Reshimming the Tevatron Dipoles.

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Abstract

A primary source of the coupling in the Tevatron is due to the change, from the time the magnet was made, in the position of the dipole coil within the cryostat. The movement can be corrected by reshimming the coils. There is sufficient time in the coming shut down (Aug. 2004) to reshim only half of the Tevatron dipoles. This note address the question which of the dipoles to correct. The proposed solution would reshim the dipoles furthest from the skew quadrupole correctors in the arcs.

Introduction

The coupling in the Tevatron is generally understood to be primarily due to the movement of the dipole coil within the cryostat, and hence the cold mass, of the Tevatron dipoles. The a_1 due to the shift is ≈ 1.4 units. The a_1 moment can be corrected by reshimming the dipoles. Approximately 100 (106) dipoles were reshimmed in the fall of 2003. The current in the skew quadrupole correction circuit needed to correct the coupling, decreased. Because of the beneficial result from the initial reshimming, an additional 12 dipoles were reshimmed in Apr-2004. The effect on the skew quadrupole currents of that reshimming are more ambiguous. The new values for the currents probably points to difficulties in how we correct for the coupling.

While it is certainly desirable to reshim all the remaining dipoles, limited resources means that no more than half of the remaining dipoles can be reshimmed during the coming shutdown. This note describes an attempt to indicate which of the dipoles should be reshimmed to produce the maximum reduction in the current in the skew quadrupole circuit.

The Model

A simple lattice consisting of Tevatron FODO cells. These cells have a phase advance of $\approx 69^0$ in each plane. $\beta_{max} \approx 100m$ and $\beta_{min} \approx 28m$. There are 96 cells in the lattice and the tune is adjusted to be 18.4 in each plane. Each half cell has 4 Tevatron dipoles.

In order to study the effect of the a1 resulting from the "cold lift" each dipole was split and a pseduo skew quad was placed in the middle of the dipole. The strength of this skew quadrupole was set to represent a skew quadrupole moment a_1 of 1.4 units.

The Tevatron lattice has skew quadrupole correctors at alternate QF locations in the arcs connected on one circuit. These elements, of which there are 48, were included in the model. Thus each skew quadrupole corrector is to correct for the skew quadrupole multipole of 16 dipoles. Since we are able to fix the cold lift of only half the dipoles during the next shut down, the question arises which of the 16 dipoles should be fixed.

Procedure

Using MINUIT within the tracking program TEVLAT the strength of the skew quadrupole corrector circuit was adjusted to minimize the tune shift with the additional constraint that the β functions at the start of the lattice remain at the values computed for the original linear lattice; $\beta_x \approx 28m$ and $\beta_y \approx 100m$.[1]

The results for three configurations (of the more than 2000 possibilities) are presented here:

1. The original configuration with $a_1 = 1.4$ units in all the dipoles
2. The 8 dipoles furthest from the skew quadrupole corrector have a_1 set to 0.0
3. The 2 dipoles on each side of each of the two QD locations.

Results

The results from fitting are shown in Table I.

[1] Fitting without this constraint can give meaningless results.

Table I
Results From Fitting for the Minimum Tune Split.
(The strength of the skew quad corrector is ksqa0)

Configuration	1	2	3
ν_x	0.38894	0.39447	0.395489
ν_y	0.39999	0.40000	0.399998
$\nu_x - \nu_y$	-0.01105	-0.00552	-0.00450
β_x	29.4	27.4	28.6
β_x	95.9	102.5	98.3
ksqa0(A)	-2.380	-1.191	-1.191

Removing half of the skew quadrupole component in the lattice results in a reduction of the of the skew quadrupole correction current a factor of two. To differentiate between the two different reshimming patterns I have looked at the cross plane amplitudes.

The cross plane amplitude will be defined as the rms size of the beam, e.g., in the vertical plane, when the beam is kicked horizontally. The cross plane amplitudes were computed for both horizontal and vertical kicks. The results are found in Table II.

Table II
Crossed Plane Amplitudes.

	Horizontal			Vertical		
Case	1	2	3	1	2	3
rms-h	1.42	1.41	1.41	0.026	0.0088	0.0122
rms-v	0.0289	0.0095	0.0132	1.41	1.40	1.40
Crossed plane ratio	0.0184	0.0063	0.0087	0.0205	0.0068	0.0098

Conclusions

Reshimming the dipoles should result in a reduction in the size of the current in the main skew quadrupole correction circuit. Since half the dipoles will be corrected the current should be reduced by a factor of two.

Of the two correction schemes analyzed the one where the dipoles furthest from the correction skew quadrupole is preferred since it results in a smaller crossed plane amplitude.