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SEXTUPOLES, DIPOLE KICKER CORRECTORS FOR BOOSTER

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SEXTUPOLES, DIPOLE KICKER CORRECTORS FOR BOOSTER

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I. Introduction

The booster[1] is designed to meet two aims of higher intensity for AGS proton acceleration and heavy ion acceleration. In this short note, we shall investigate the chromatic correction and orbit correction scheme needed for the booster. In Section 2, we discuss the simple two-family sextupole correction for such a simple machine. In Section 3, we investigate the orbit correction and calculate the resonance strength for the polarized proton.

II. Chromatic Sextupoles

The booster is a 12 superperiod lattice without long straight sections. Each superperiod is composed of four half cells with one missing magnet. Table 1 lists parameters of the lattice and the sextupole strength needed in correcting chromaticities to values of

$$X^x = X^y = 0.5$$

for particles with $\Delta p/p = 0$. Figures 1 and 2 show the amplitude and tune modulation for momentum spread of $\pm$ 0.0025. We observe that the two-family scheme is appropriate for the good performance of the booster. We find that the sextupole field (Table 1) needed is about 50 T/m^2 or 0.5 T pole-tip field with 10 cm aperture.

A problem that can be addressed here is the head-tail instability of a single bunched beam discovered by Pellegrini[2] and Sands.[3] Since the chromaticity is positive within the momentum spread of the beam, there is no head-tail instability for mode number zero.

Table 1

	Proton	Heavy Ion
$B\rho$ (Tm)	5.6574	17.6
μ/superperiod	0.5583333	0.395833
γ_T	6.74	4.74
$Q_x = Q_y$	6.7	4.75
X_N^x (natural chromaticity)	-8.55	-4.76
X_N^y (natural chromaticity)	-8.88	-5.09

Chromatic Correction Sextupoles $X^x = X^y = 0.5$ for $\delta = \frac{\Delta p}{p} = 0.$

	Proton	Heavy Ion
K_{SF}	+0.4014	+0.1910
K_{SD}	-0.7727	-0.3033
B''_D (10 cm long sextupole)	43.7 T/m^2	53.4 T/m^2

III. Orbit Correction Scheme

Because of magnet alignment errors, particle orbits may deviate from the design orbit. This deviation can be minimized by introducing a set of position monitors and dipole kickers. The orbit correction program in SYNCH is used to calculate the kicker strength for a given set of randomly generated errors. We found that the best place for the position monitors and dipole kickers are at the high β positions, i.e. next to the quadrupoles. We choose the alignment errors to be ± 0.2 mm (a factor of two larger than the current achievable accuracy) and measurement of beam position to be within ± 0.2 mm.

Tables 2 and 3 show the dipole kicker strengths needed in the orbit corrections for proton acceleration. Table 4 shows the depolarizing imperfection resonance strength (calculated from DEPOL[4]) for the polarized proton acceleration. We found that 11 kickers were needed to correct the vertical orbit and 15 kickers for the horizontal orbit. The maximum kicker field (using a 10 cm dipole kicker) is estimated to be 21 Gauss (i.e. 0.037 mrad bend) in horizontal and vetical directions (see Tables 2 and 3). The only proton depolarizing resonance in the booster energy range for polarized proton acceleration is the imperfection resonance at $\gamma G = 3$ with a resonance strength of $|\varepsilon| = 1.2 \times 10^{-4}$ (without orbit correction) (see Table 4). This resonance is not important even without the orbit corrections (for 1% depolarization, the resonance strength would be 1.3×10^{-4}). The vertical orbit correctors are most effective on correcting the imperfection resonances about $\gamma G \approx \nu$ which are outside the energy range of the booster.

The horizontal orbit correction is found to reduce the aperture requirement by about 1 mm over a range of $\Delta p/p = 0.0025$ as compared to the uncorrected case.

Table 2

Horizontal Orbit Correctors for Proton Acceleration

Kicker No.	Angle (mr)	Field (Gauss)
19	-0.2842	-16.08
2	-0.02112	-11.95
13	0.02110	11.94
23	-0.02776	-15.70
7	0.03672	20.77
12	0.01287	7.28
21	0.02440	13.80
15	-0.02502	-14.15
20	-0.02978	-16.85
14	-0.02420	-13.69
17	0.02248	12.72
6	-0.02135	-12.08
24	0.01525	8.63
11	-0.01673	- 9.46
5	-0.01593	- 9.01

Table 3

Vertical Orbit Correctors for Proton Acceleration

Kicker No.	Angle (mr)	Field (Gauss)
2	0.02298	13.00
23	0.03691	20.88
8	0.1726	9.76
17	0.03651	20.66
4	-0.02943	-16.65
22	0.01835	10.38
21	-0.01956	-11.07
6	-0.2770	-15.67
7	-0.02802	-15.85
11	0.01535	8.68
3	0.01818	10.29

$B\rho = 5.6574$ Tm

Kicker length = 10 cm

Table 4

Imperfection Resonance Strengths for Polarized Proton Acceleration

γG	Before Correction $\|\varepsilon\| \times 10^4$	After Correction $\|\varepsilon\| \times 10^4$
1	0.4574	0.1796
2	0.3146	0.5897
3	1.1861	0.3215
4	2.7866	0.9155
5	8.0305	0.5276
6	2.3278	0.3191
7	22.5655	0.7354
8	14.6351	1.7167
9	4.4379	1.3223
10	4.4692	2.4520
11	4.5636	2.3341
12	1.9315	2.1780
13	0.7950	3.4102
14	7.9754	4.7242
15	2.5021	2.1539
16	27.8788	3.5080

For $\|\varepsilon\| < 1.303 \times 10^{-4}$ then $\Delta S_z < 1\%$ in the booster.

IV. Conclusions

In conclusion, we have calculated (1) the sextupole strength needed for the booster chromatic correction and (2) the orbit correction dipole kickers strength for magnet placement error. Our results show that (1) two families of sextupoles are appropriate for chromatic correction. Head-tail instability of mode number zero is also cured by the chromatic sextupoles. (2) The orbit correction can also be devised simply by a dozen dipole kickers. The kicker field needed for proton orbit correction is typically within 20 Gauss for a 10 cm kicker.

A similar calculation has also been performed for the heavy ion acceleration. The kicker field needed is of the order of 68 Gauss (because of larger $B\rho$ operation).

V. References

1. Accumulator/Booster Proposal for the AGS, BNL-32949-R.
2. C. Pellegrini, Frascati LMF-69/44.
3. M. Sands, SLAC-TN-69-8.
4. E. Courant and R. Ruth, BNL-51270.

mvh

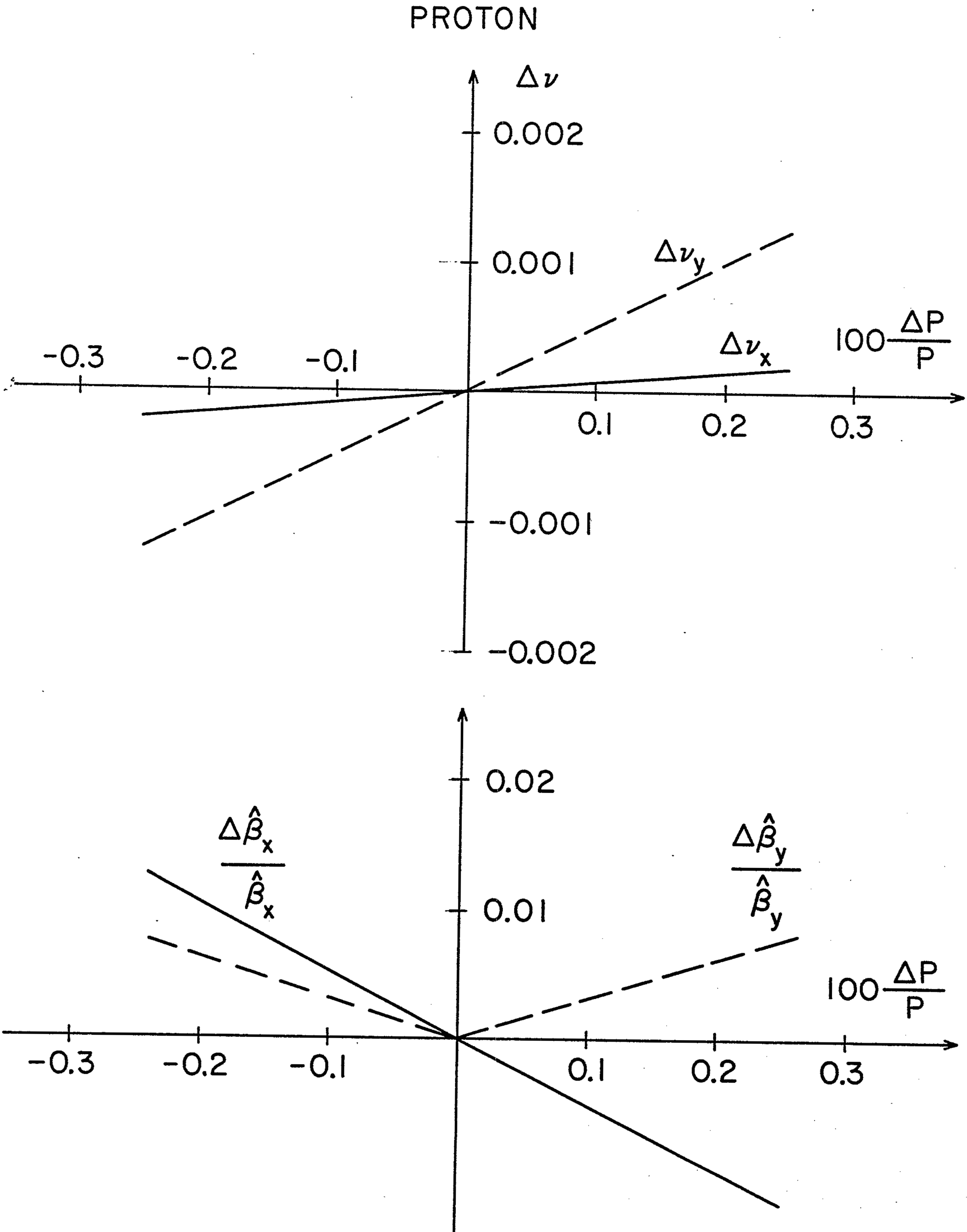
PROTON
Δν
0.002
0.001
-0.001
-0.002
Δν_y
Δν_x
100 ΔP/P
-0.3
-0.2
-0.1
0.1
0.2
0.3
0.02
0.01
Δβ̂_x/β̂_x
Δβ̂_y/β̂_y

Fig. 1

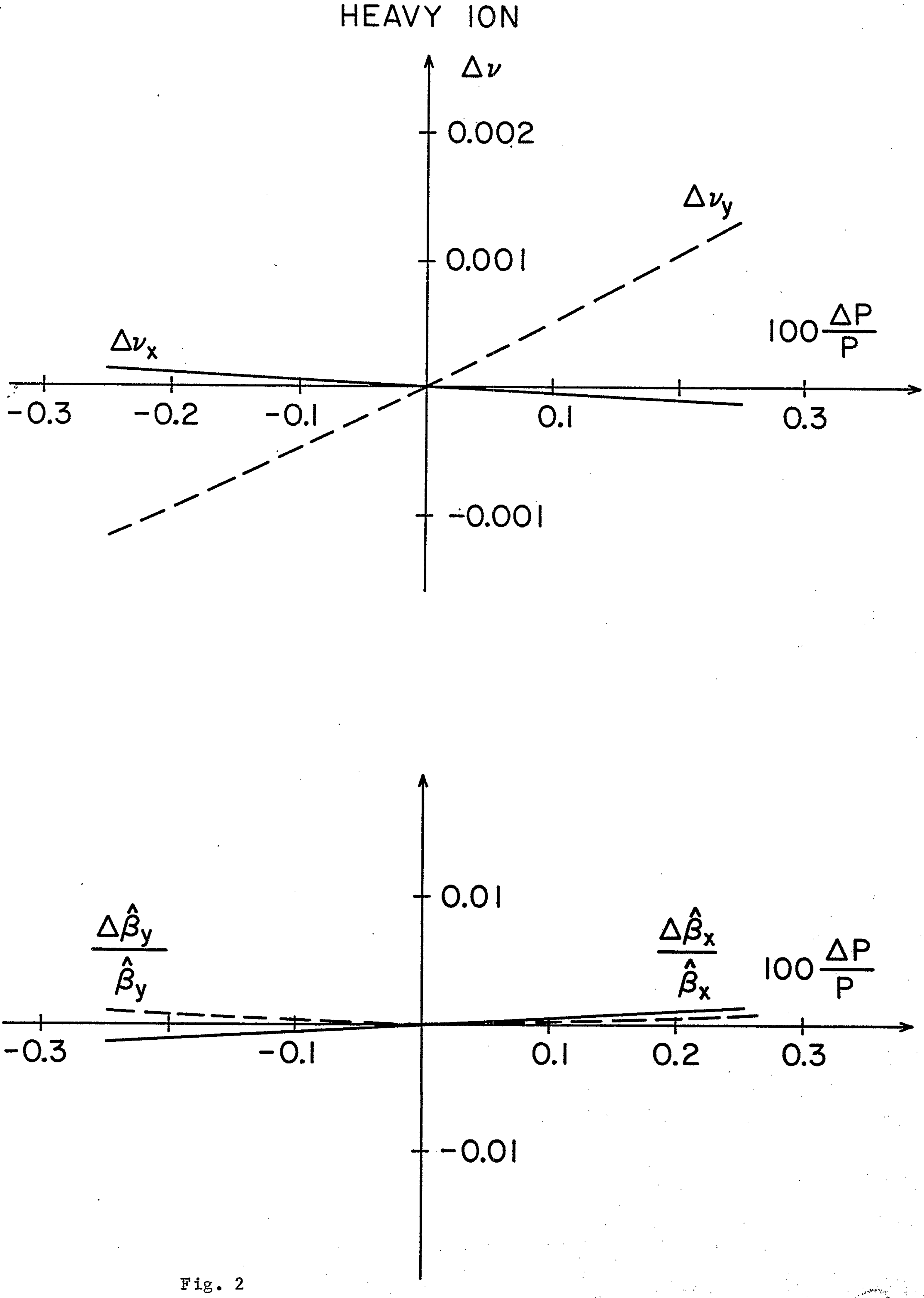
HEAVY ION
$\Delta\nu$
0.002
$\Delta\nu_y$
0.001
$100\frac{\Delta P}{P}$
$\Delta\nu_x$
-0.3
-0.2
-0.1
0.1
0.3
-0.001
0.01
$\frac{\Delta\hat{\beta}_y}{\hat{\beta}_y}$
$\frac{\Delta\hat{\beta}_x}{\hat{\beta}_x}$
$100\frac{\Delta P}{P}$
-0.3
-0.1
0.1
0.2
0.3
-0.01

Fig. 2