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# Simulation study of the longitudinal damper

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March 1993

Collider Accelerator Department

**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC)

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RHIC/RF-11

# RHIC Project
BROOKHAVEN NATIONAL LABORATORY

## RHIC/RF Technical Note No. 11

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# Simulation Study of the Longitudinal Damper

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Simulation Program: Tibetan Version 1.4 (by Jie Wei)

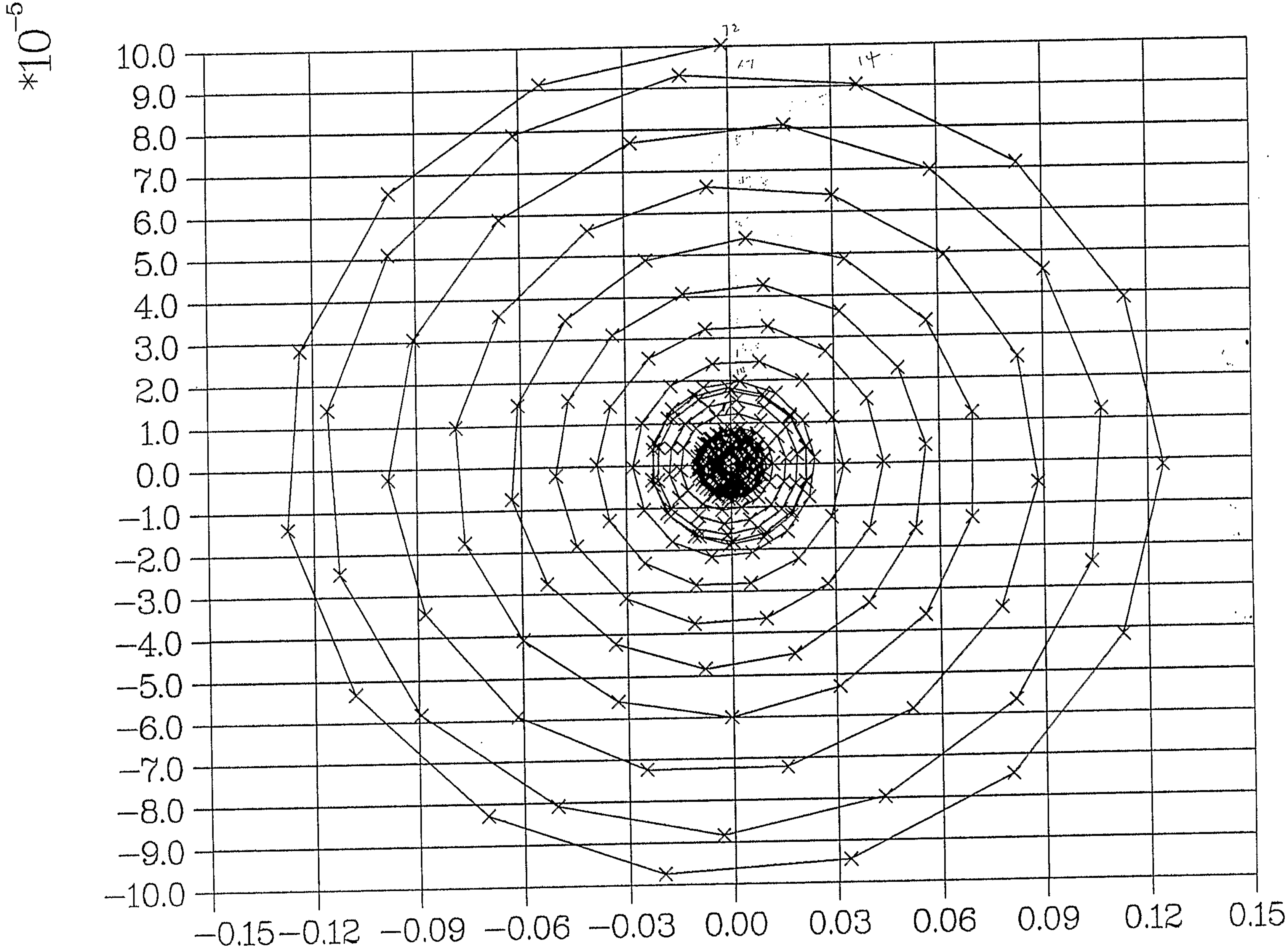
10000 particles.

## I. The Motion of the Center of Mass

a. The average time constant of the smear process (for an initial moment error $\left(\frac{\Delta p}{p}\right)_0 = 10^{-4}$) is about 100 msec $\sim$ 0.1 sec.

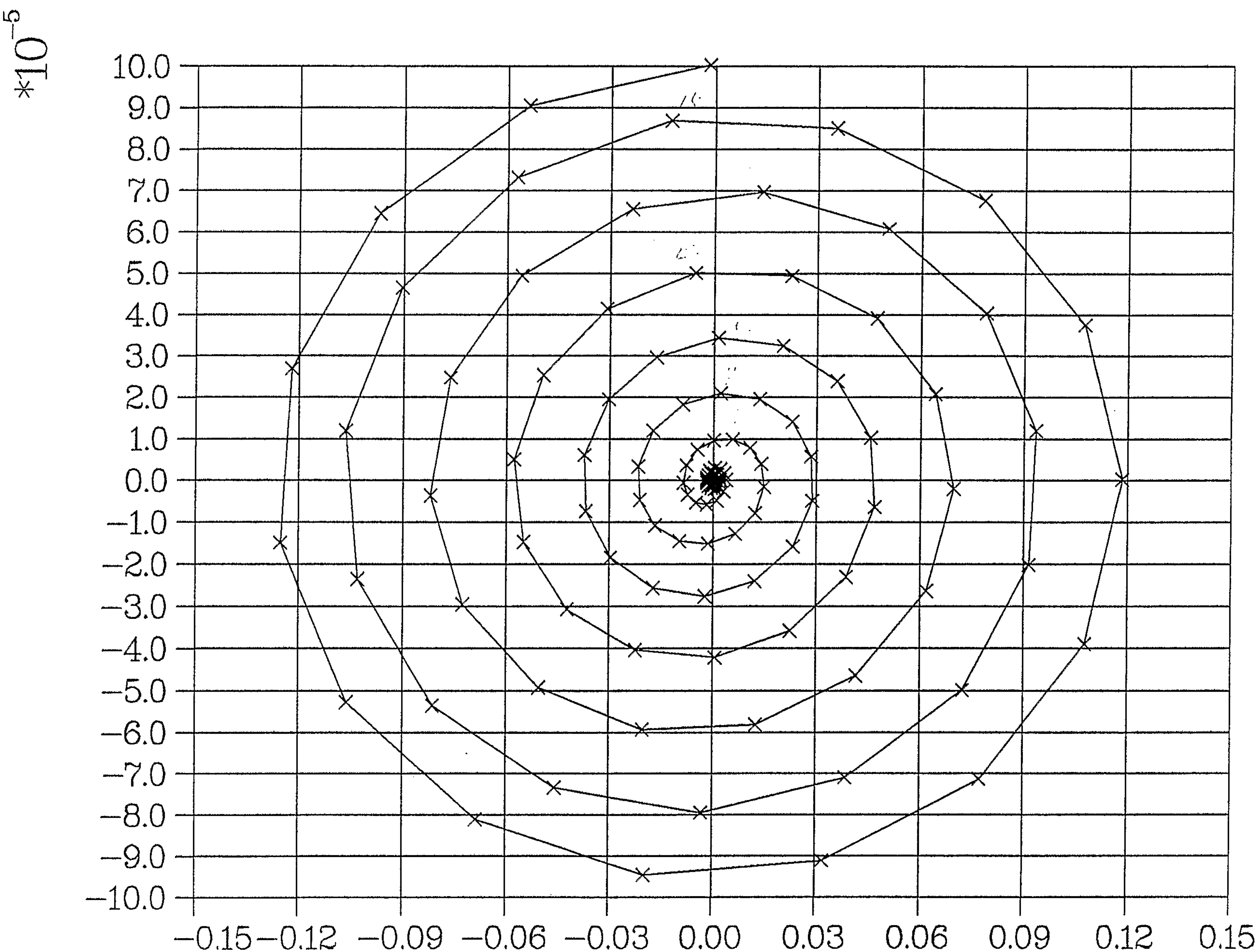
b. Damper voltage 375 V (constant voltage mode) (Damper + Smear) Average time constant is about 50 msec.

c. Damper voltage 750 V (constant voltage mode) (Damper + Smear) Average time constant is about 40 msec.

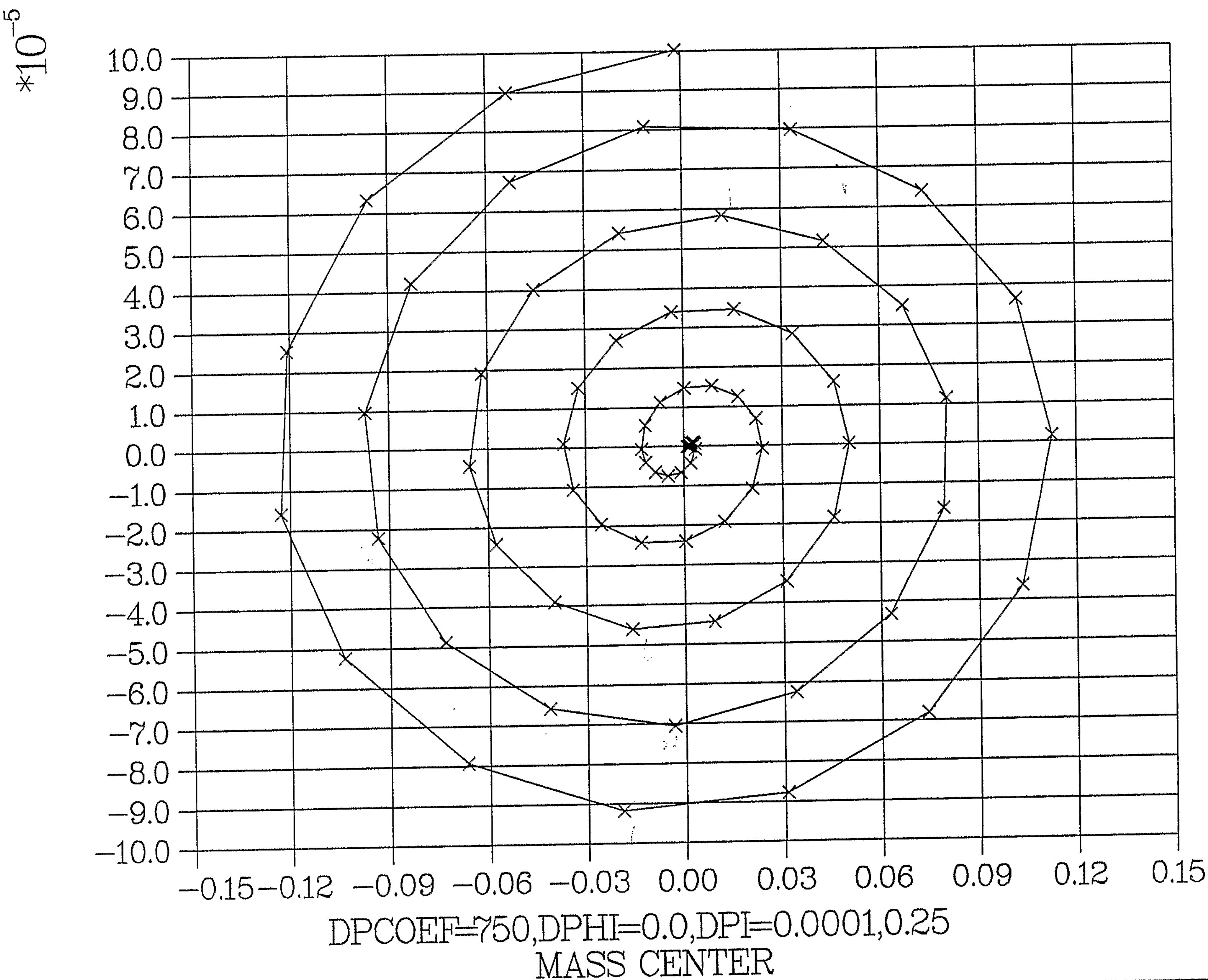


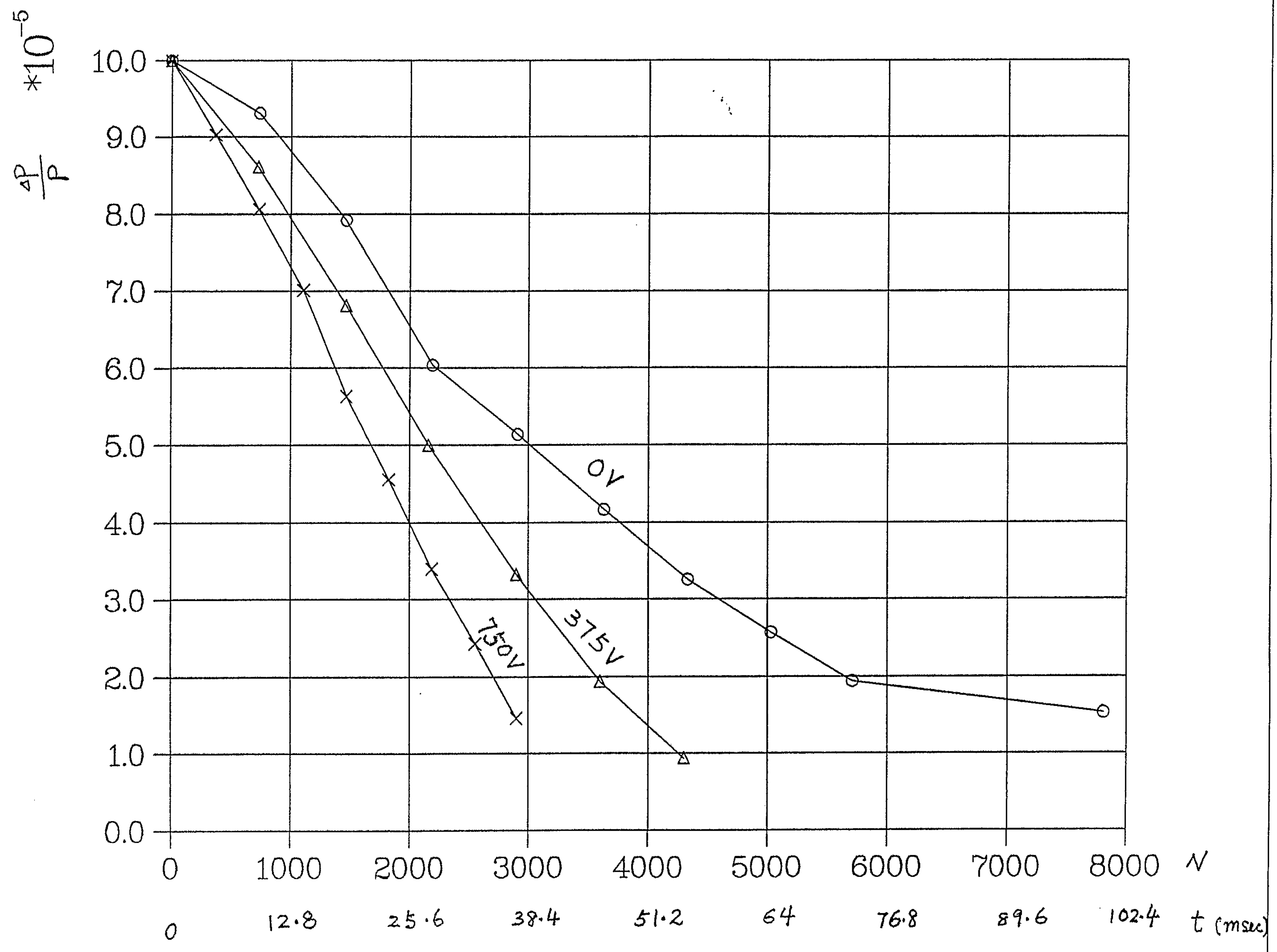

DPCOEF=0,DPHI=0.0,DPI=0.0001,0.25

MASS CENTER



DPCOEF=375,DPHI=0.0,DPI=0.0001,0.25
MASS CENTER


*10^-5
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
−7.0
−8.0
−9.0
−10.0
−0.15 −0.12 −0.09 −0.06 −0.03 0.00 0.03 0.06 0.09 0.12 0.15
DPCOEF=750,DPHI=0.0,DPI=0.0001,0.25
MASS CENTER

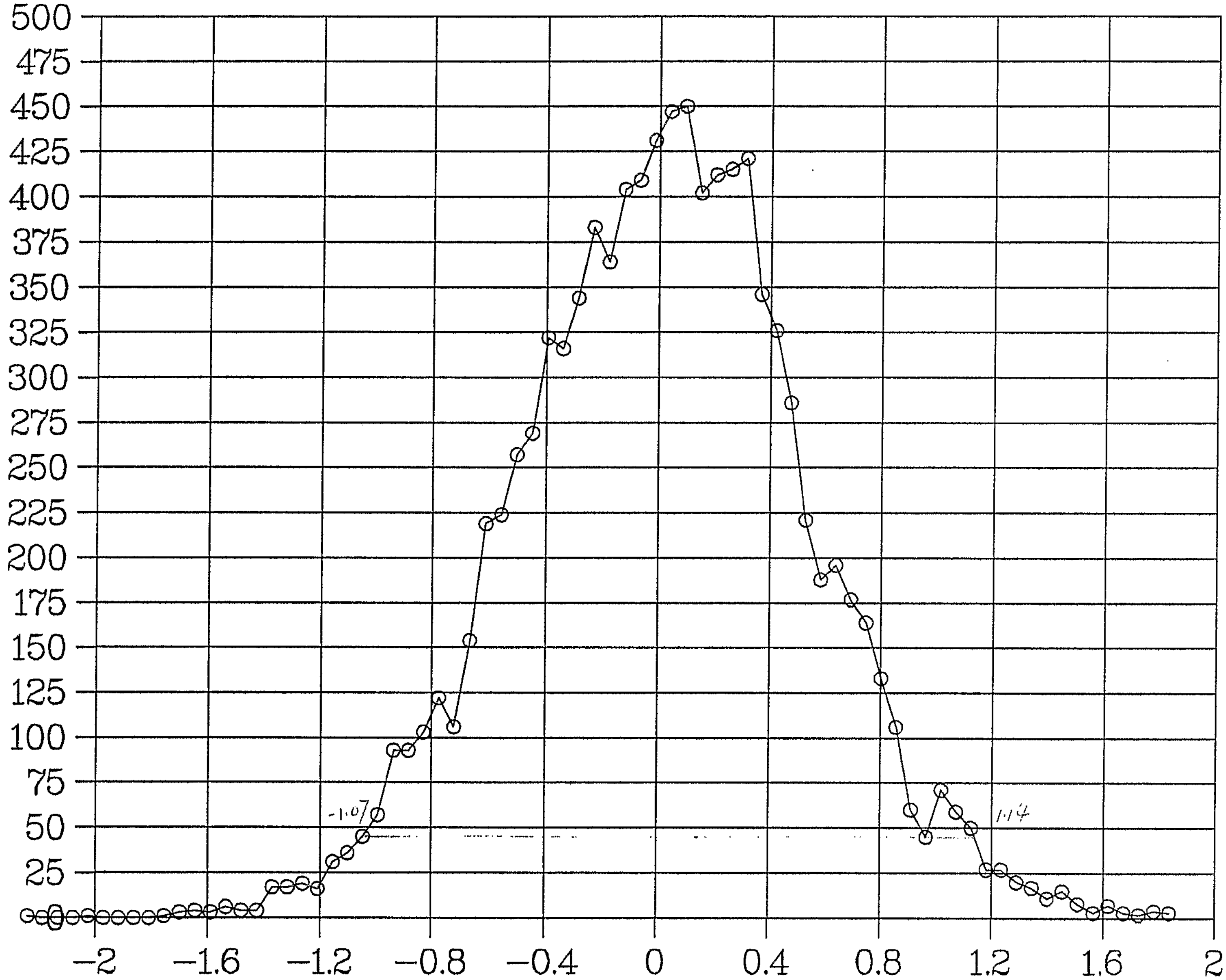


$\frac{\Delta P}{P}$ $*10^{-5}$
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
N
0
12.8
25.6
38.4
51.2
64
76.8
89.6
102.4
t (msec)
0V
375V
750V

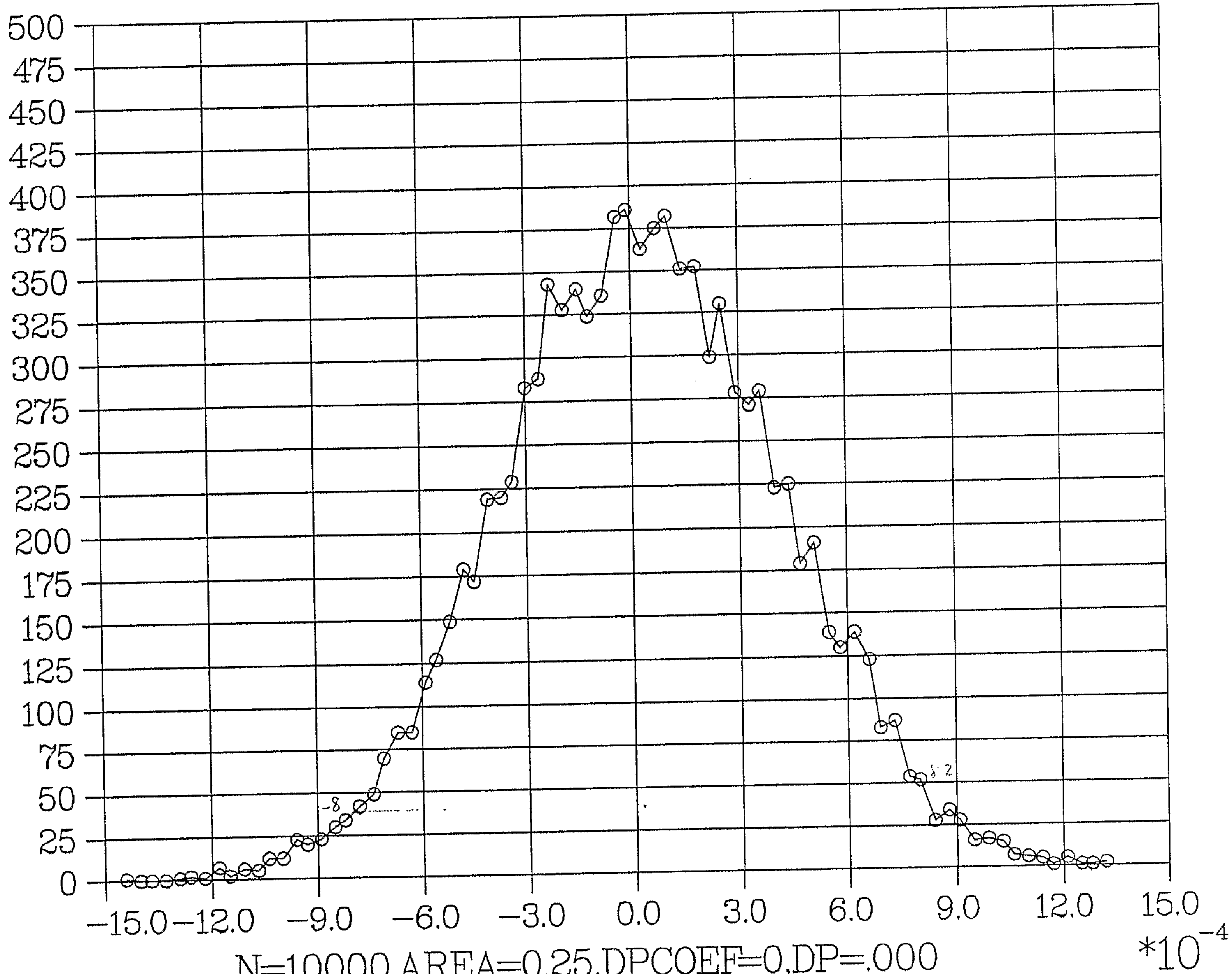
## II. Bunch Area Blow Up

After tracking 20000 turns (about 25 times the smear time constant), the mass center is very close to the bucket center. For no damper case, the mass center $\frac{\Delta p}{p} \leq 10^{-6}$, $\Delta\phi \leq 1$ mrad. The bunch blow up process almost stops. From the projections of the particle intensity on $\frac{\Delta p}{p}$ and $\Delta\phi$ axis, we can get the width of the bunch boundary in $\frac{\Delta p}{p}$ and $\Delta\phi$ axis. We select 10% intensity to be the bunch boundary. Every 50 turns (about $\frac{1}{14}$ synchronous oscillation period) we make a projection and get the width of bunch boundary so that to find the maximum required longitudinal admittance to circumscribe the bunch.

The tracking has been done for no damping, damping voltage = 375 V and damping voltage = 750 V.

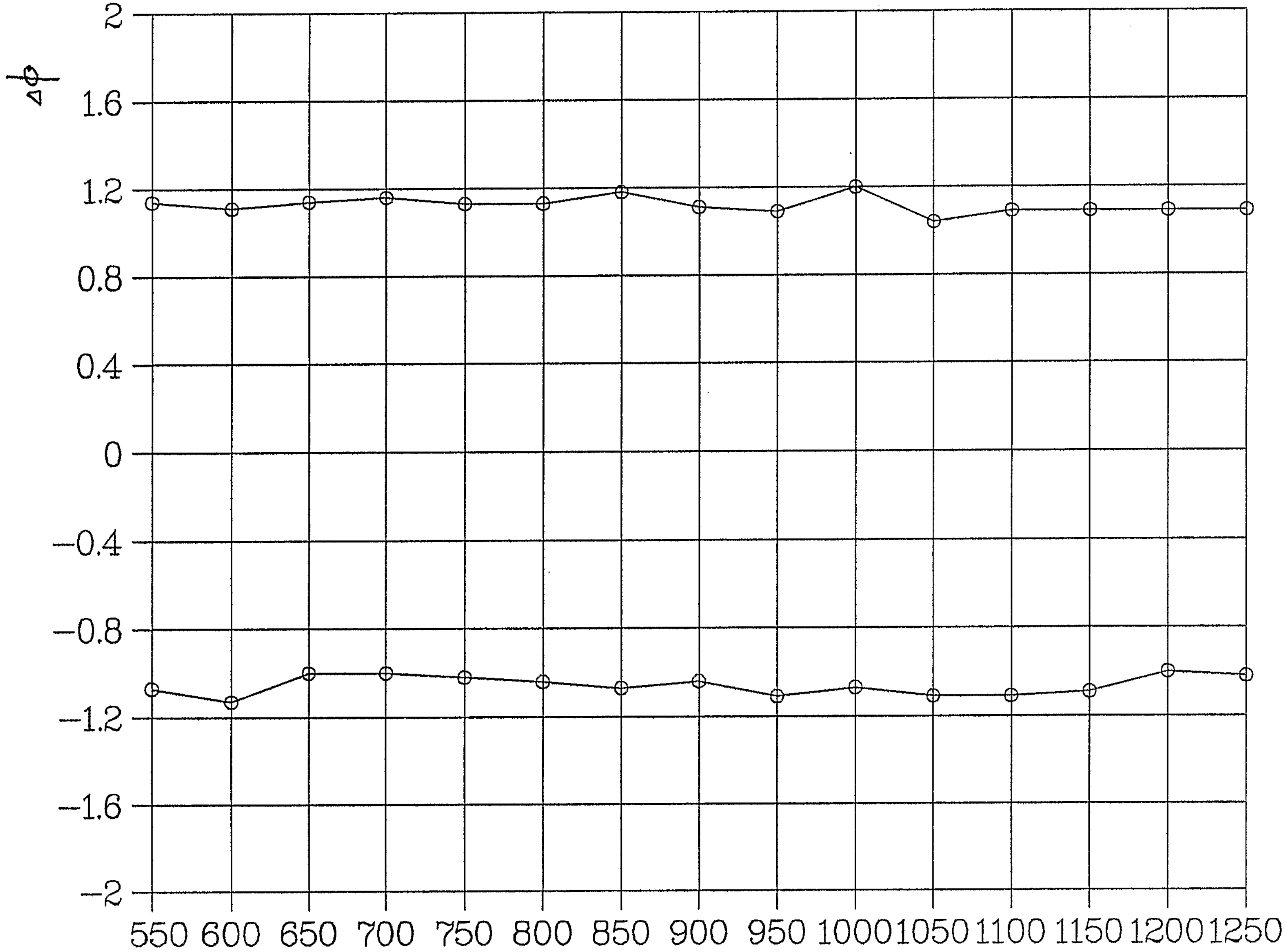



N=10000,AREA=0.25,DPCOEF=0,DP=.0001
205[illegible]turns

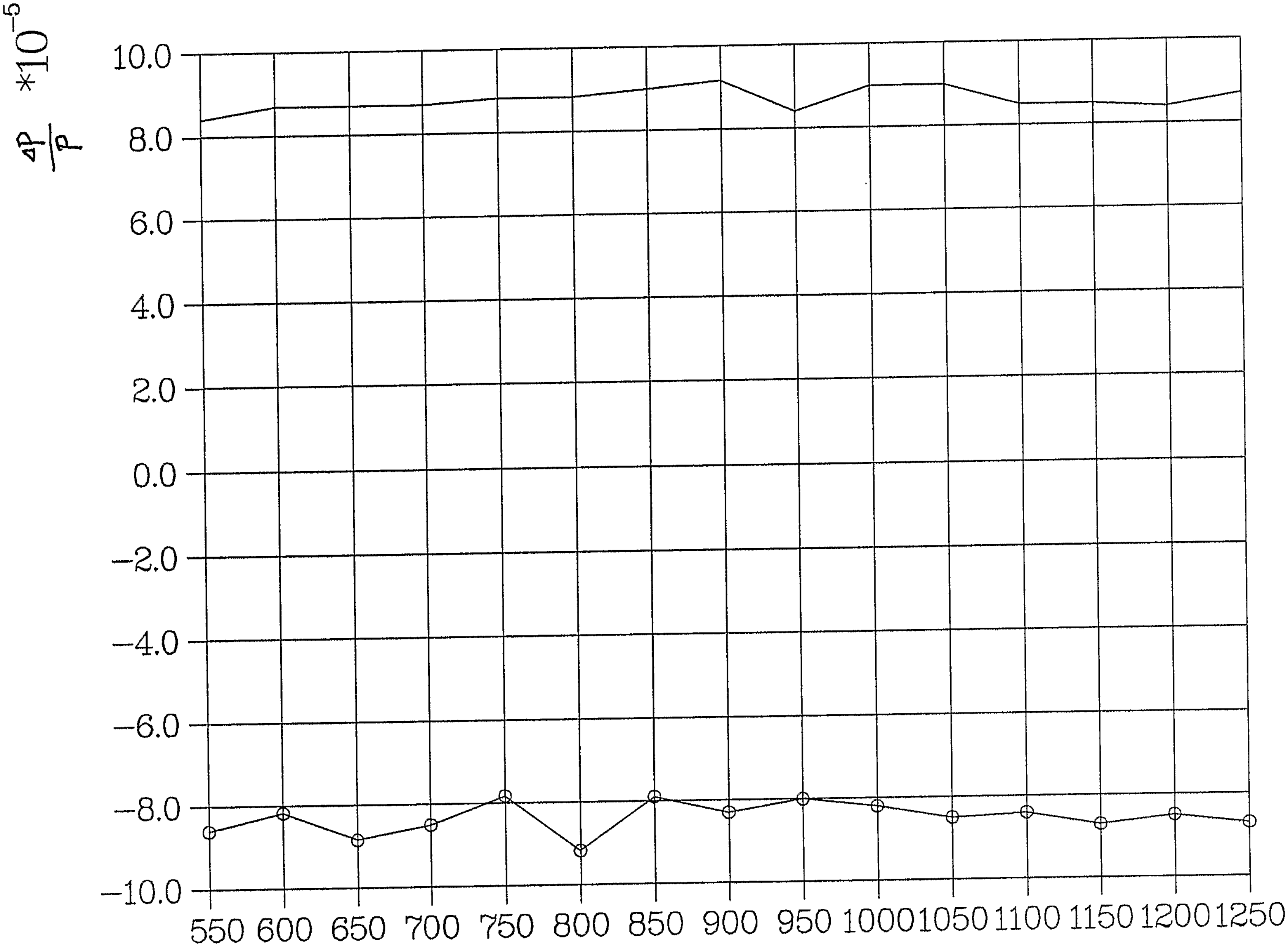



N=10000,AREA=0.25,DPCOEF=0,DP=.000

205 turns



Δϕ
2
1.6
1.2
0.8
0.4
0
−0.4
−0.8
−1.2
−1.6
−2
550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250



$\frac{\Delta P}{P}$ *10$^{-5}$
10.0
8.0
6.0
4.0
2.0
0.0
−2.0
−4.0
−6.0
−8.0
−10.0
550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250

The results are:

| | Initial | No damping (after 20000 revoltrons) | 375 V | 750 V |
|---|---|---|---|---|
| Area | 28.7 | 33.9 | 32.5 | 30.7 |
| Ratio | 100% | 118% | 113% | 107% |

The damper system can reduce the bunch area blow up.

## III. Coupled Bunch Instability

From Mike Blaskiewicz the growth time for coherent instability is of the order of tenths of second which is much longer than the damper time constant 50 or 40 msec. The damper can suppress this instability. If the monitor is very sensitive, the coherent oscillation induced by these instability will be suppress near zero. But the monitor has a finite sensitivity for example, $10^{-5}$ for $\frac{\Delta p}{p}$ or about $0.7^o$ for phase. Then the amplitude of coherent oscillation induced by the instability will oscillate around a value equal to the monitor sensitivity. Once there is coherent oscillation, the bunch will smear and bunch area blow up. When the amplitude is about $\frac{\Delta p}{p} = 10^{-4}$, the blow up speed is of the order of 10-20%/0.1 sec. If the monitor sensitivity is of the order of $0.7^o$ (which corresponds to $\frac{\Delta p}{p} \approx 10^{-5}$) the coherent oscillation amplitude will keep about this value $(10^{-5})$, the bunch area blow up continuously, with a speed 2 or 3 order less than 10-20%/0.1 sec. But if the exciting voltage of the instability lasts a long time, hundreds of second the area blow up may be the same order or even much larger than that caused by injection error.

## IV. Monitor Sensitivity

1. Cause some bunch area blow up during there is coupled bunch instability. If the instability lasts a longer time (hundreds or even thousands seconds). This blow up may be much larger than that by injection error. This blow up can not be reduced effectively by the increase of damper voltage, it mainly depends upon the monitor sensitivity and the last time.
2. Reduce the damping effect. The damper will work only when the coherent oscillation larger than the monitor sensitivity.

Let $a_s$ the monitor sensitivity, $A_0$ initial amplitude of coherent oscillation, $\overline{R}$ the Reducing factor. Then

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\frac{a_s}{A_0}$ | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | |
| $\overline{R}$ | 1 | 0.82 | 0.77 | 0.68 | 0.60 | 0.52 | 0.46 | 0.39 | 0.34 | 0.26 | 0.2 | 0 |

And damper voltage $V_d$

$$V_d = \frac{1}{\overline{R}}.$$

If $\frac{a_s}{A_0} \approx 0.1$. The actual damper voltage should be about 1000 V to 500 V. So that the effect damping effect is equivalent to 750 V and 375 V.

## V. Damper Power $P_D$

$$P_D = \frac{V_D^2}{N_c r}$$

$V_D$ damper voltage

$N_c$ number of cavity

$r$ impedance

| | | | | | | |
|---|---|---|---|---|---|---|
| $V_d$(V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| $N_c$ | 1 | 1 | 1 | 2 | 2 | 2 |
| $r$ (Ω) | 50 | 100 | 200 | 50 | 100 | 200 |
| $P_D$(kW) | 20 | 10 | 5 | 10 | 5 | 2.5 |
| | | | | | | |
| $V_d$ | 500 | 500 | 500 | 500 | 500 | 500 |
| $N_c$ | 1 | 1 | 1 | 2 | 2 | 2 |
| $r$ | 50 | 100 | 200 | 50 | 100 | 200 |
| $P_D$ | 5 | 2.5 | 1.25 | 2.5 | 1.25 | 0.625 |