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Chromatic Correction for the RHIC Lattice

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Abstract

We study the chromatic correction for the RHIC lattic. The scheme requires three families of sextupoles in the inner arc and outer arc respectively. It works very well to correct the tune and betatron amplitude modulations.

1.) Introduction.

Large colliders, such as RHIC ,require a careful correction for the chromatic properties,especially when the betatron function at the interaction point is tuned to a small value for the high luminosity experiments. Fig. 1 shows the natural chromaticity of the machine as a function of the betatron amplitude at the interaction point. We note that when the natural chromaticity becomes large, the nonlinear chromatic components also becomes larger. It is clear that the sextupole configuration and the sextupole location are important in the chromatic correction procedure(Ref.1). Fig.2 shows one example of the betatron amplitude of the betatron amplitude at the momentum dp/p=-.01. We observe that the x-beta function is highly modulating in the inner arc and well-behaved at the outer arc. On the other hand, the y-beta function is well behaved at the inner arc and highly modulating in the outer arc. This suggests that the stop-band contribution is in phase at qf in the inner arc and out of phase in the outer arc,i.e.

$$\frac{\Delta\beta}{\beta} = -\frac{\nu}{4\pi}\sum_{p}\frac{J_p e^{ip\varphi}}{\nu^2-(p/2)^2} \sim -\frac{J_p \cos(p\varphi+\delta)}{4\pi(\nu-p/2)}$$

where the stop-band width, J_p , is given by (Ref. 2)

$$J_p = \int_0^C \beta(s)\, k(s)\, e^{-in\varphi(s)}\, ds \quad ; \quad \varphi_s = \frac{1}{\nu}\int^s \frac{ds}{\beta}$$

It is suggestive that two families of focusing sextupole and one family of defocusing sextupole in the inner arc are needed to correct these dependence(Ref. 3). Similar reversed configuration is needed in the outer arc. In this study, we shall try to calculate the effect of this correction scheme. Since the sextupole also contributes to the nonlinear effect in the betatron amplitude modulation, we shall use the interlace scheme with the phase advance of approximately 90 degrees per cell. Therefore the lowest order contribution due to the sextupole to the nonlinear effect is minimized. The sextupole scheme is outlined in the following diagram.

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  SCHEMATIC DIAGRAM OF SEXTUPOLE CORRECTION
           ONE SEXTANT OF RHIC
  -----------------------------------------

  sf  sf  sf  sf  sf  sf  sf  sf  sf  sf  sf  sf
__O___O___O___O___O___O___O___O___O___O___O___O__      OUTER
O   O   O   O   O   O   O   O   O   O   O   O   O      ARC
sd4 sd3 sd4 sd3 sd4 sd3 sd4 sd3 sd4 sd3 sd4 sd3


sf1 sf2 sf1 sf2 sf1 sf2 sf1 sf2 sf1 sf2 sf1 sf2
I___I___I___I___I___I___I___I___I___I___I___I___I      INNER
  I   I   I   I   I   I   I   I   I   I   I   I        ARC
  sd  sd  sd  sd  sd  sd  sd  sd  sd  sd  sd  sd
```

These sextupole configuration has been the extensively used in the other acclerator design work such as CERN, SLAC FNAL and SSC design center.

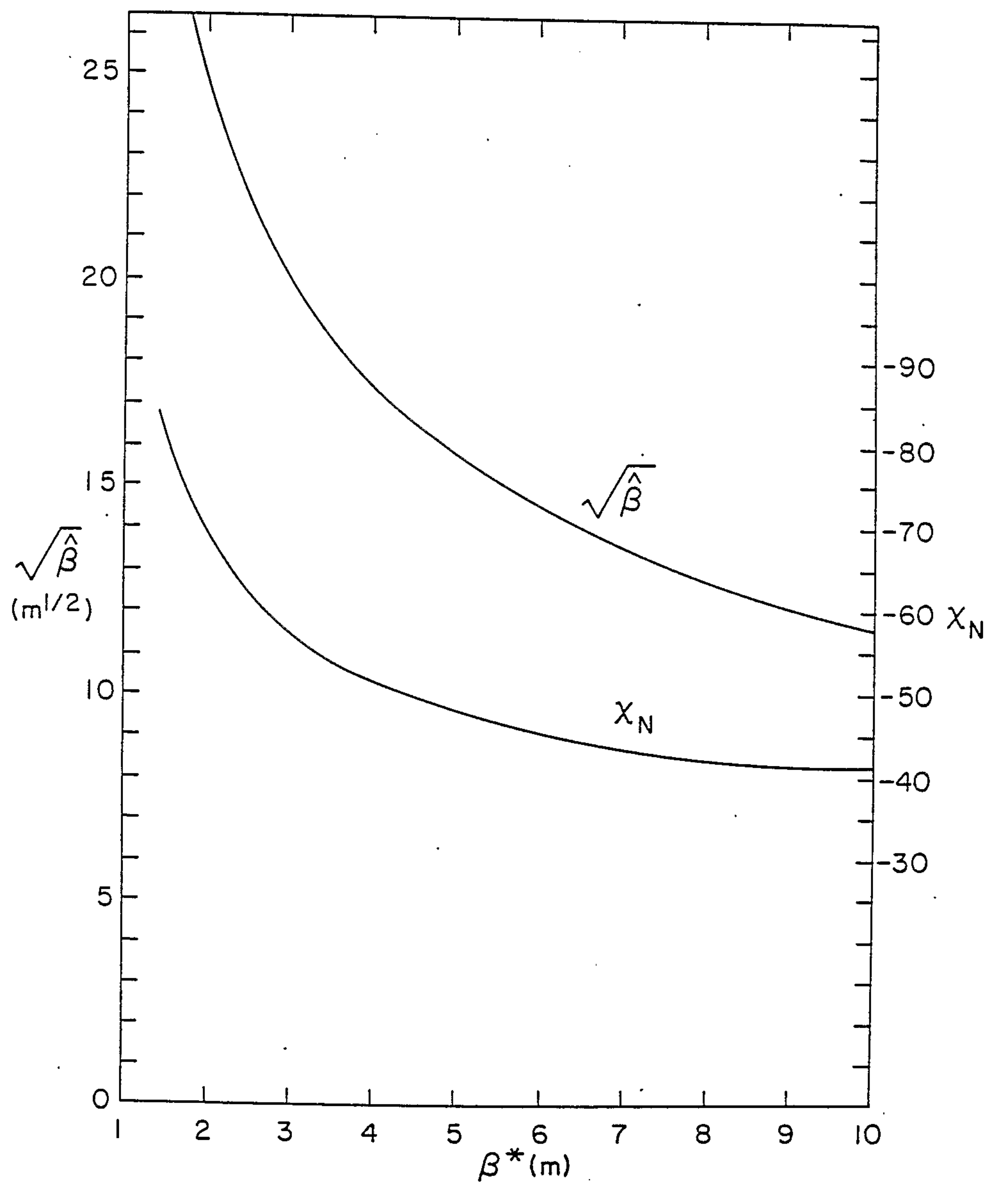

Fig. 1 The maximum amplitude function and the total natural chromaticity is shown as a function of β^*.

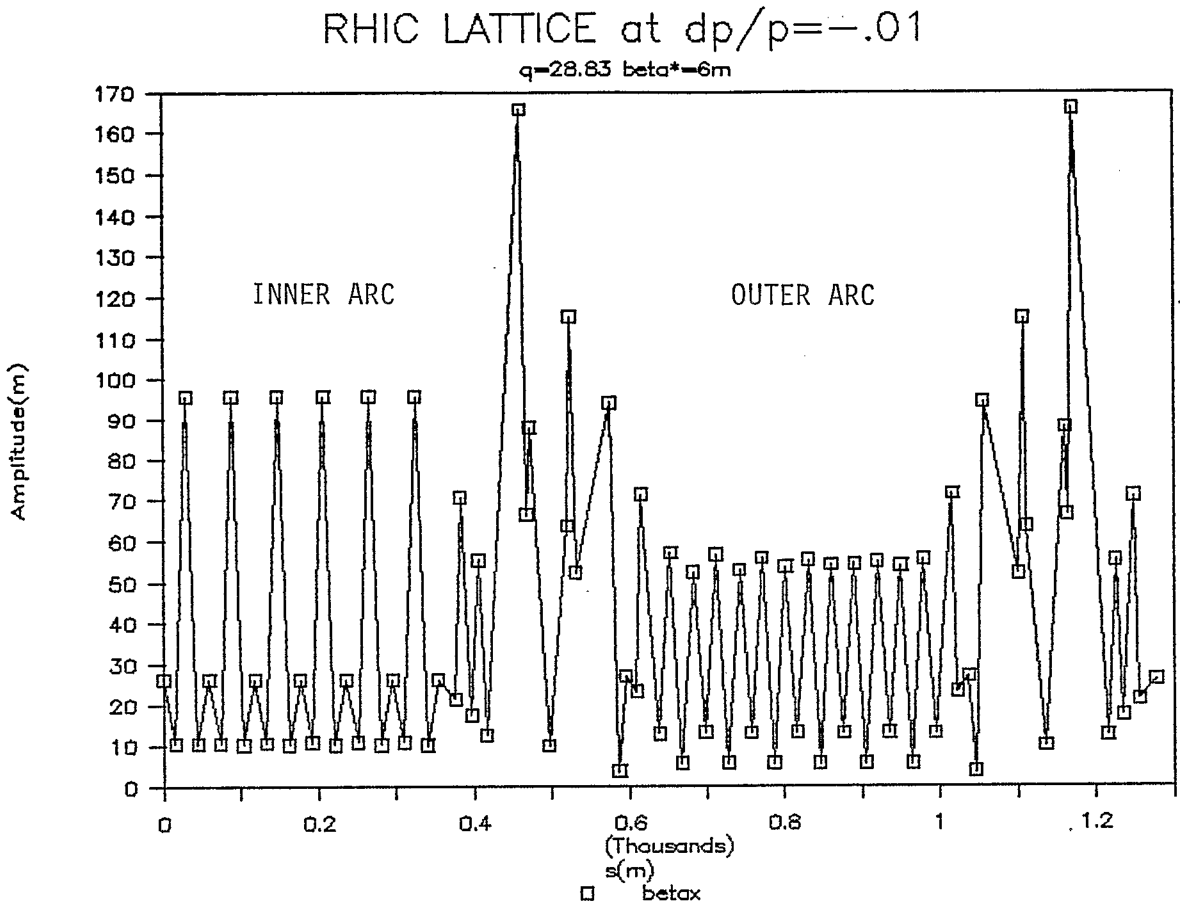

Fig. 2. Betatron amplitude modulation at dp/p=-.01. Shown in the graph is the horizontal plane betatron function. The corresponding y or vertical plane has large modulation in the outer arc only.

2.) Numerical calculations

We shall use the synch program(Ref. 4). The procedure is to use the sextupole strengths of the following four families of sextupoles,with

sf1 □ sf + dsf

sf2 □ sf - dsf

sd3 = sd + dsd

sd4 = sd - dsd

so that the total chromaticity will not be changed in the process of tuning the betatron amplitude modulation.We found that at dsf=0.4*sf and dsd=-.4*sd, the amplitude modulation become rather small. Figs.3-7 show the chromatic dependence of the machine betatron functions for the setting of

sf1 = 1.4 sf
sf2 = 0.6 sf
sd3 = 0.6 sd
sd4 □ 1.4 sd

The chromatic behavior of the machine with these sextupole configuration is acceptable. The corresponding tune vs. momentum dependence also resonably good. The correponding sextupole strength in the vertical sextupole correction is

ksd2 = $\int B'' dl / B\rho$ □ -0.4032 (m^-2)

The sextupole strength needed may be increased when beta*=3m mode is in operation.

3.) Discussion

We have used three family sextupole per sextant to study the machine chromatic correction problem. Satisfactory result has been obtained with minimum number of knobs. It is however important to note that the chromatic properties of the bare machine depends sensitively on the quadrupole distribution in the insertion region. The design of the insertion matching is a multi-variable problem. As an example, Figure 8 with beta*=6m and q=28.83 gives a much smaller chromatic variations with momentum although the natural chromaticity is identical to that of the machine shown in Fig.1. In this study, we shows that in the case of a bad chromatic machine, we can also easily corrected the chromatic property with three-family of sextupoles in each sextant. We however would like a machine which has a machine with smaller nonlinear chromatic behavior. It is therefore the latter machine(quadrupole distribution in the insertion region) would be preferable. However multi-family sextupole correction scheme is definitely needed in the case of low beta insertion(e.g. beta*=3m). The sextupole correction scheme should also work in this situation. We shall study the correction scheme for beta*=3m in the future.

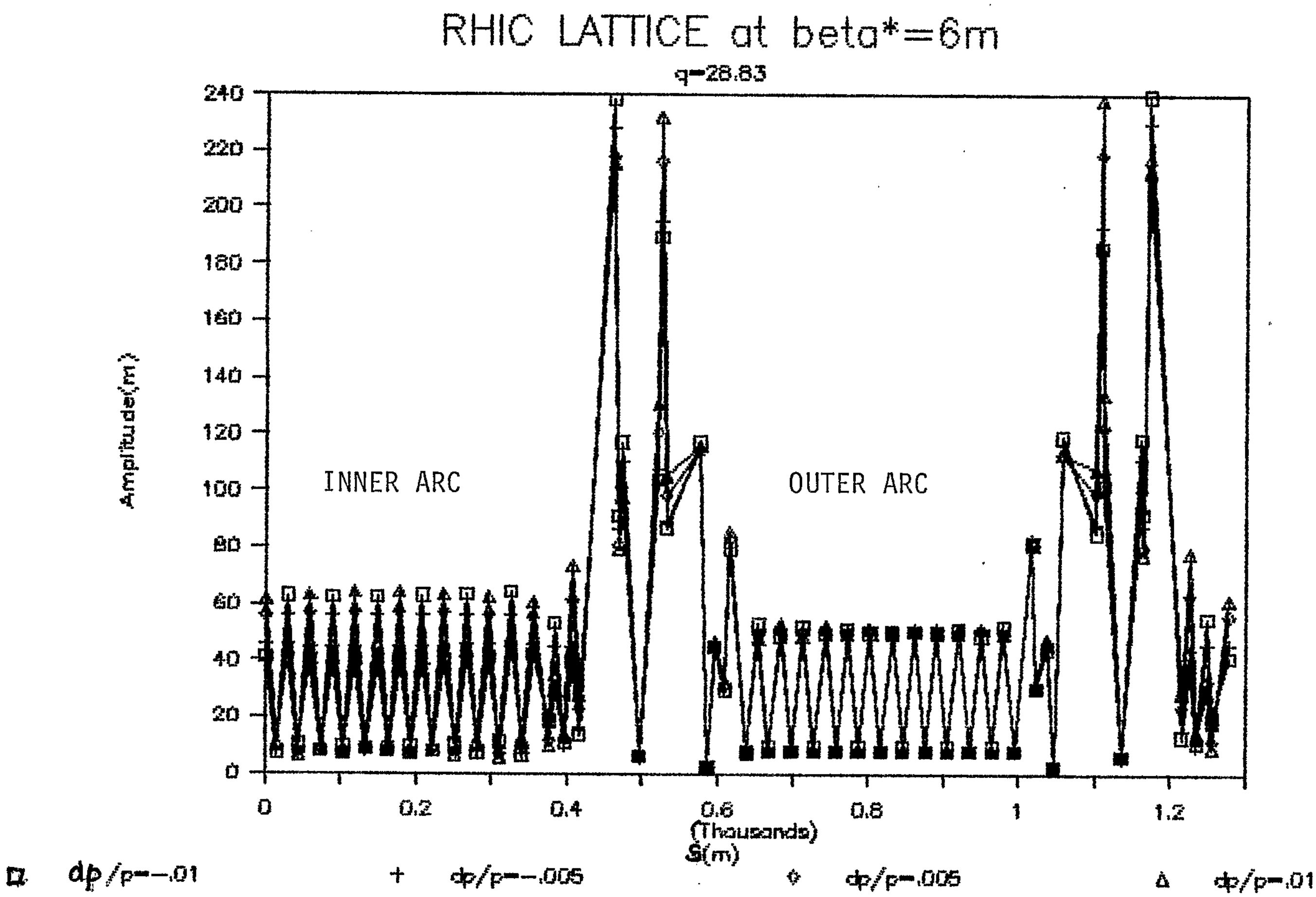

Fig. 3 Same as that of Fig.1 after the sextupole corrections
(six - family total)

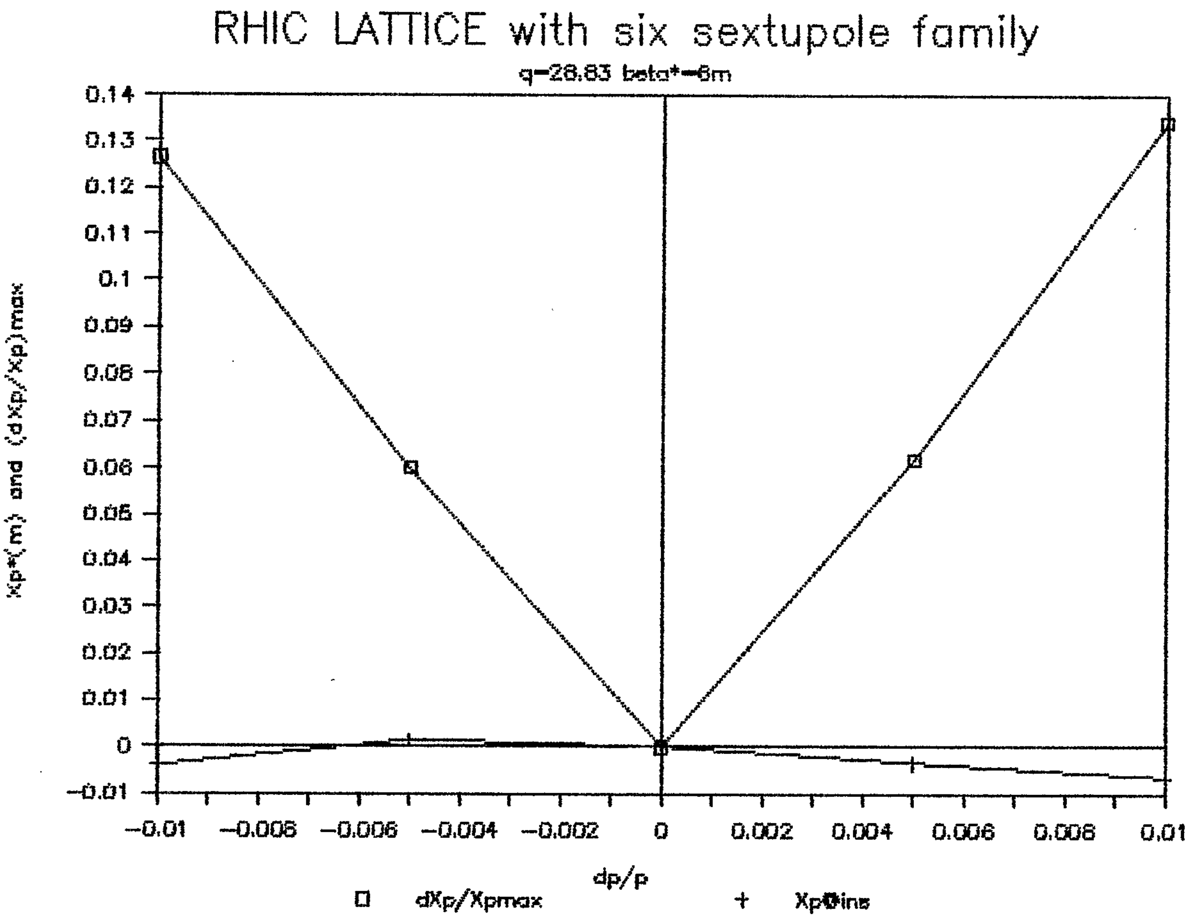

Fig.4 Xp vs dp/p

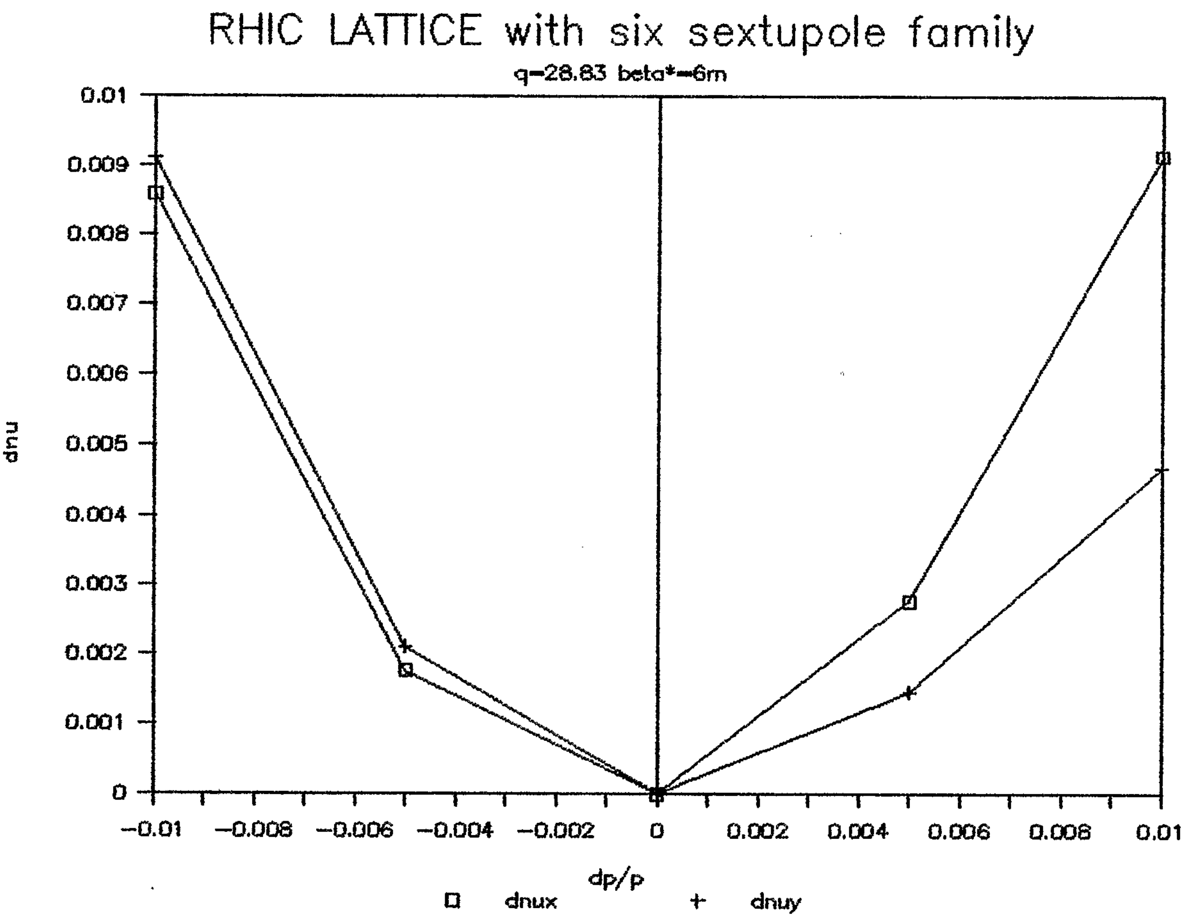

Fig.5 $\Delta\nu$ vs $\Delta P/P$

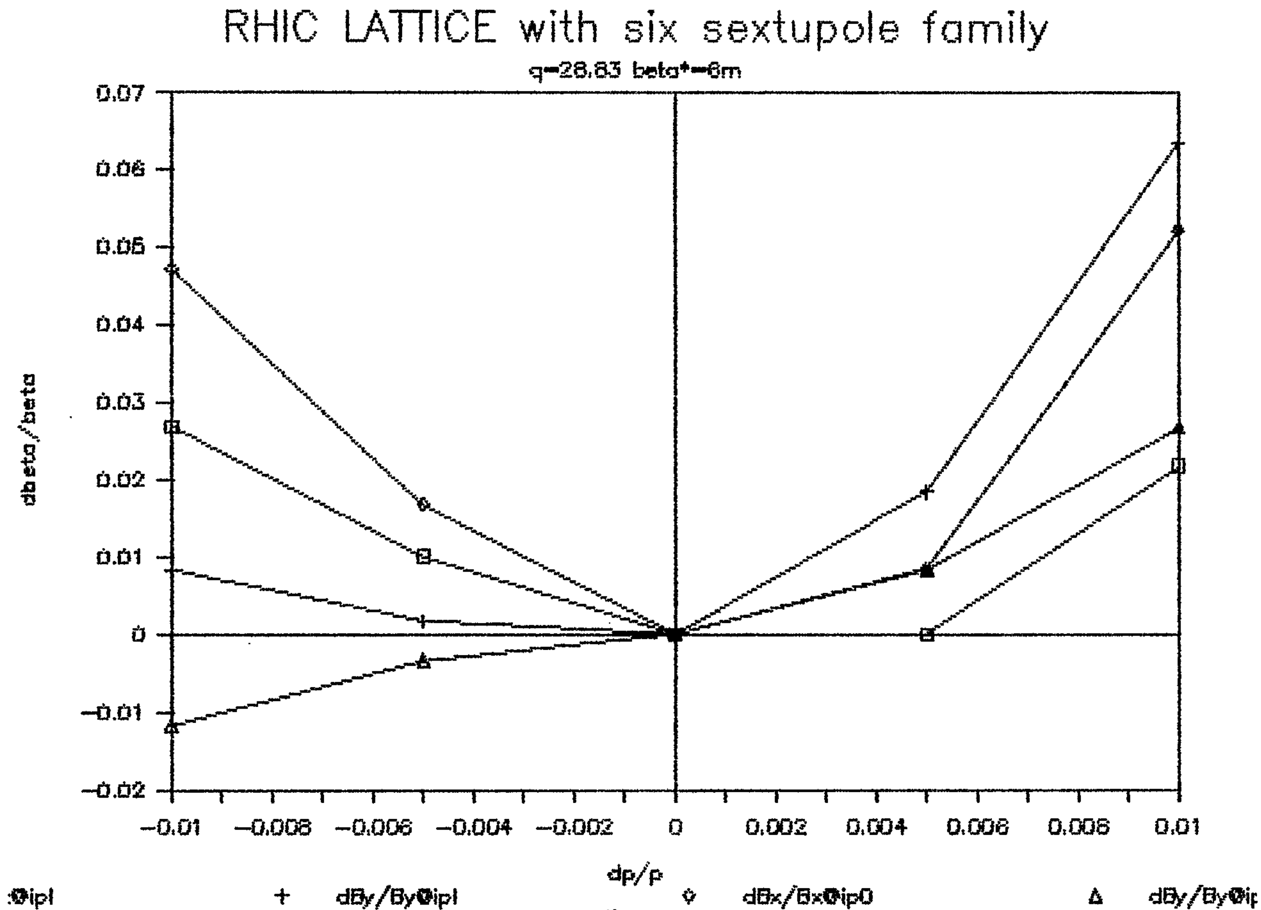

Fig.6 β^* vs dp/p

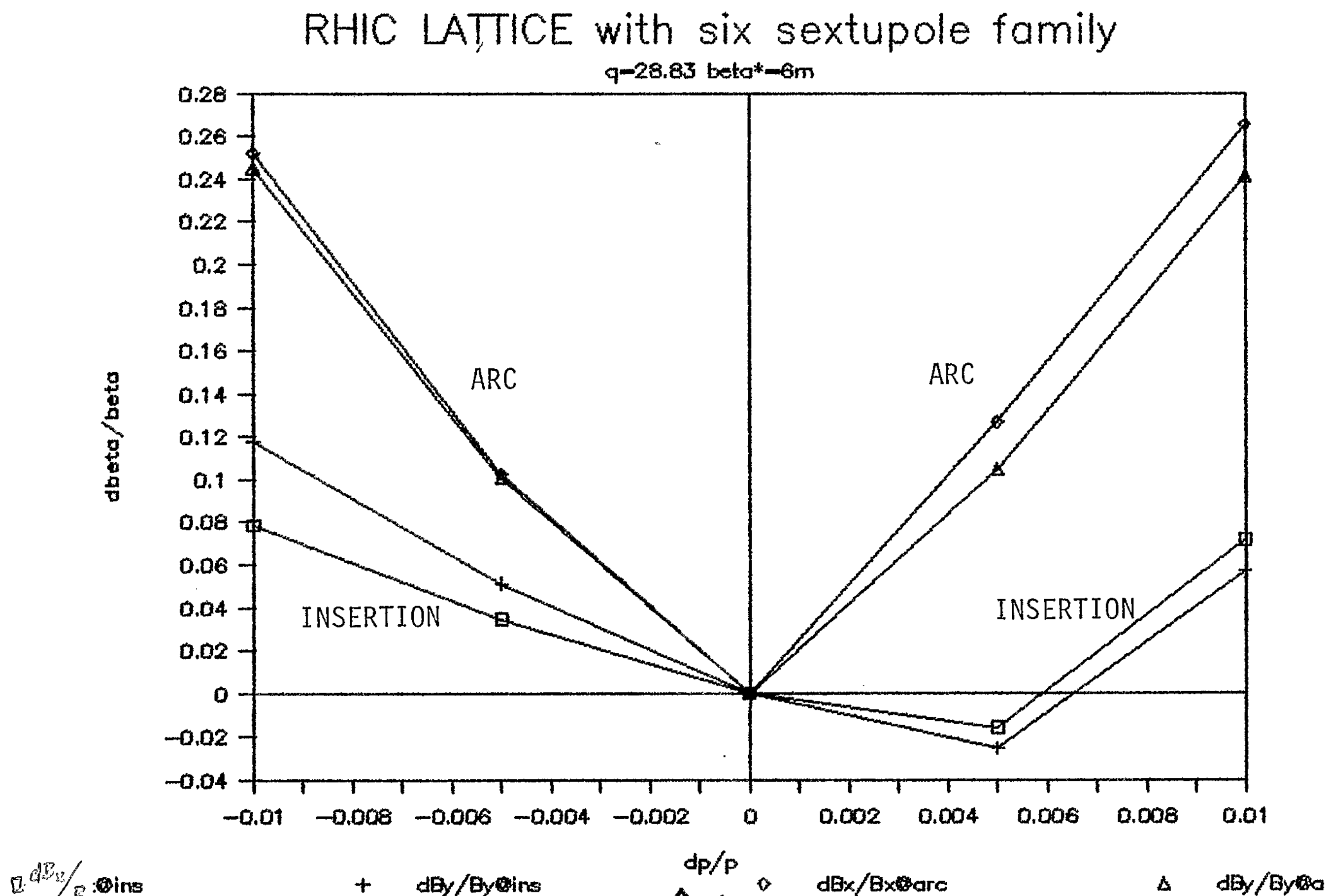

Fig. 7 $\Delta\hat{\beta}/\hat{\beta}$ vs $\Delta P/P$

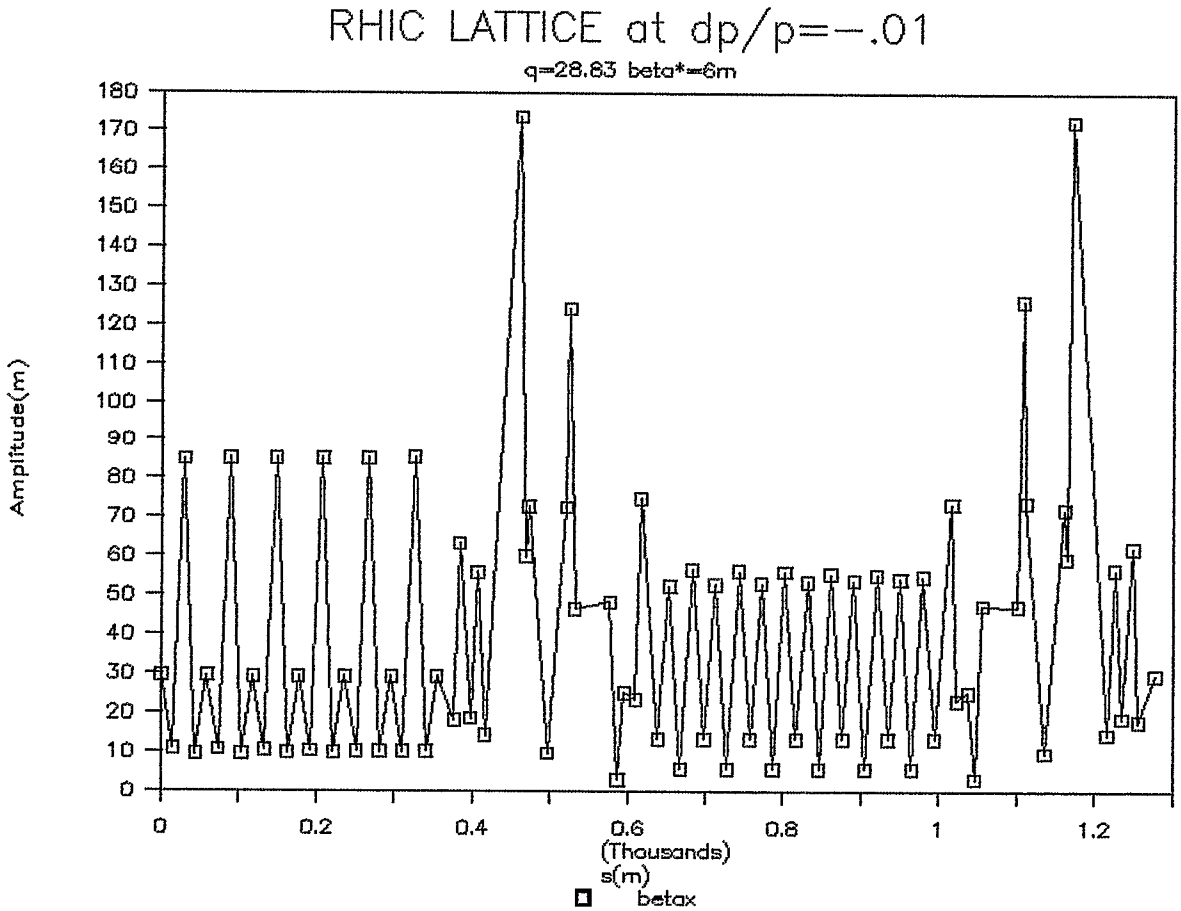

Fig. 8 Same as that of Fig. 1 with two family sextupole correction only. The quadrupole distribution in the insertion gives a slightly smaller stop-band width.

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