RESONANCE CORRECTION IN THE SNS

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Assumptions

1. assume one wants to correct non-lieneer resonances driven by magnet errors.
2. Initial correction will be done for low intensity, no space charge effects, case. (~~This may be sufficient~~)
3. Assume one can use BPM and fourier analyis to measure tunes as ~~func~~ function of betatron oscillation amplitude. HERA, FNAL (1990) to correct linear coupling resonance. (see Bourianoff and Pilat (SSC, 1991))
4. Tune versus amplitude can be used to correct non-linear resonences.

   Hayes, Schmidt, Tomas (2002, SPS)

   Bai, Blaskewitz, Lehrach, Rosen, Schmidt, Van Asselt (2001, BNL)

   Bartolini, Schmidt (1996, Simulation)

   Schmidt, Tomás, Faus-Golfe (2001, SPS)

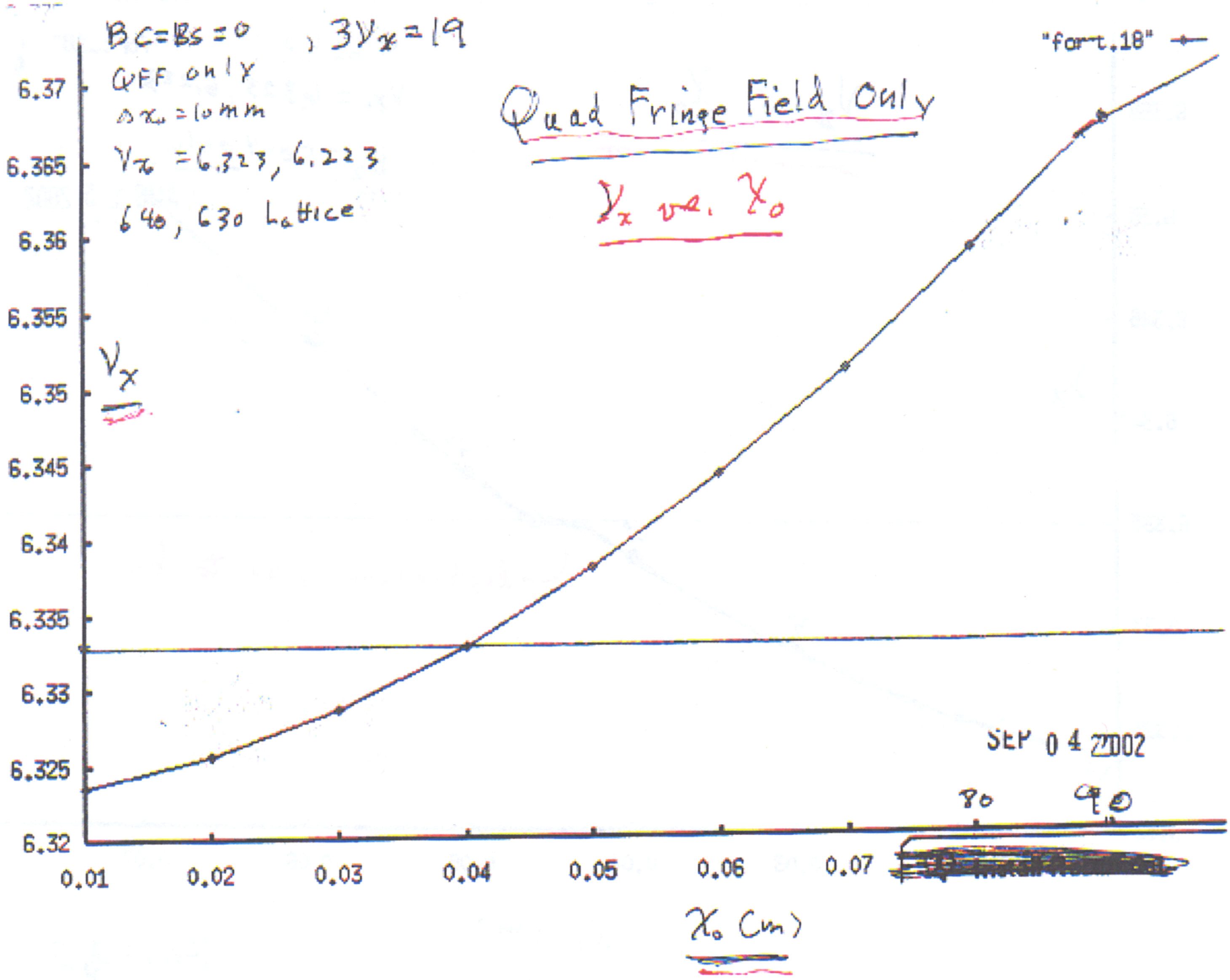
   Pruett, Wallenmeyer (1960, MURA)

Resonance Meter Choice

Resonance Meter – a measureable effect due to presence of non-linear resonance which can be used to measure "strength" of the resonance – depends on which resonance is to be corrected, and what other non-linear fields are present.

For SNS, tune verses amplitude due to quad fringe fields is strong enough to affect the effects of non-linear resonances due to magnet ~~effects~~ errors. One sees islands and distortions in phase space plots, but no direct instability.

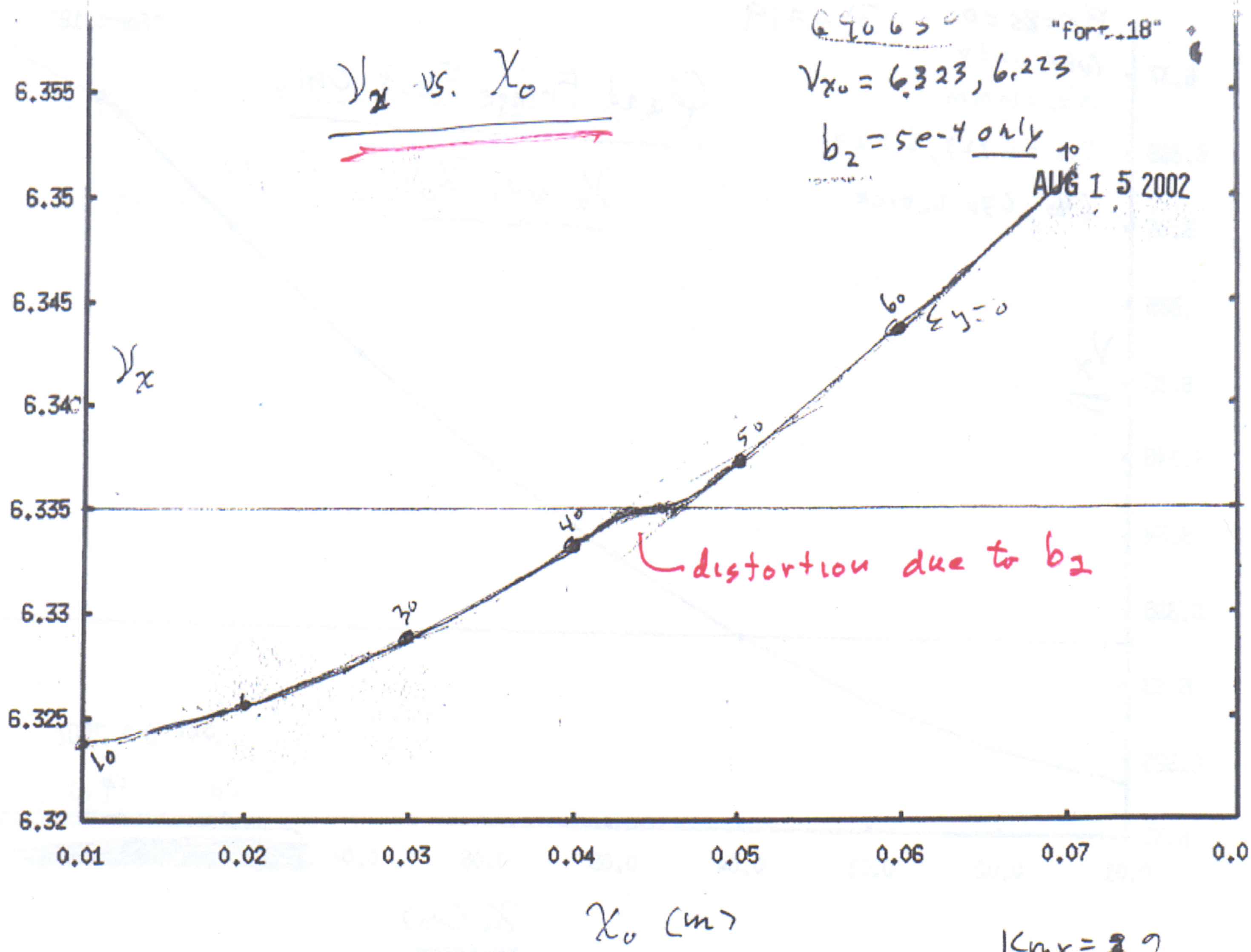
Simulation studies will indicate the choice of resonance meter.



6.40, 6.30 lattice

Move tune to 6.323, 6.223 for $3\nu_x=19$ resonance

Measure ν_x vs. x_0 ; y_0 small, $\epsilon_{y_0} = 1\times10^{-4}\,\epsilon_{x_0}$



Kmx = 2

energyc = 1n2

jthm xo = 1000

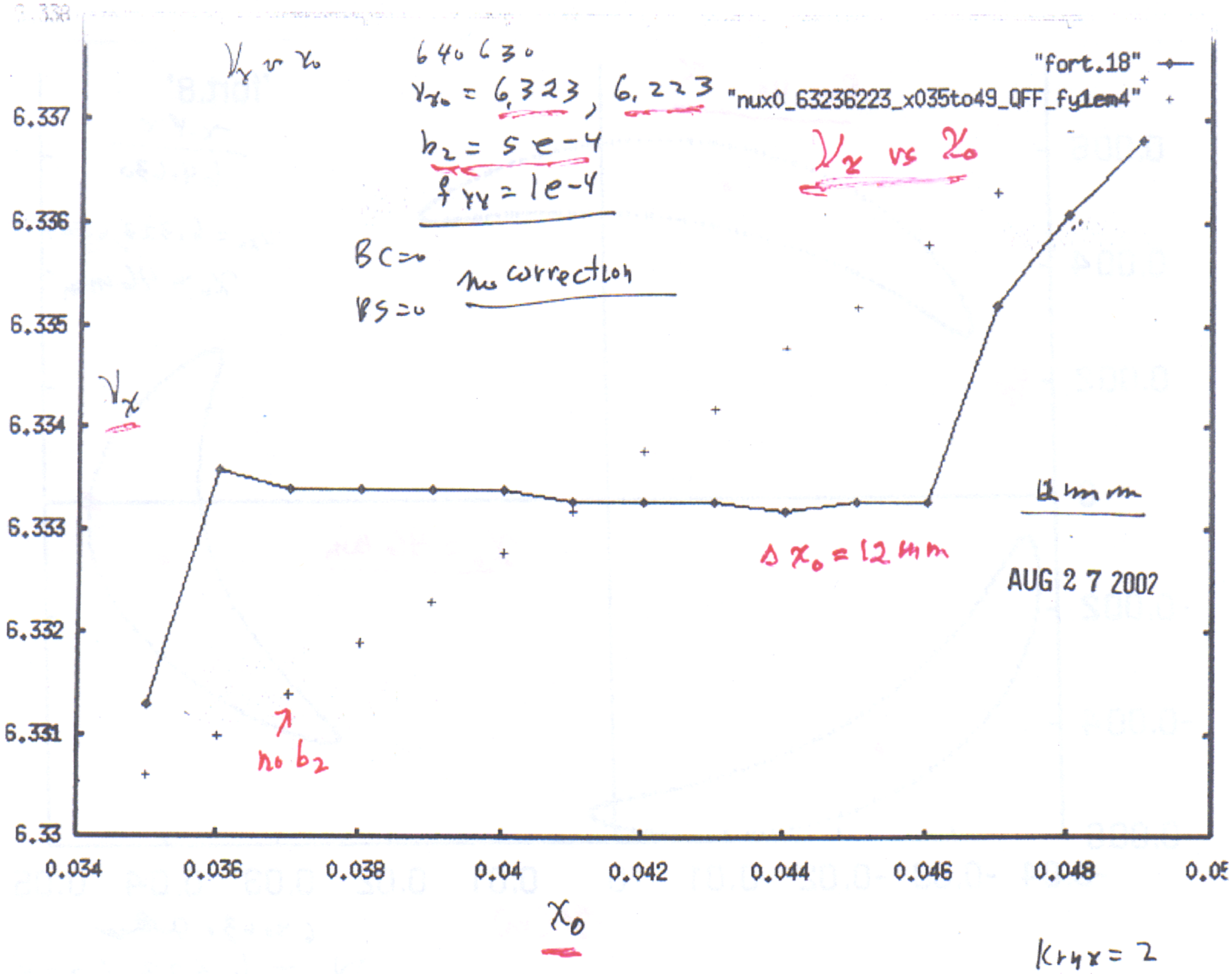
fxx=1, =vy=1e-4

y_0 small, ~~[illegible]~~ $\varepsilon_{y_0} = 10^{-4}\ \varepsilon_{x_0}$

$b_2 = 5 \times 10^{-4}$ at R of Iron.

$\simeq 3 \times 10^{-4}$ at R = 2/3 (R iron)

3-2



$b = 5e-4$ at R_{iron}

$b_2 = 3.3e-4$ at $\frac{2}{3} R_{iron}$

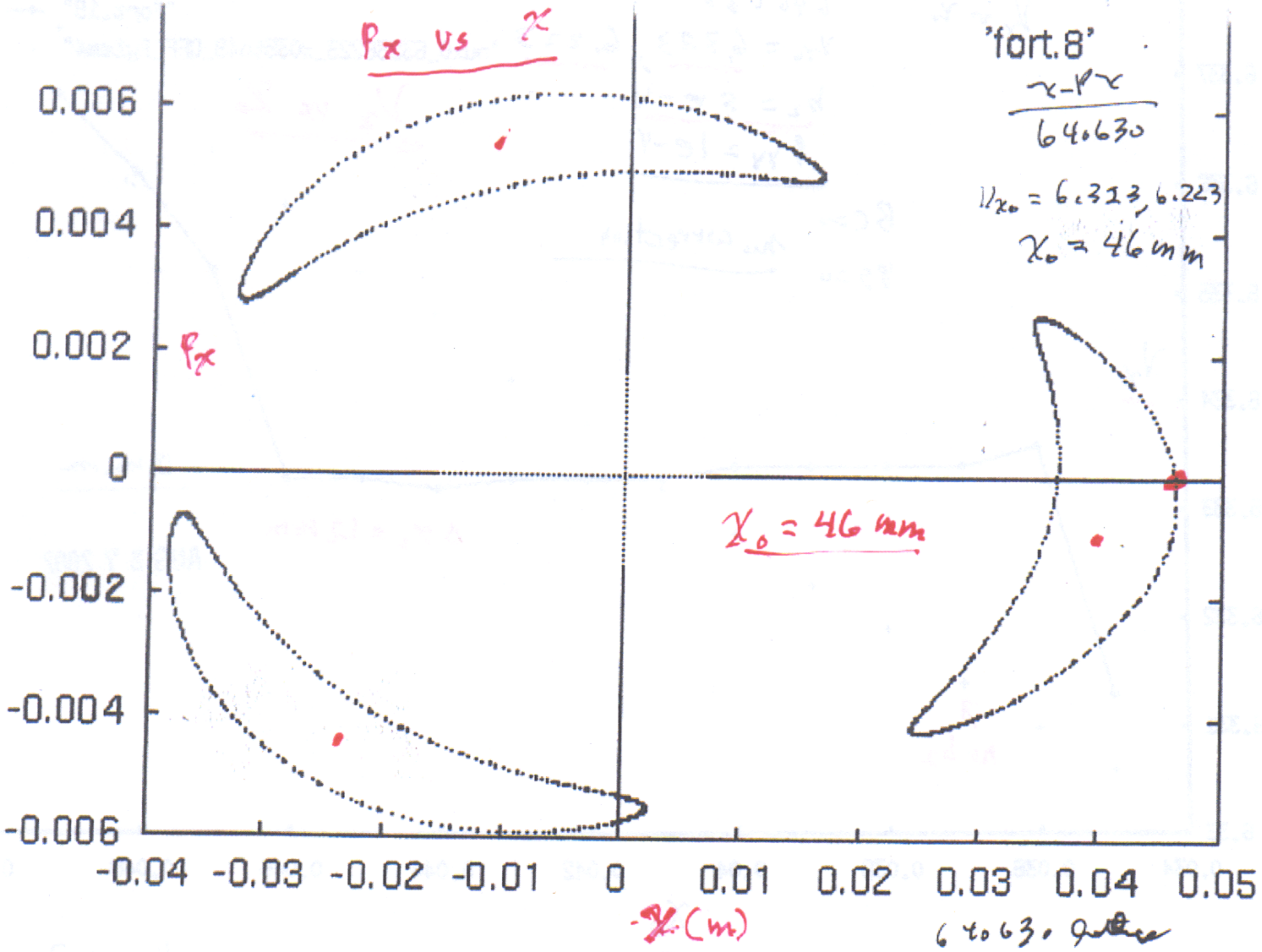
$k_{rhx} = 2$

$g_{tmax} = 500$

$f_{xx}=1$

$f_{yy}=1e-4$

3-3



6.4063, [illegible]

$\nu_{x_0} = 6.323, 6.223$

no [illegible]

BC, BS = 0

$k r_n x = 3$

~~[illegible]~~ in 2

1000 turns

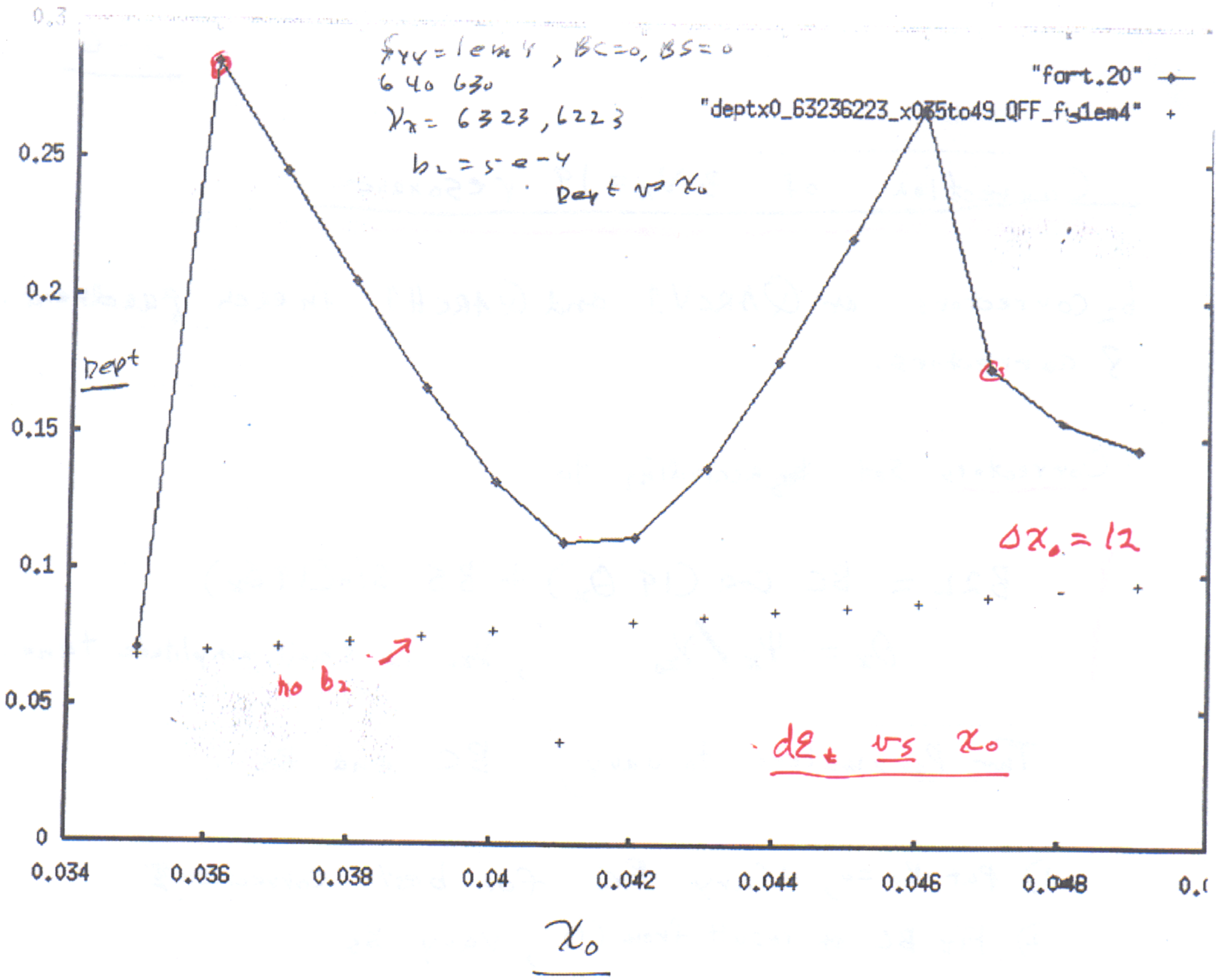
$x_0 = 46$

$f_{YY} = 1e{-4}$

ν_x appears constant across island.

ν_x in ν_x vs x_0 plot, is not tune, but is the main harmonic found by the Fourier Analysis which is $\nu_x = \cancel{[illegible]}\ 6.3333$ inside the island.

3-4



$$d\varepsilon_t = \frac{\varepsilon_{tmx} - \varepsilon_{tmn}}{\varepsilon_{tmx} + \varepsilon_{tmn}} = \text{emittance spread}$$

Does Δx_0 from distortion in ν_x vs x_0 give the width of the resonance?

Correction of $3\nu_x = 19$ resonance

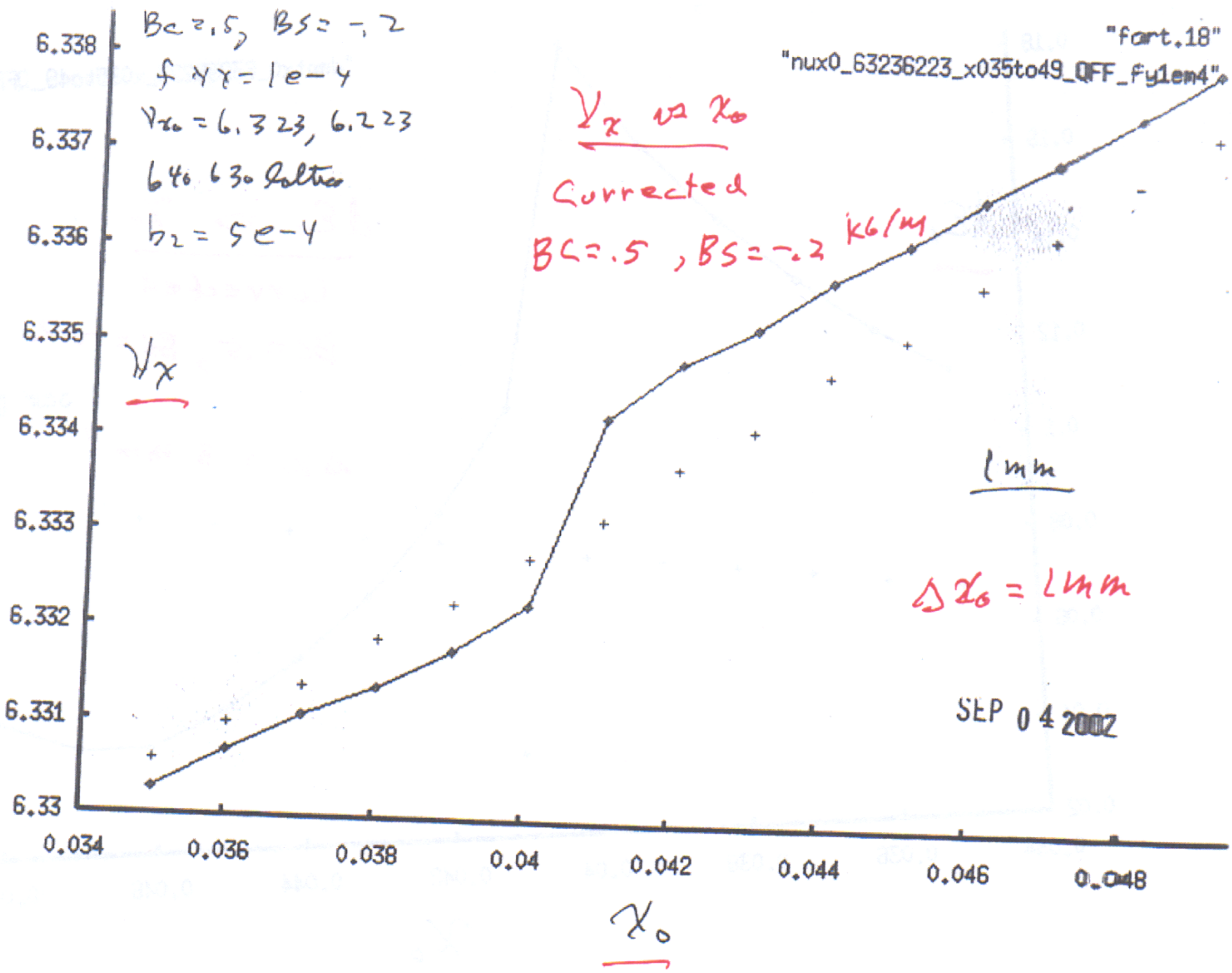
b_2 correctors at QARCV1 and QARCH1 in each quadrant.
8 correctors.

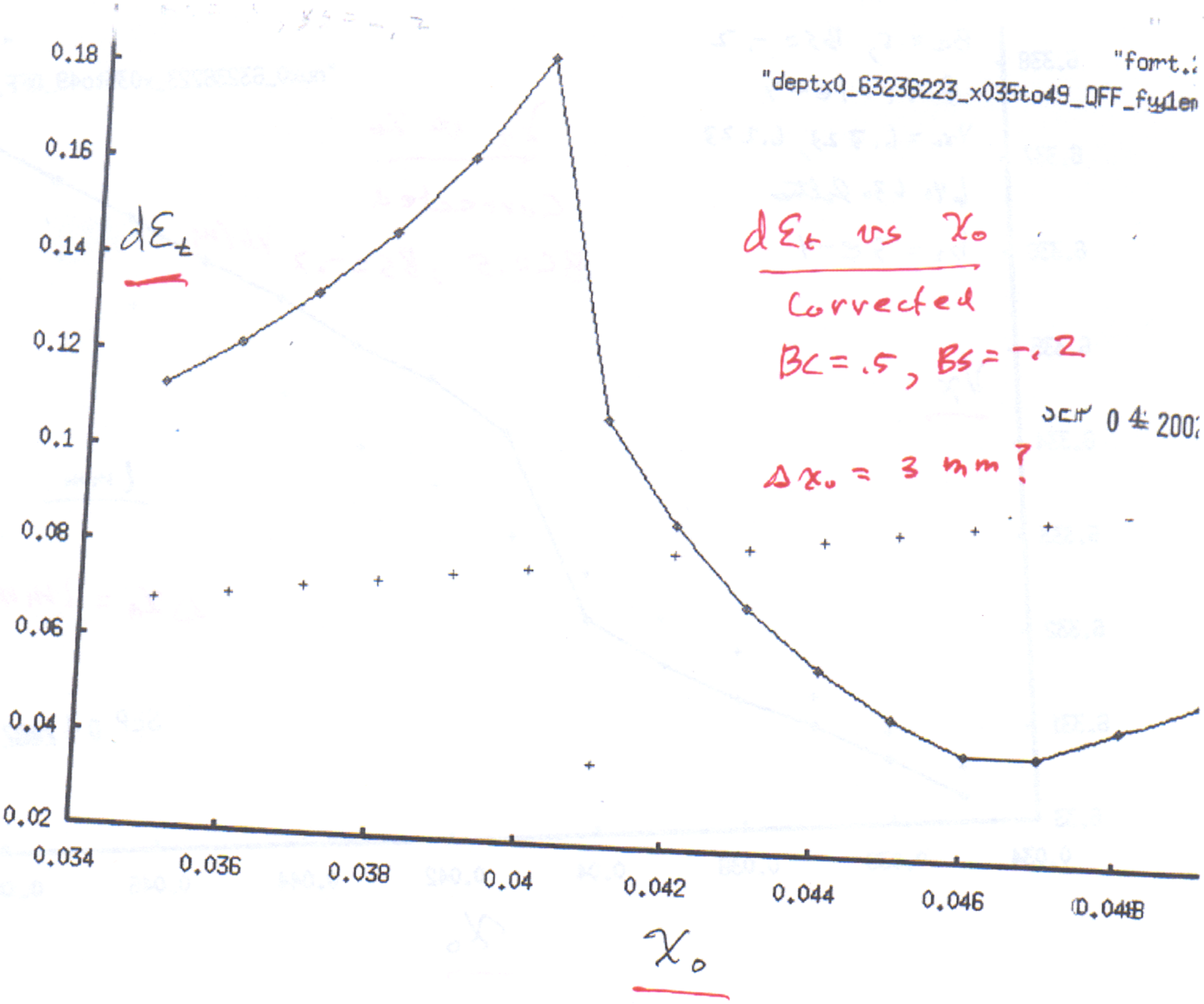
Correctors set ~~by~~ according to

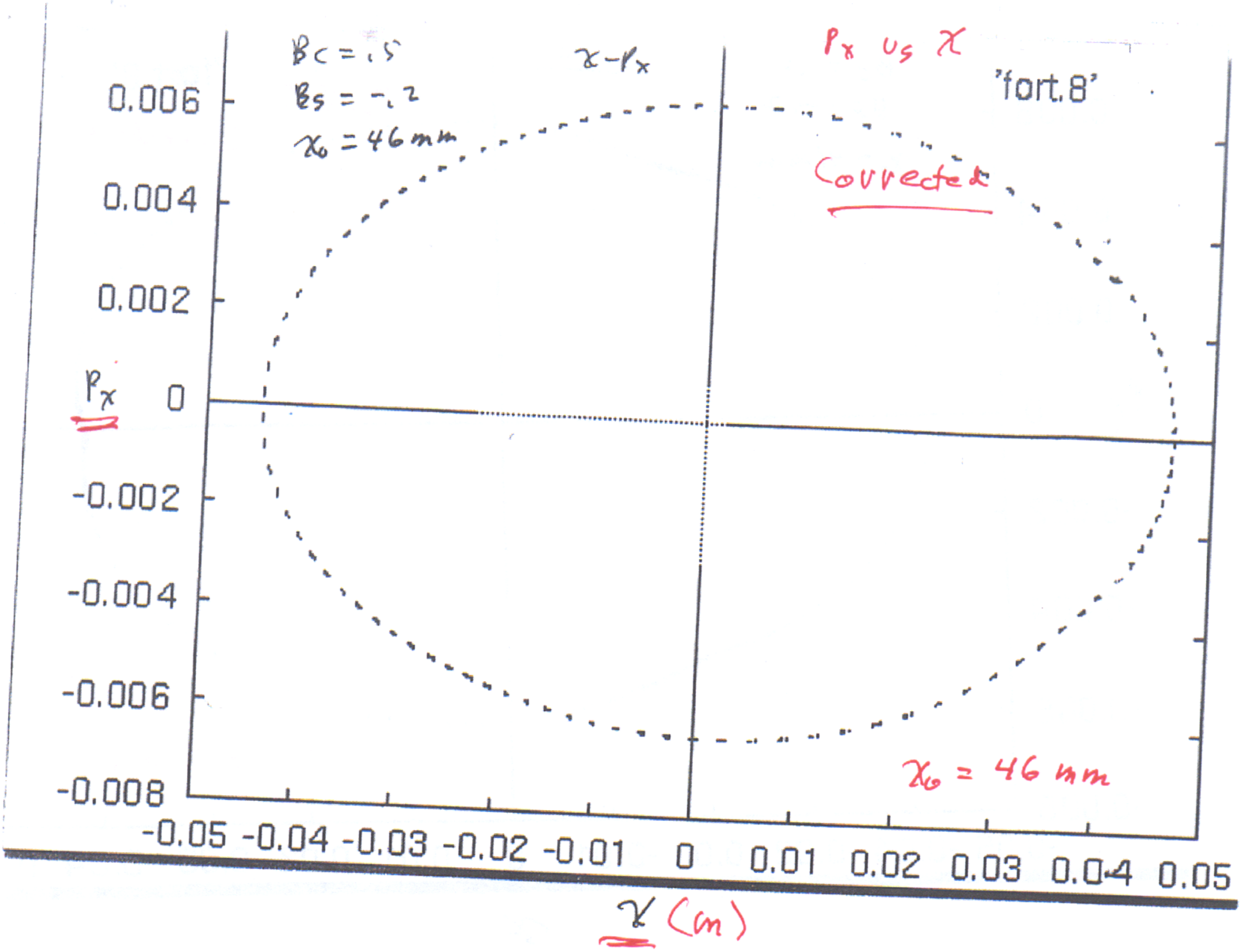
$$B2L = BC \cos(19\,\theta_x) + BS \sin(19\,\theta_x)$$
$$\theta_x = \psi_x / \nu_{x0}$$, ν_{x0} is small amplitude tune.

Two Parameters to vary, BC and BS

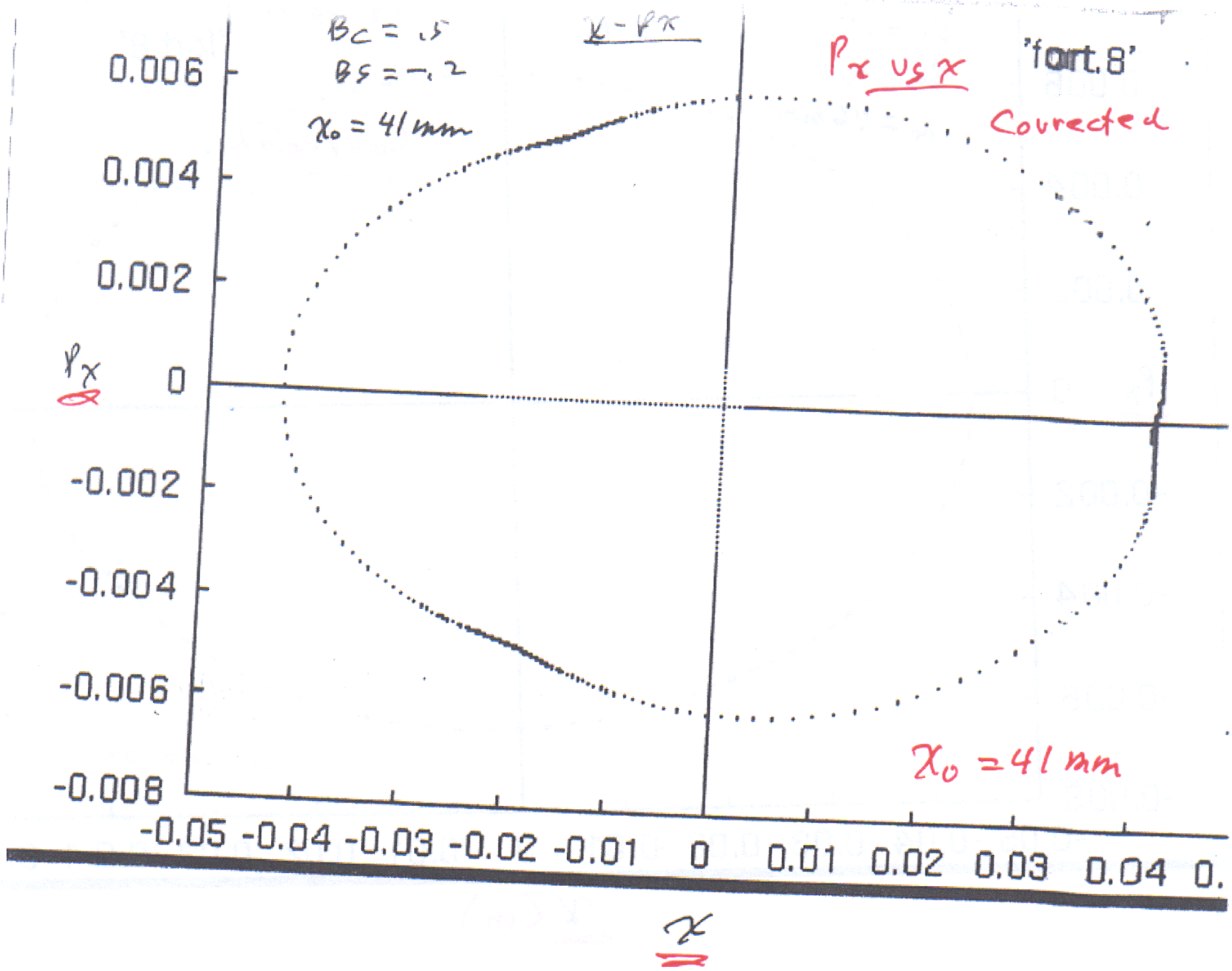
1) Put $B_S = 0$, Vary BC for best correction.
2) Fix BC at result from 1, vary B_S
3) repeat


Bc=.5, Bs=-.2
f xx=1e-4
νx0 = 6.323, 6.223
640 630 Saltu
b2 = 5e-4
"fort.18"
"nux0_63236223_x035to49_QFF_fy1em4"
νx vs x0
Corrected
BC=.5 , BS=-.2 KG/m
νx
1mm
Δx0 = 1mm
SEP 0 4 2002
6.338
6.337
6.336
6.335
6.334
6.333
6.332
6.331
6.33
0.034
0.036
0.038
0.04
0.042
0.044
0.046
0.048
x0


"fort.:
"deptx0_63236223_x035to49_QFF_fy1em
dE_t
dE_t vs x_0
Corrected
Bc = .5, Bs = -.2
SEP 0 4 200
Δx_0 = 3 mm?
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0.034
0.036
0.038
0.04
0.042
0.044
0.046
0.048
x_0



$x_0 = 46$ mm gave the islands uncorrected



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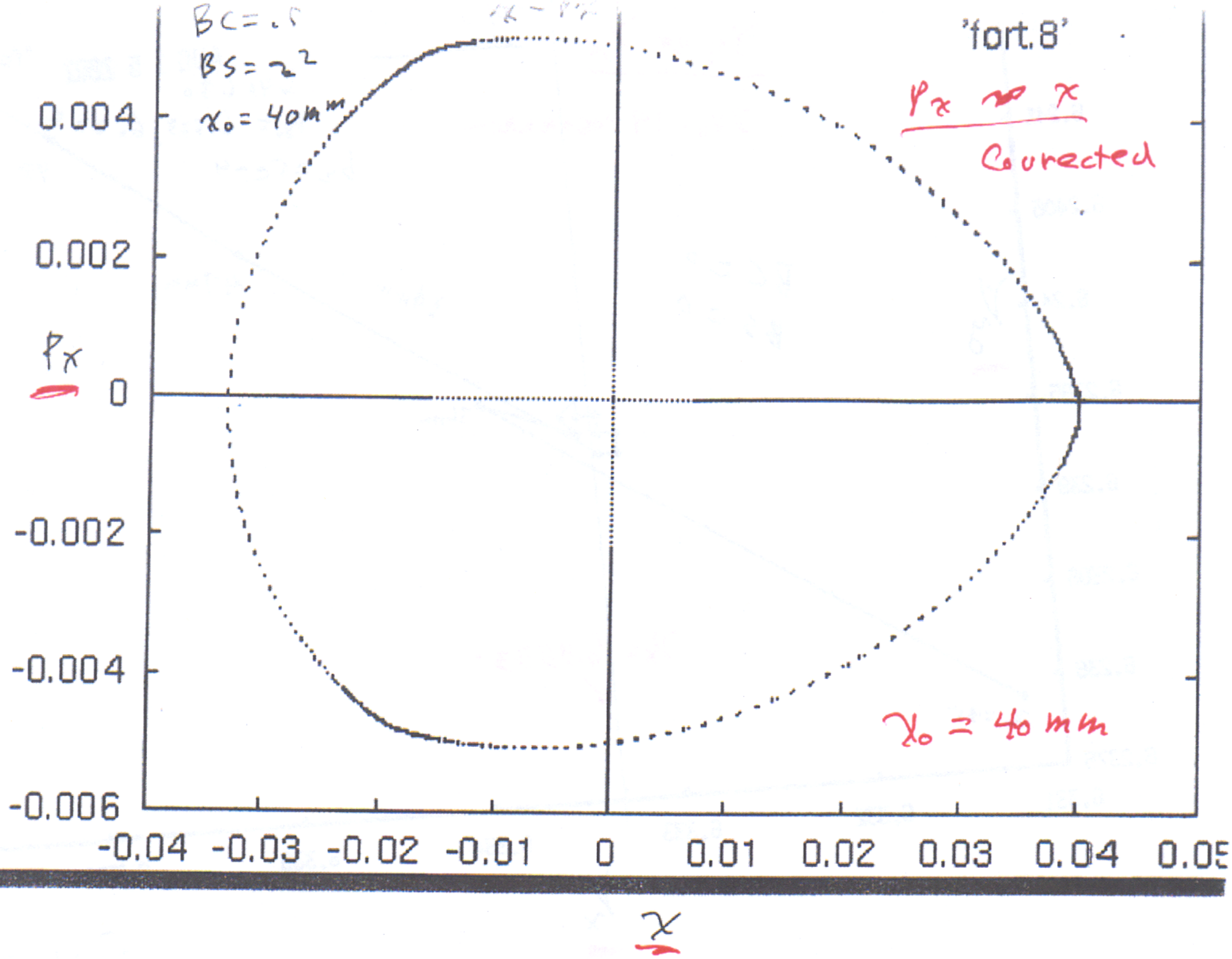
ν_x vs x_0 distortion indicates resonance

extends from $x_0 = 40$ to $x_0 = 41\,mm$



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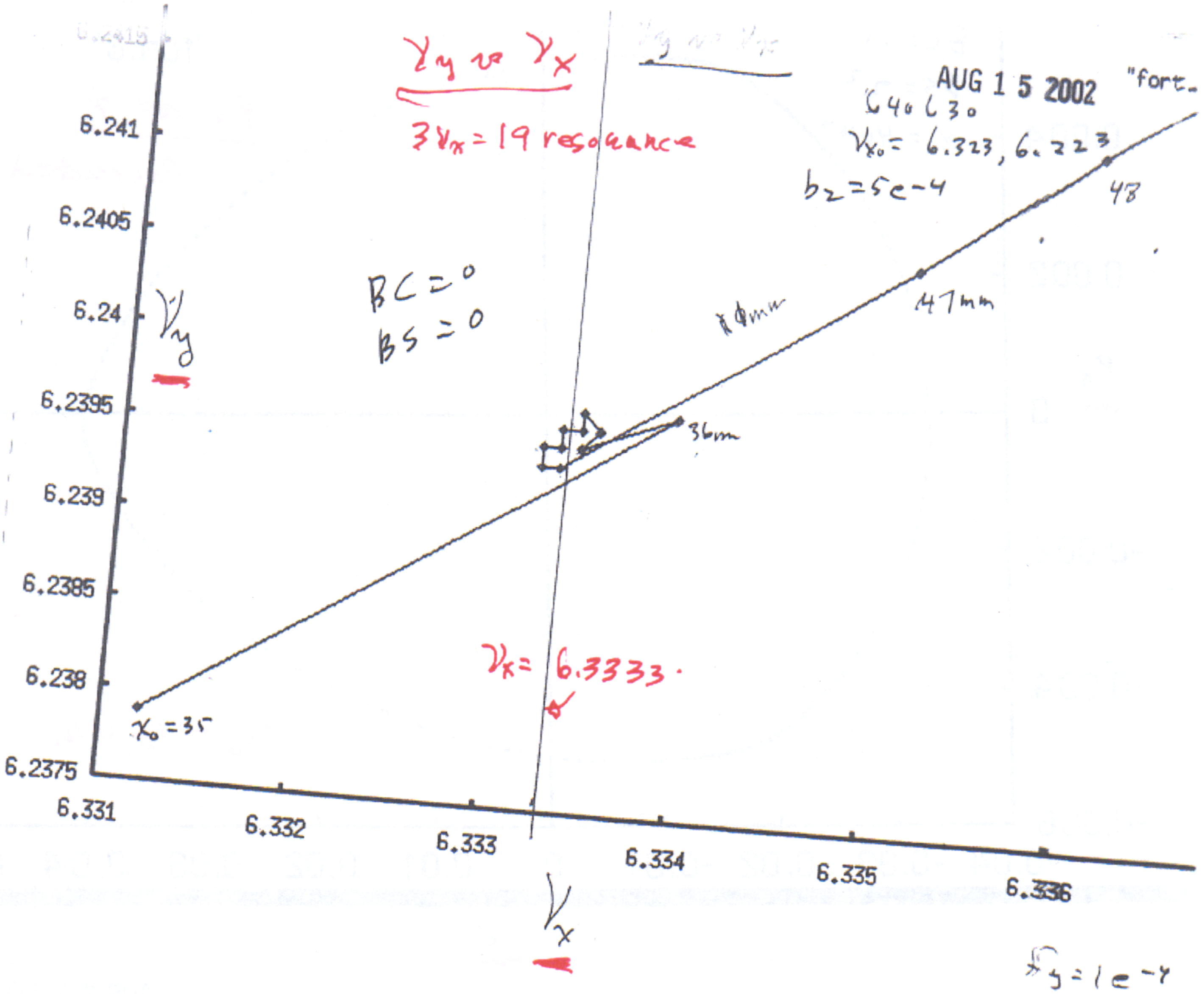
3-11



$\delta_y = 1e^{-4}$

$\delta x = 1$

#turn = 1000

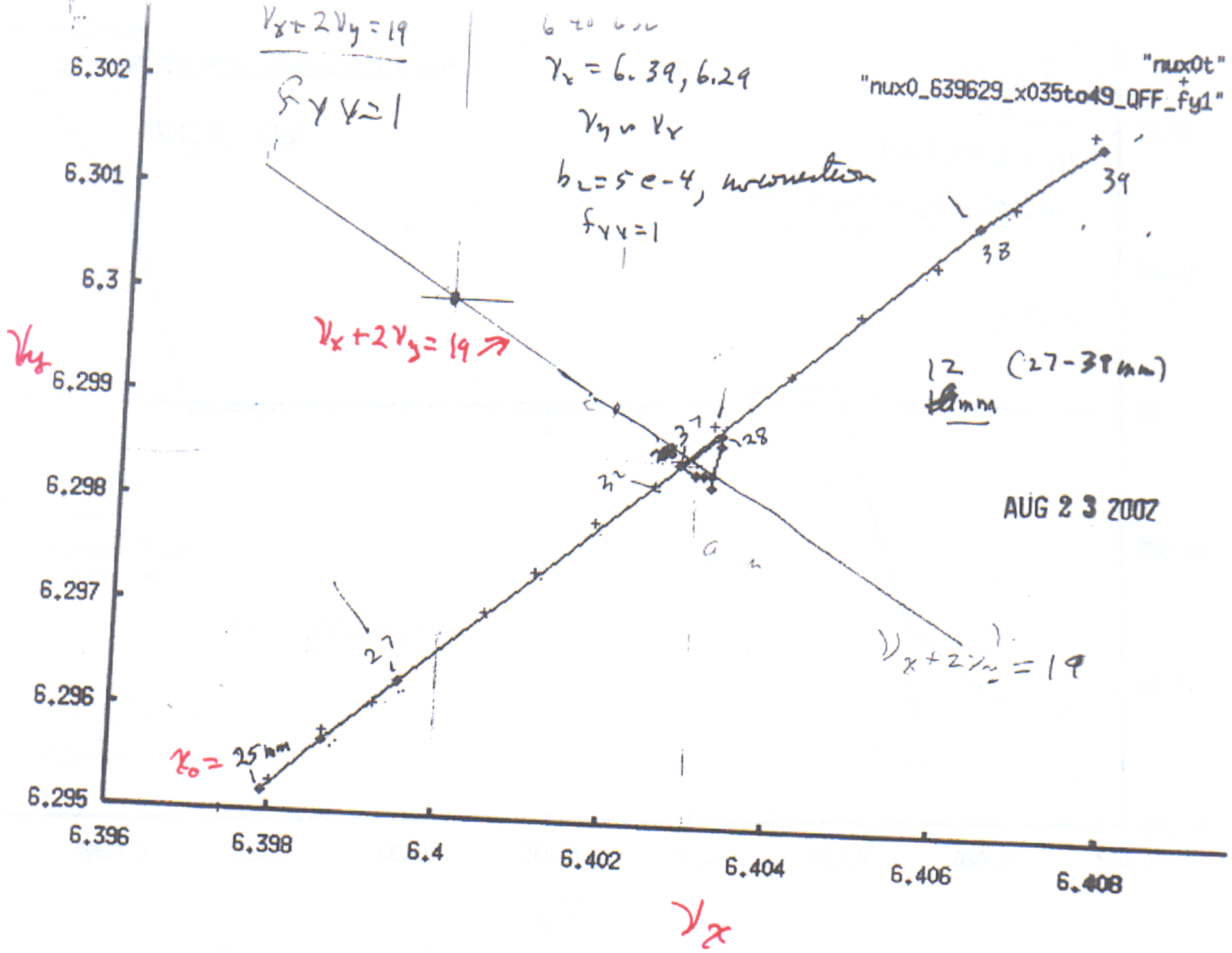
krux = 3

$b_2 = 5e^{-4}$

ν_y vs ν_x Could be used to correct

ν_y, ν_x distortion due to b_2

but more difficult to interpert.



$f_{yy}=1$

krnx =

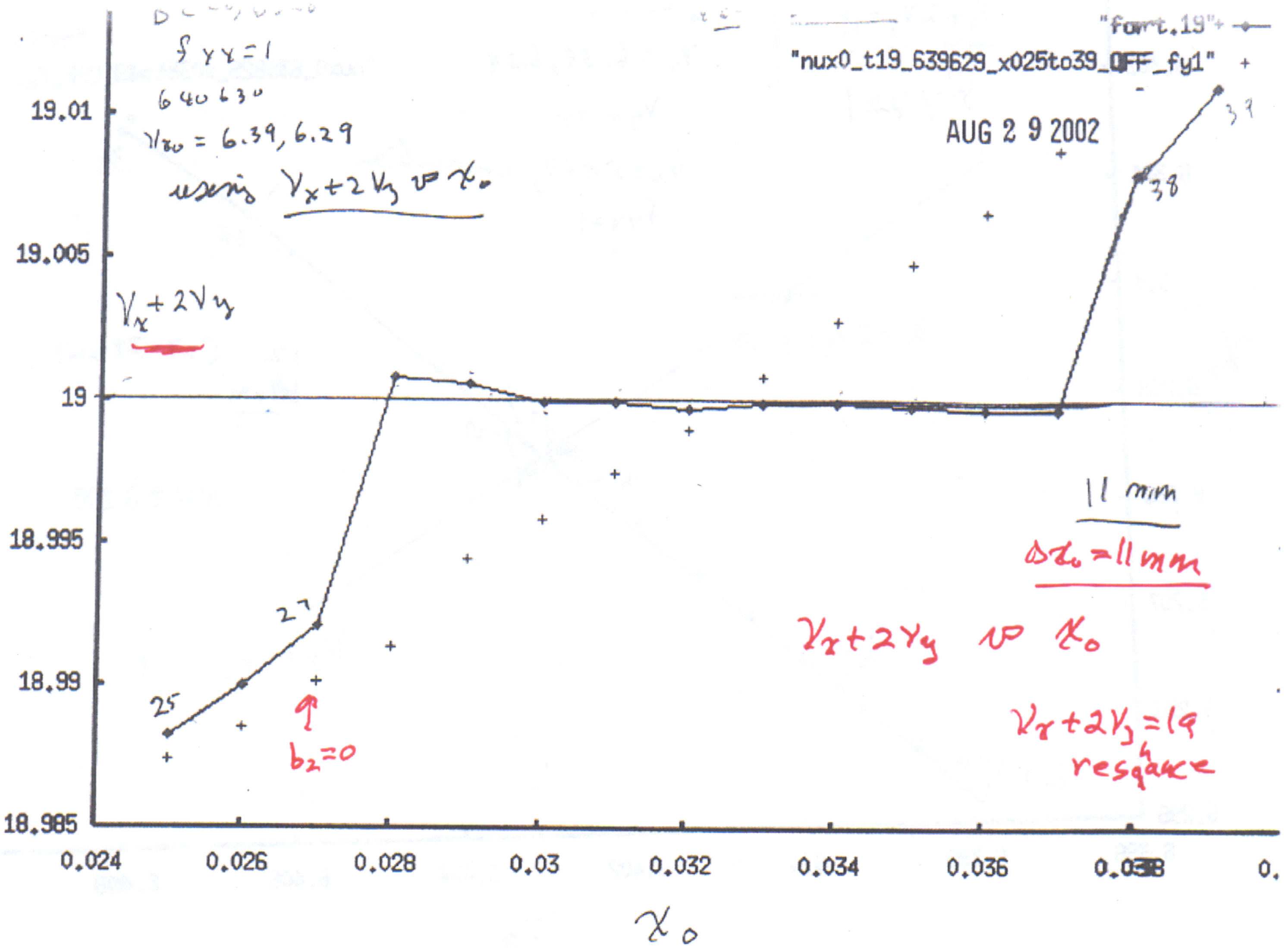
Ln 2

$\nu_x+2\nu_y=19$ resonance

move ν_{x0}, ν_{y0} to 6.39, 6.29

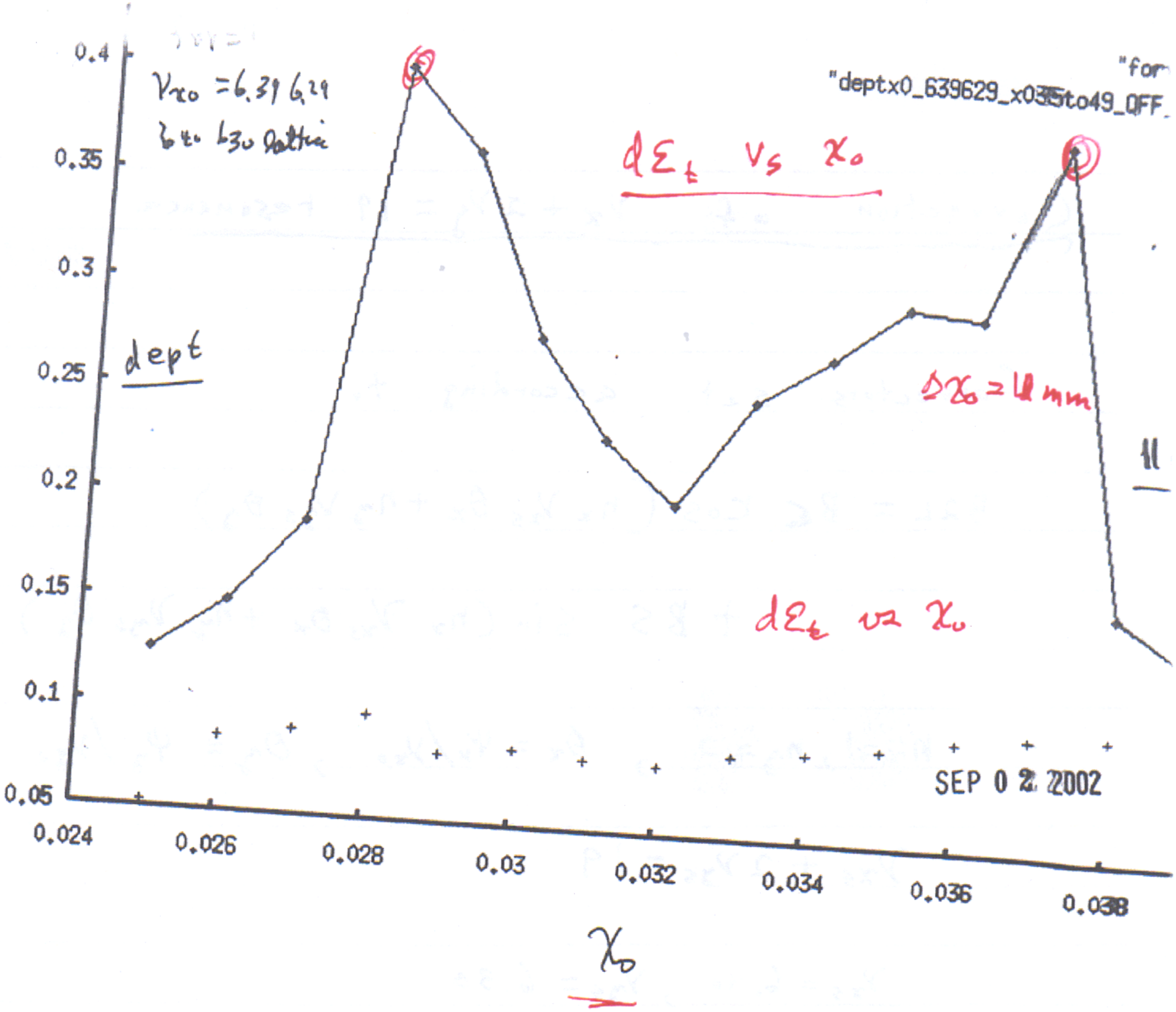
just below $\nu_x+2\nu_y=19$ resonance

$\varepsilon_y = \varepsilon_x$, y motion large.



$\varepsilon_y = \varepsilon_x$

"Islands" in 4D phase space –
main harmonics in x motion and y motion
obey $\nu_x + 2\nu_y = 19$.



"for
"deptx0_639629_x035to49_OFF_
$\nu_{x0} = 6.39\ 6.29$
dept
$d\varepsilon_t$ vs x_0
$\Delta x_0 = 11\ mm$
$d\varepsilon_t$ vs x_0
SEP 0 2 2002
x_0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0.024
0.026
0.028
0.03
0.032
0.034
0.036
0.038

Correction of $\nu_x + 2\nu_y = 19$ resonance

Correctors set according to

$$B2L = BC \cos(n_x \nu_{xs} \theta_x + n_y \nu_{ys} \theta_y)$$

$$+ BS \sin(n_x \nu_{xs} \theta_x + n_y \nu_{ys} \theta_y)$$

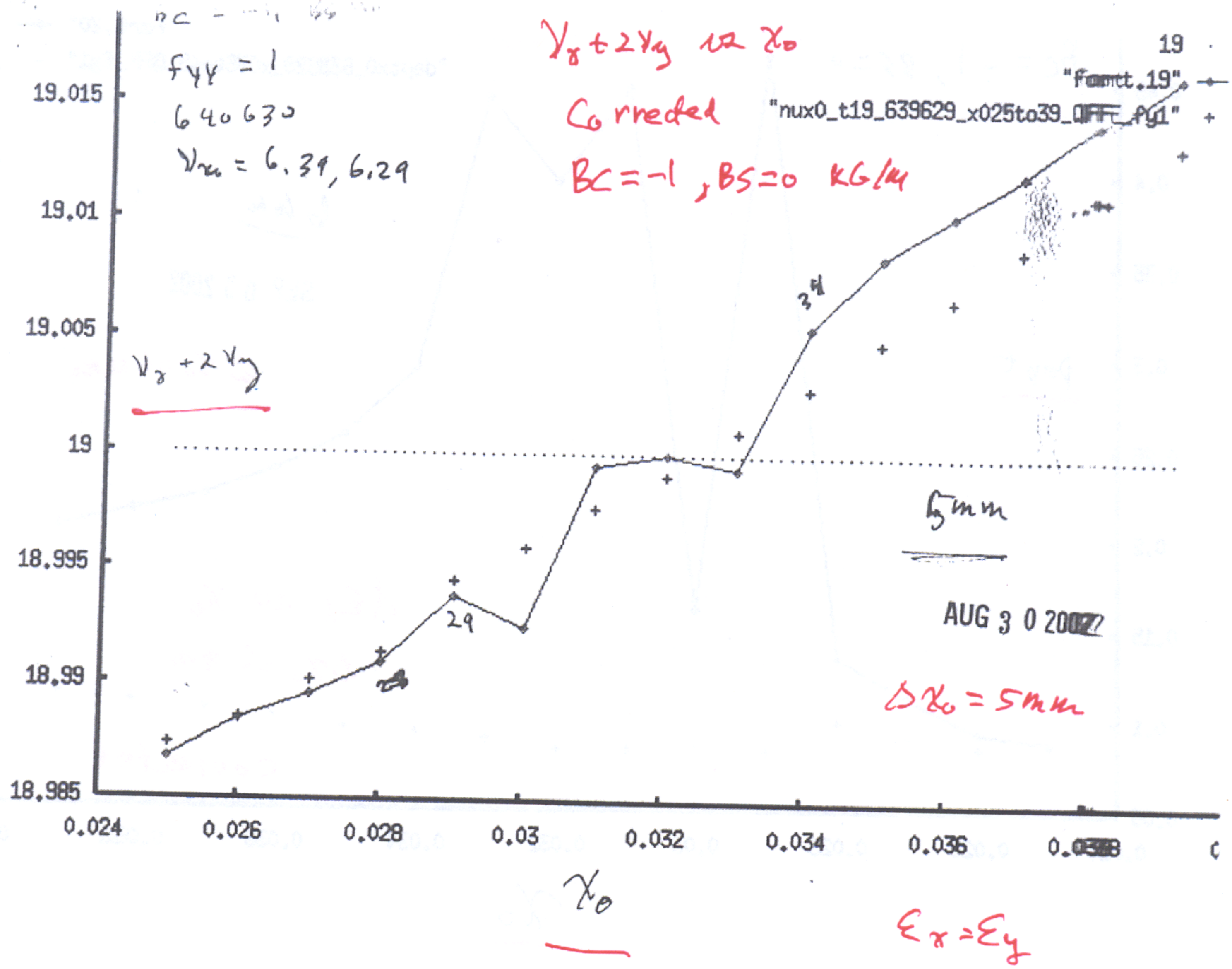
$n_x = 1, n_y = 2$, $\theta_x = \psi_x / \nu_{x0}$, $\theta_y = \psi_y / \nu_{y0}$

$\nu_{xs} + 2\nu_{ys} = 19$

$\nu_{xs} = 6.40$, $\nu_{ys} = 6.30$

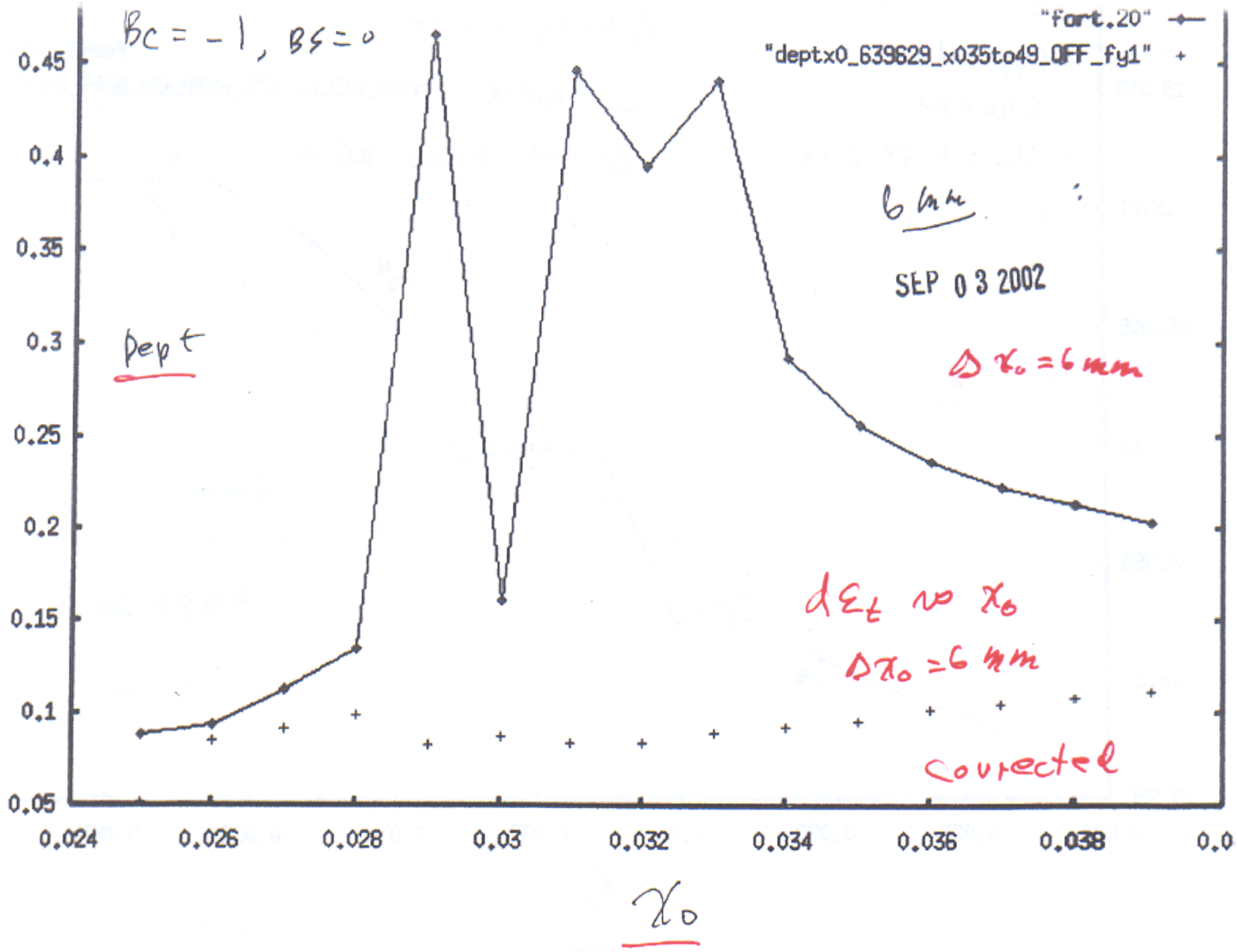
$\nu_{xs} = 6.4030$, $\nu_{ys} = 6.2985$

Vary 2 parameters, BC, BS

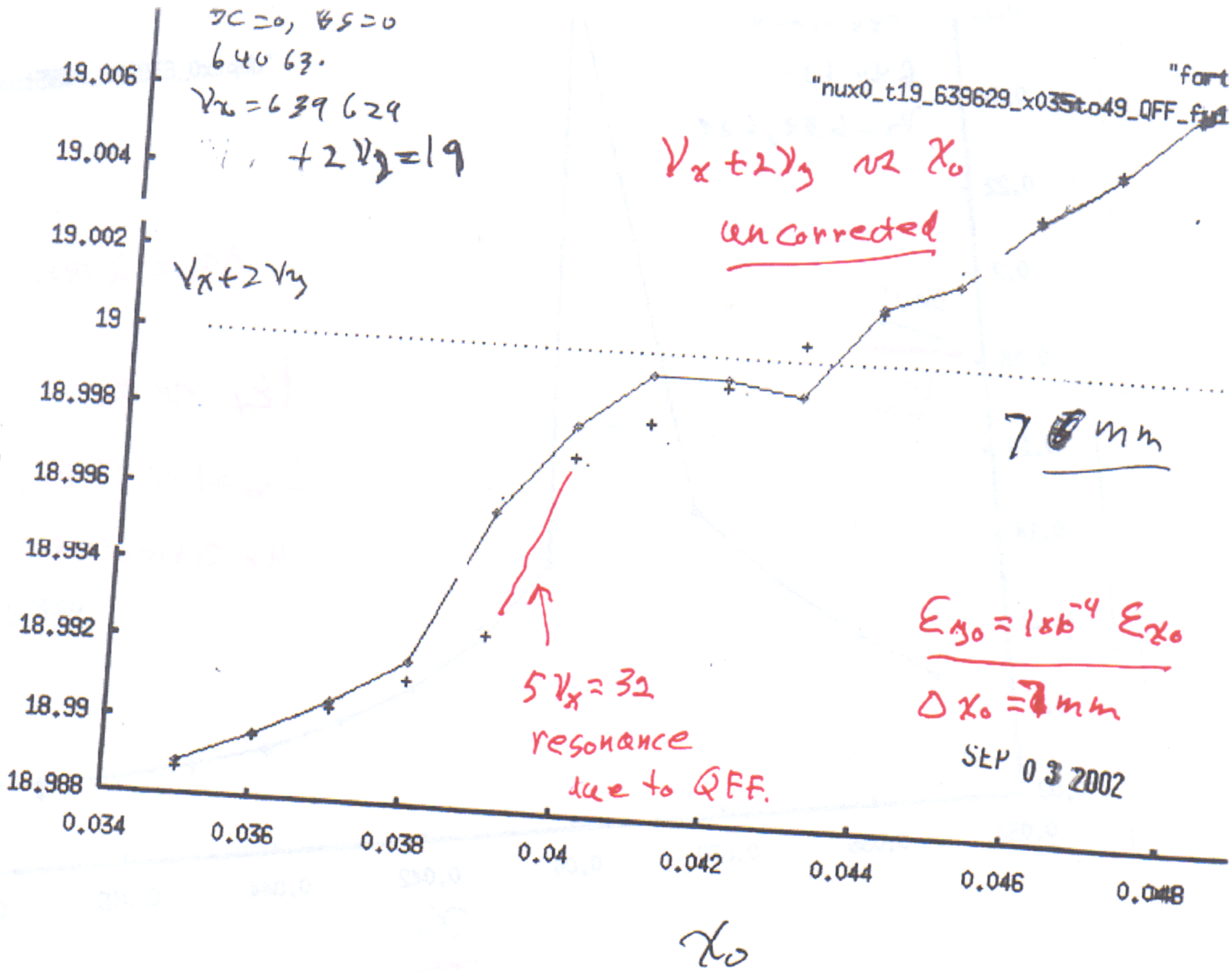


Δx reduced from 11mm to 5 mm.

How to improve Correction?



$B_C = -1, B_S = 0$
"fort.20"
"deptx0_639629_x035to49_OFF_fy1"
6 mm
SEP 0 3 2002
Dept
$\Delta x_0 = 6$ mm
$d\varepsilon_t$ vs x_0
$\Delta x_0 = 6$ mm
corrected
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0.024
0.026
0.028
0.03
0.032
0.034
0.036
0.038
0.0
x_0



For $\varepsilon_{y0} = 1 \times 10^{-4} \cdot \varepsilon_{x0}$.

resonance width is smaller

Complicated by $5\nu_x = 32$ resonance.

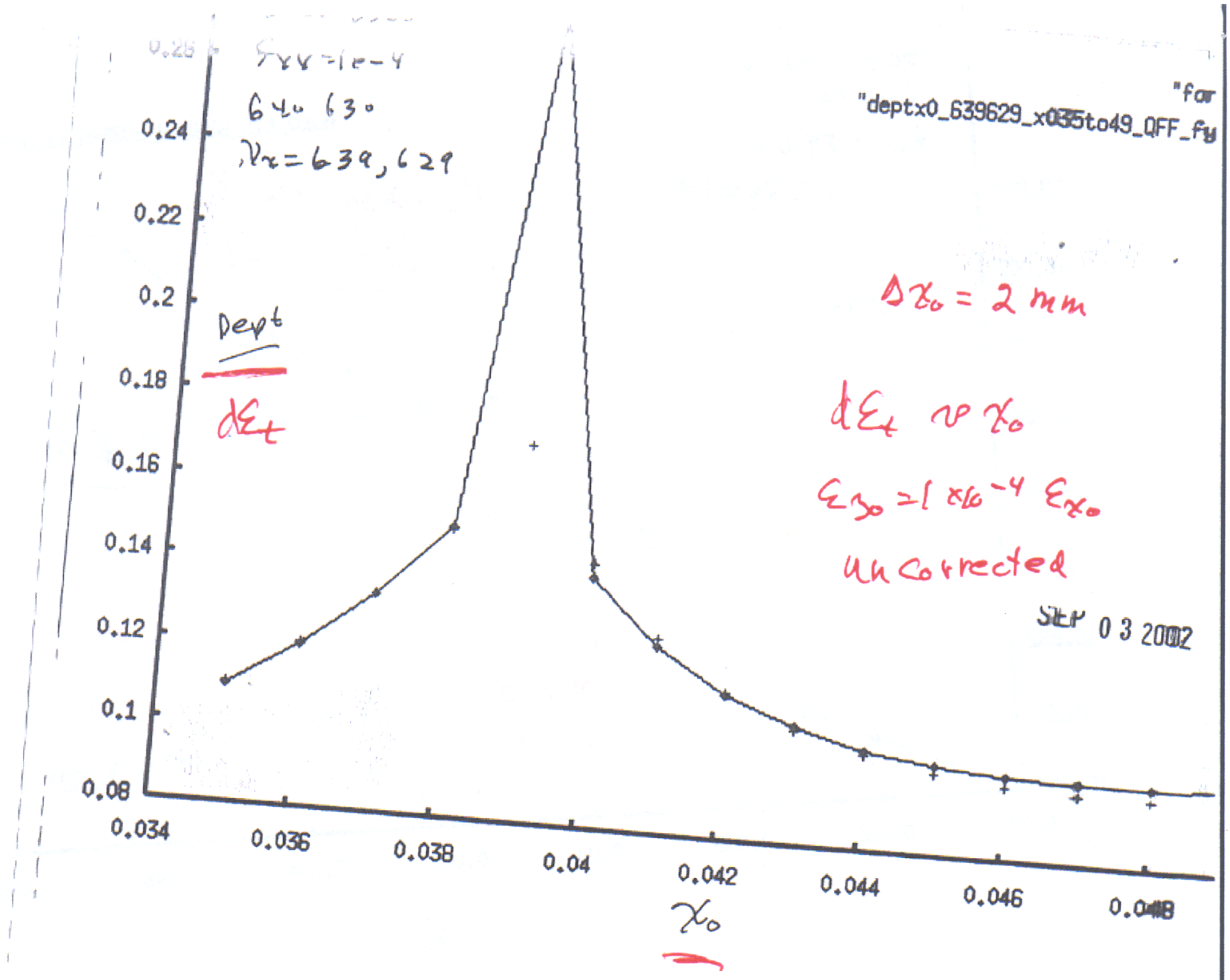
Two reasons not to use

$\varepsilon_{y0} = 1 \times 10^{-4}\ \varepsilon_{x0}$

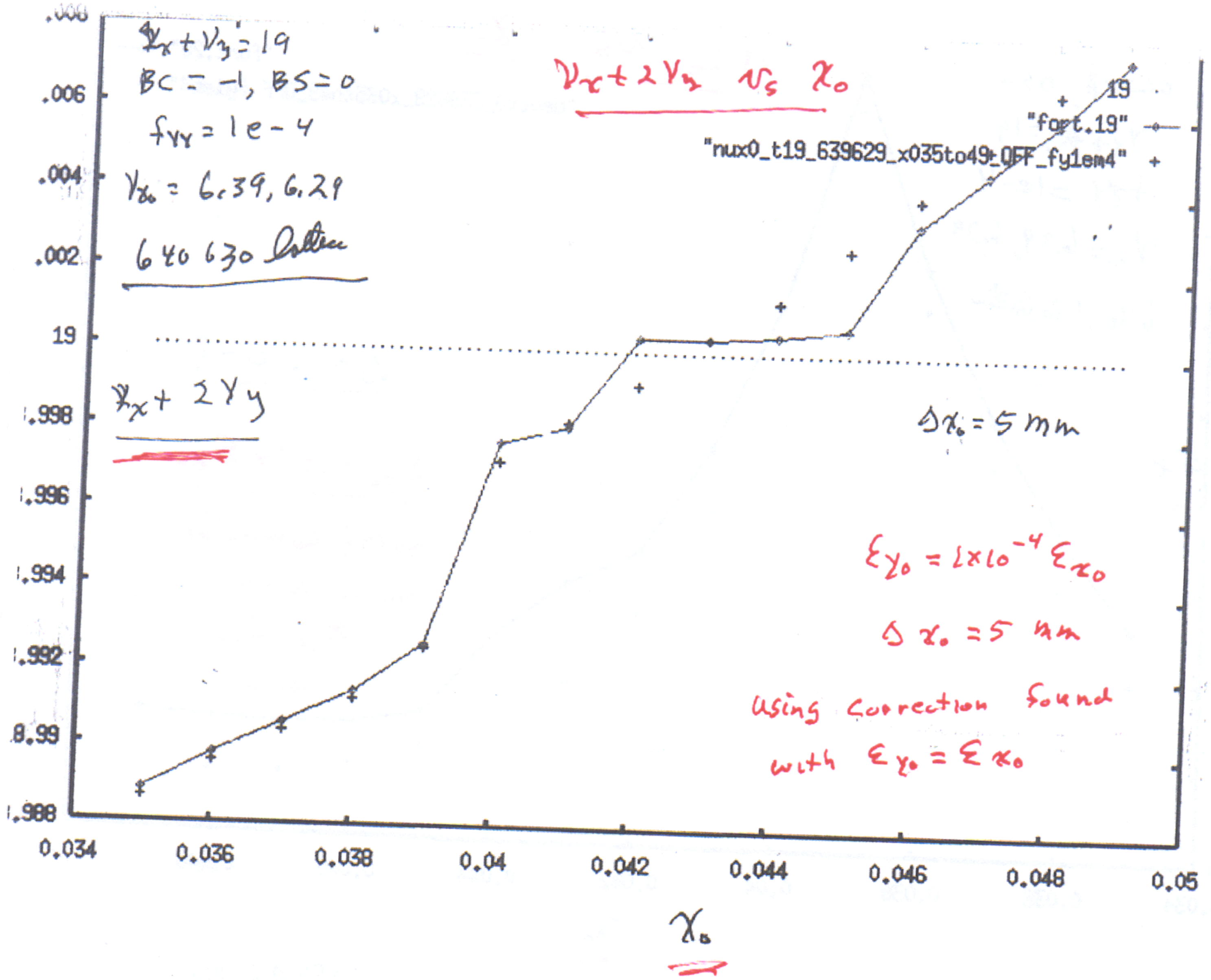
using $f_{YX} = 1e-4$ distribution

resonance width small

One has to use the $f_{YX} = 1$ distribution

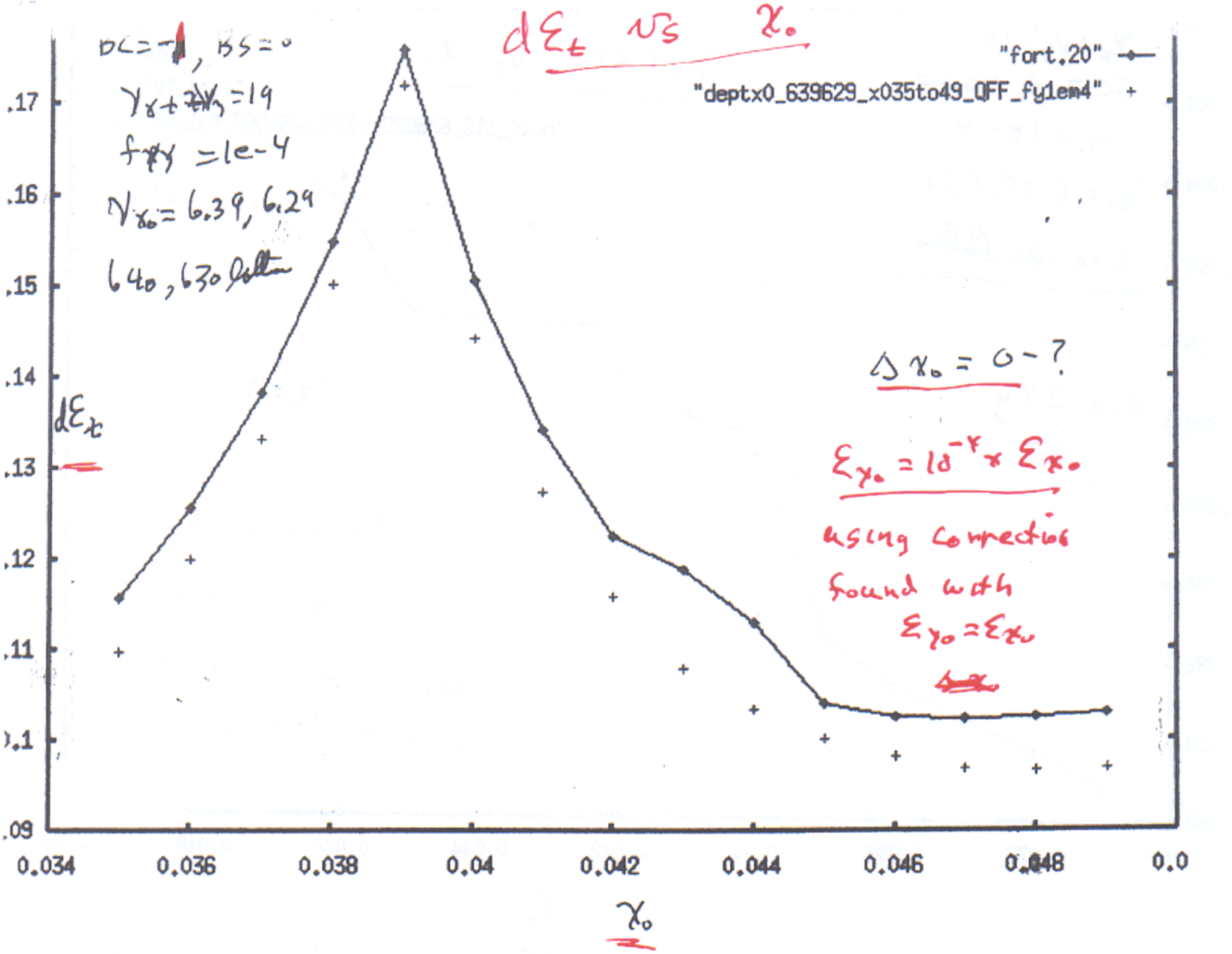


$\epsilon_{yy} = 1e-4$
640 630
$\nu_x = 639, 629$
"for
"deptx0_639629_x035to49_QFF_fy
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.034
0.036
0.038
0.04
0.042
0.044
0.046
0.048
Dept
$d\mathcal{E}_t$
x_0
$\Delta x_0 = 2$ mm
$d\mathcal{E}_t$ v x_0
$\mathcal{E}_{y_0} = 1 \times 10^{-4}\ \mathcal{E}_{x_0}$
uncorrected
SEP 0 3 2002



νx + νy = 19
BC = -1, BS = 0
fYY = 1e-4
νx0 = 6.39, 6.29
640 630 lattice
νx + 2νy vs x0
19
"fort.19"
"nux0_t19_639629_x035to49_OFF_fy1em4"
νx + 2νy
Δx0 = 5 mm
εy0 = 1×10^-4 εx0
Δ x0 = 5 mm
using correction found
with εy0 = ε x0
.006
.004
.002
19
.998
.996
.994
.992
8.99
.988
0.034
0.036
0.038
0.04
0.042
0.044
0.046
0.048
0.05
x0

SEP 0 6 2002



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Questions – To do List

1. Octupole correctors – There are b_3 correctors but no skew, a_3, correctors

2. Correction of a_2 driven resonances.
   $2\nu_x + \nu_y = 19$, $3\nu_y = 19$

3. Correction of b_3 driven resonances
   $4\nu_x = 25$, $2\nu_x + 2\nu_y = 25$ $4\nu_y = 25$

4. Hardware and Software for tune versus amplitude correction using BPM.