Fermi National Accelerator Laboratory

FERMILAB-Conf- 91/109

Model Performance of the New Tevatron Collider Lattice

S. Saritepe and S. Peggs
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Illinois 60510

May 1991

* Submitted at the *1991 IEEE Particle Accelerator Conference*, May 6-9, 1991, San Francisco.

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

Model Performance of the New Tevatron Collider Lattice

S. SARITEPE and S. PEGGS
Fermilab*, P.O. Box 500, Batavia, IL 60510

Introduction

The 1991 Tevatron Collider lattice contains new elements such as electrostatic separators, feed-down sextupoles and new low-beta quadrupoles. The new low-beta section at B0 is a matched insertion. One can vary the β^* from 1.7 m to 0.25 m while keeping the lattice parameters around the ring constant. Another important characteristic of the new insertion is that it provides zero dispersion at the interaction point. An identical (matched) low-beta insertion will be installed at D0. These low-beta insertions use two new types of cold-iron, high gradient quadrupoles. In this paper we concentrate on the effects of the measured multipoles[1] of the new low-beta quadrupoles. We have calculated the tune shift and smear caused by the multipole content of these magnets.

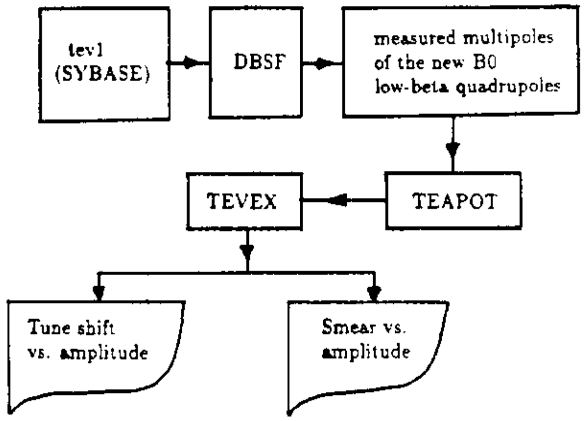

Figure 1: The flow of the tracking study.

The Setup

We have implemented the 1991 Tevatron Collider lattice as a database using the commercial relational database management software SYBASE. This effort was part of the larger effort at FERMILAB and SSCL [2] to install lattice parameter databases with the ultimate objective of building interfaces to operational simulation.

The name of the 1991 Tevatron Collider lattice residing in SYBASE is "tev1". It uses the data structures designed by one of us (S.P). One can switch from injection lattice to low-beta lattice by simply changing the "strength" table in the database. The user extracts the lattice information from "tev1" using the program DBSF [2] which can translate it to MAD,SYNCH,FLAT,MAGIC,X formats. In this study we used TEAPOT which requires an input in MAD format. Once the lattice is created, the measured multipoles of the new low-beta quadrupoles are entered. The lattice, multipoles, and the TEAPOT commands form the TEAPOT input. The TEAPOT output was analysed by TEVEX [3]. Fig.(1) shows the flow of the tracking study.

We restrict our analysis to tune shift versus amplitude and smear versus amplitude plots arising from the measured multipoles of the new low-beta quadrupoles. The dynamic aperture due to new low-beta insertions was studied in Ref.[4]. General Tevatron tracking, including the measured multipoles for all the magnets in the ring was carried out by N.Gelfand using the tracking code TEVLAT [5]

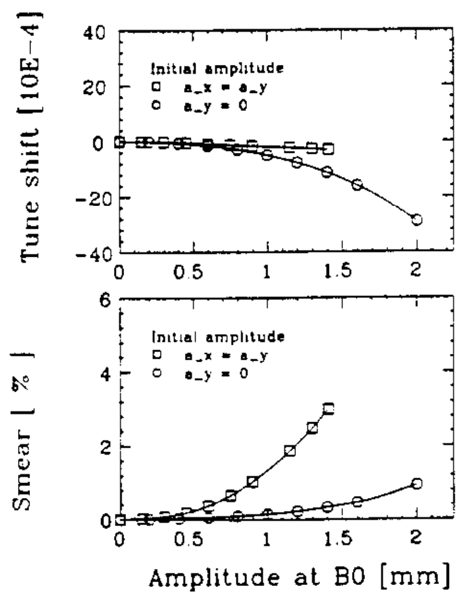

Figure 2: Horizontal tune shift and smear caused by the multipole content of the new low-beta quadrupoles at injection when the particle is on the the central orbit.

Injection

The colliding beams sequence starts with the injection of proton bunches into the Tevatron at 150 GeV. Then

*Operated by the Universities Research Association, Inc., under contract with the U.S. Department of Energy.

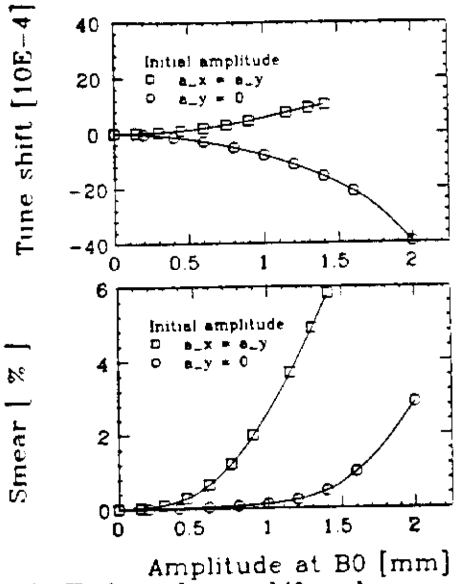

Figure 3: Horizontal tune shift and smear caused by the multipole content of the new low-beta quadrupoles at injection when the particle is on the helical orbit.

the separators are turned on forming a helical orbit. The β^* at B0 during injection is 1.7 m. A particle following the new helical orbit will sample different field errors than one circulating through the centers of magnets. The resulting tune shifts and smears should be different for the helical orbit. In this section we demonstrate the difference. Throughout this study we used the separator voltage programs designed by A.Russell [6].

In Fig.(2) we show the tune shift and smear as a function of horizontal amplitude for the central orbit. Fig.(3) shows the same for the helical orbit. The "smear" is defined as

$$\text{smear} = \frac{< a^2 > - < a >^2}{< a >^2} \tag{1}$$

where a is the normalized particle amplitude.

We have chosen the amplitude scale such that the largest amplitude in mm corresponds to 5σ in normalized amplitude if the emittance of the beam is 100 πmm-mr (Fermilab uses the 95% definition for the emittance). The typical emittance for the Tevatron beam is 20-25 πmm-mr so it never gets as large as 100 πmm-mr. The large emittance was chosen to illustrate the amplitude dependence better. We compare the performance of the two orbits in Fig.(4) and Fig.(5).

Low-Beta

After proton injection and opening of the helix , antiproton bunches are injected onto the (antiproton) helix. At this stage protons and antiprotons circulate on different orbits without colliding. Then they are accelerated to 900 Gev on the helix. Separators as well as certain low-beta quadrupoles are ramped during the acceleration process. At flattop (900 Gev) the size of the helix is reduced due to the increased energy but the separation in terms of beam sigmas is kept the same. Then the triplet quadrupoles are

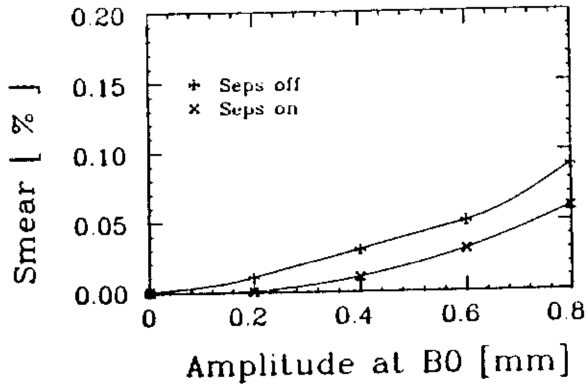

Figure 4: Comparison of horizontal smear measures at injection. The largest amplitude in this case corresponds to 5σ of a 20 πmm-mr beam. Here we compare the curves with the initial amplitude $a_y = 0$.

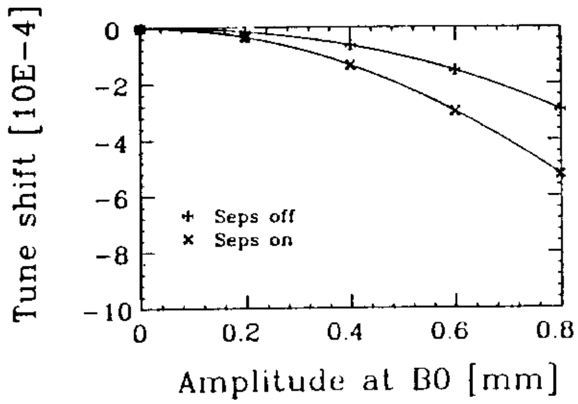

Figure 5: Comparison of horizontal tuneshifts at injection. The largest amplitude in this case corresponds to 5σ of a 20 πmm-mr beam. Here we compare the curves with the initial amplitude $a_y = 0$.

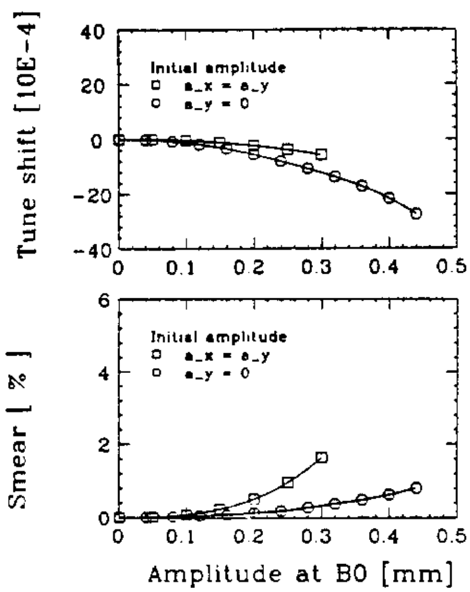

Figure 6: Horizontal tune shift and smear caused by the multipole content of the new low-beta quadrupoles at 900 GeV when $\beta^* = 0.5m$ and beams are not colliding.

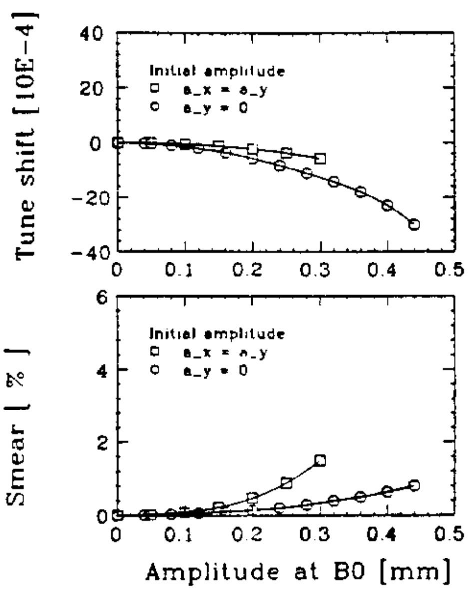

Figure 7: Horizontal tune shift and smear caused by the multipole content of the new low-beta quadrupoles at 900 GeV when $\beta^* = 0.5m$ and there is head-on collision at B0.

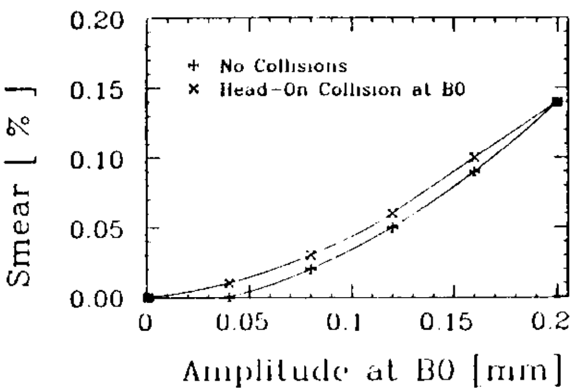

Figure 8: Comparison of horizontal smear measures at low-beta, 900 GeV. The largest amplitude corresponds to 5σ of a 20 πmm-mr beam. Here we compare the curves with the initial amplitude $a_y = 0$.

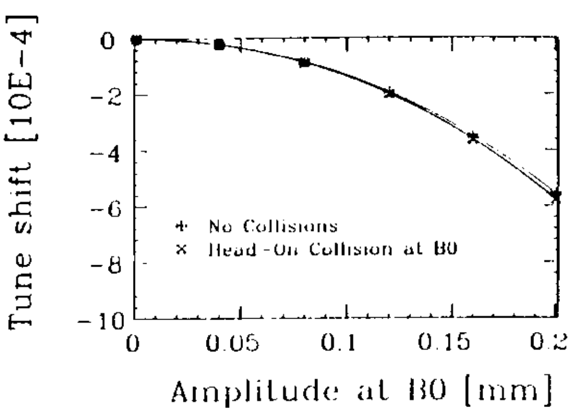

Figure 9: Comparison of horizontal tuneshifts at low-beta, 900 GeV. The largest amplitude corresponds to 5σ of a 20 πmm-mr beam. Here we compare the curves with the initial amplitude $a_y = 0$.

powered to reduce the β^* from 1.7m to 0.5m. At this stage protons and antiprotons are still circulating on different helical orbits. To initiate the head-on beam-beam collision at B0 one has to adjust the voltages of the specific separators (forming a 3-bump). Therefore one has two different orbit configurations in the low-beta lattice.

If the strength of the field errors stay constant, increasing the beam energy will cause smaller tune shift and smear. Therefore one naively expects to see things getting better at 900 GeV compared to 150 GeV. This however is not the case. First; the strength of field errors do not stay constant, they ramp with energy, second; at 900 GeV when we turn on the triplet quadrupoles additional field errors are introduced. Since the triplet magnets are the strongest quadrupoles in the lattice the tune shift and smear measures will be determined mostly by the multipole content of the triplet quadrupoles. Fig.(6) and Fig.(7) show the amplitude dependence upto 5σ of a 100 πmm-mr emittance beam. Fig.(8) compares the smear measures, Fig.(9) compares the tune shifts arising from two different orbit configurations.

Conclusions

This study has shown that the tune shift and the smear caused by the multipole content of the new low-beta quadrupoles are within the tolerable limits. For a typical beam emittance of 20 πmm-mr the particles in the (transverse) tail of the beam suffer a tune shift less than 0.0005. In general, increasing the helix amplitude causes a larger tune shift. This is more visible at 150 GeV. In the low-beta lattice (900 GeV), the helix amplitude is small therefore it makes very little difference. The tune shift in the low-beta lattice is approximately twice as large as the tune shift observed in injection (central orbit) lattice.

References

[1] The error harmonics were measured at the Fermilab Magnet Test Facility (MTF).

[2] G.Trahern, S.Peggs, A.Russell, S.Saritepe, and E.Barr, " Lattice Parameters Database and Interface to Operational Simulation at SSCL and FNAL", Proc.1991 IEEE Particle Accelerator Conf. (San Francisco).

[3] N. Merminga, " A Study of Nonlinear Dynamics in the Fermilab Tevatron", Ph.D Thesis (1989), University of Michigan.

[4] V.Visnjic, " Study of Dynamic Aperture of Low Beta Lattices at Tevatron Collider", FERMILAB-Pub-90/80

[5] N.Gelfand, Private Communication.

[6] A.Russell, "Turning On Collisions" (July 25,1989), "Relocating S2H from B48 to B17" (Aug 4, 1989), Fermilab, Unpublished notes.