Booster Corrector System Specification

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DRAFT Version – to be updated soon

Existing System

The Fermilab Booster includes corrector packages in each of the 48 sub periods. Each corrector package includes:

- Horizontal trim
- Vertical trim
- Quadrupole
- Skew Quadrupole

Each type of quadrupole has an individual DC offset to which is added ramped current which is common to one quarter of the ring (although operationally, all four quadrants have identical ramps). The trim for which the subperiod in question is a high-beta region has a ramped controller while the other one has a DC setting. That is

- Short straights: Horizontal ramped, Vertical DC
- Long straights: Vertical ramped, Horizontal DC

The existing system is not strong enough to adequately control beam position or tune through the cycle.

Requirements

Position

Figure 1a shows the beam position at all points around the ring, at roughly 5 minute intervals throughout the acceleration relative to the position at injection. Because the tuned injection orbit represents the optimum beam position, this plot would ideally be flat. Unfortunately the existing corrector system is only capable of moving he beam a few millimeters at high field. Figure 1b shows one of the most extreme cases of motion throughout the cycle.

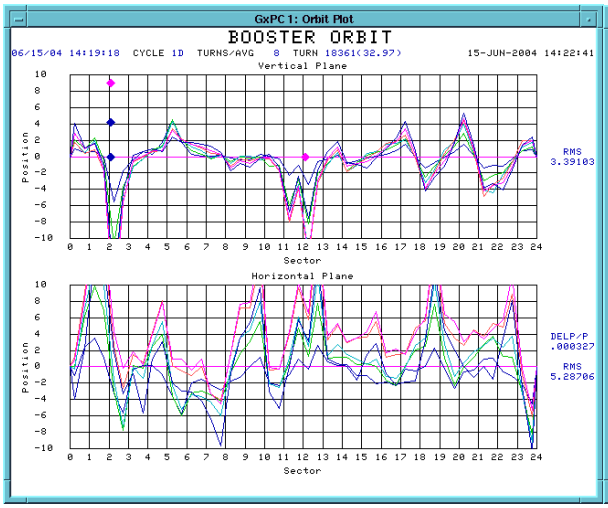

Fig. 1a

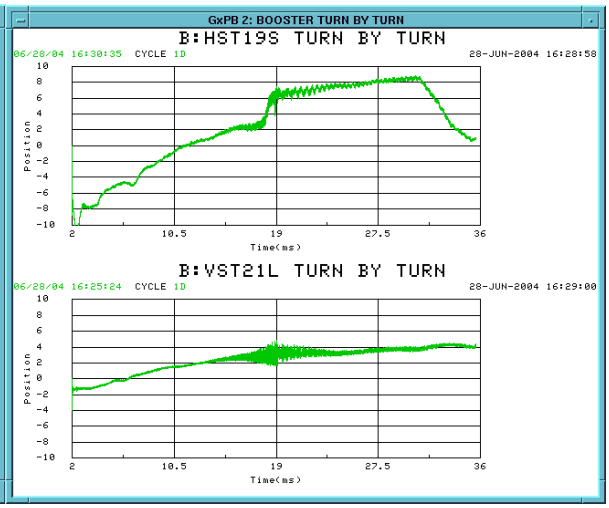

Fig. 1b

It appears from these pictures that a reasonable specification would be 1cm of beam motion at high field and a slew rate of 1mm/ms up to the middle of the cycle.

Tune

Figure 2 shows the horizontal and vertical tunes throughout the cycle. In addition to being able to stabilize the tunes, we have considered halo removal schemes in which we shift the tune near an resonance in one plane or the other.

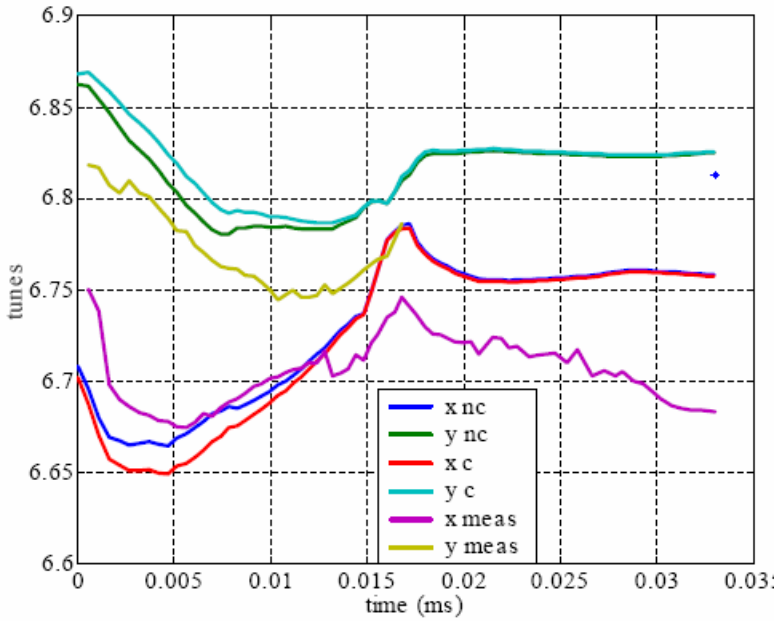

Figure 2: calculated and measured tunes

From this, it appears that a reasonable specification would be += .1 tune control at the high field, with a .01 unit/ms maximum slewing rate at all energies.

Physical Specifications

The basis for these specifications is presented here. The results are summarized in table 1.

Trim Dipoles

The majority of the beam motion is controlled at the high-β regions. The maximum horizontal and vertical β are 33 m and 20 m respectively. There are roughly 100 degrees of phase advance between high-β regions in both planes. The bend angle needed to make a specified lateral deflection in three-bump is maximum at the end correctors and is given by:

$$\Delta x_2 = \theta_1 \sqrt{\beta_1 \beta_2}\, \sin\psi_{12} = \theta_{\max} \beta_{\max} \sin\psi_{\text{period}}$$

So a maximum deflection of 1cm would require bend angles of

- .3 mrad in the horizontal plane
- .5 mrad in the vertical plane

The top momentum in the Booster is about 9 GeV/c, at which these angles correspond to .009 and .015 T-m respectively. The specification of 1 mm/ms up to roughly half way through the cycle corresponds to about .5 and .8 T-m/s, respectively.

Quadrupoles

The quadrupoles are driven by the requirement that the system can induce a .1 unit tune shift at the highest fields. This will take a higher field lower-β vertical plane. Using the formula

$$\Delta\nu = N \cdot \frac{1}{4\pi}\frac{\beta_{\max}}{f}$$

Where N (=24) is the number of correctors, we get

$$f = N \cdot \frac{1}{4\pi}\frac{\beta_{\max}}{\Delta\nu} = (24) \cdot \frac{1}{4\pi}\frac{(20)}{(.1)} = 380\ \text{m}$$

At the highest momentum, this corresponds to about .08 T-m/m. The slew rate specification of .01/mm at all fields gives a slew rate spec of 8 (T-m/m)/s.

Skew Quadrupoles

???

Aperture

The existing corrector packages attach around the standard 3.5" beam pipe. If is simplifies the design and reduces the cost, we could consider going down to a custom beam pipe of 2.5" diameter.

Summary

The following table summarized the parameters of the proposed corrector system:

Type	Max. Field	Max. Slew Rate
Horizontal Trim	.009 T-m	.5 T-m/s
Vertical Trim	.015 T-m	.8 T-m/s
Quadrupole	.08 T-m/m	8 (T-m/m)/s
Skew Quadrupole	??	??

Table 1