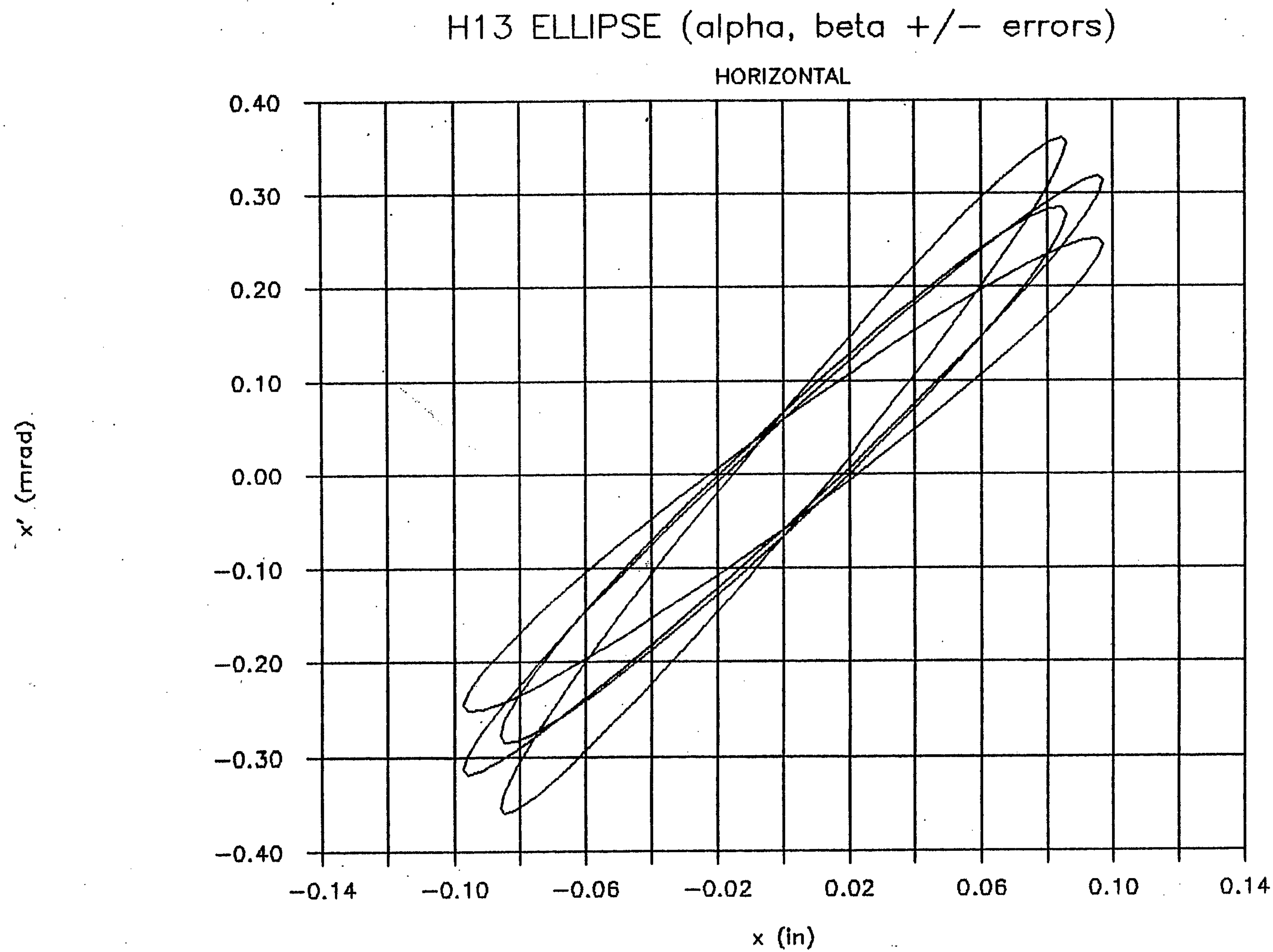

H13 ELLIPSE (alpha, beta +/- errors)
HORIZONTAL
0.40
0.30
0.20
0.10
0.00
−0.10
−0.20
−0.30
−0.40
x' (mrad)
−0.14
−0.10
−0.06
−0.02
0.02
0.06
0.10
0.14
x (in)

Figure 9