Characteristics of the New Tevatron Lattice

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Abstract

The new Tevatron low β lattice that allows operation of two independent low β insertions is described. The measurement of the beta functions at various locations near the interaction region at B0 and the comparison to theoretical calculation are reported.

1 Introduction

A new low β insertion has been installed at B0 in the Tevatron. This new insertion [1] is designed to match into the FODO lattice of the Tevatron and will therefore permit the installation of an additional independent low β insertion at D0. The insertions at B0 and D0 will eventually be optically identical. Matched low β insertions in the Tevatron collider are independent except for the need to maintain a constant tune with distributed tune correction quadrupoles.

2 Tevatron Low Beta Lattice

The layout of the low β insertion at B0 is shown in figure 1. Also shown are the beta functions and dispersion at $\beta^* = 50cm$. The insertion is composed of 18 quadrupoles that are physically placed approximately symmetric relative to the center of the straight section. The magnetic gradients are antisymmetric relative to the center. A field free region of 15.24 m long at the center is left for the detector at B0, as with the old insertion. Two 9 m long straight regions located between Q1 and Q2 on both sides of the interaction region are left for installation of electrostatic separators.

If we proceed outward form the interaction point, the quadrupoles in the triplet (Q1 to Q3) and the next two quadrupoles (Q4 and Q5) are 1.4 T/cm 2 shell magnets; the Q6 quadrupoles are 1.4 T/cm magnets physically joined to a correction piece in the so-called "spool". Q7 to Q9 are 0.7 T/cm 1 shell magnets joined to the correction magnets in spools. The 1.4 T/cm magnets have essentially the same aperture as the quadrupoles used in the old B0 low β insertion but are 40% stronger. The avalability of higher gradient quadruples permits β^* as low as 25 cm.

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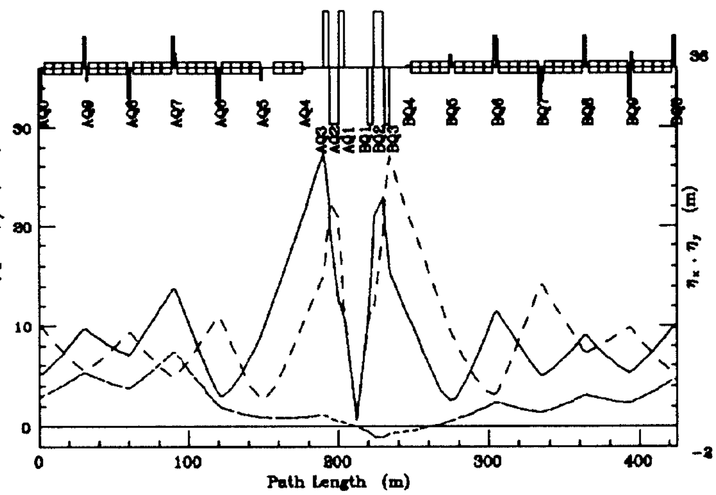

Figure 1: Low β magnets layout at B0. The solid line is β_x, the dashed line β_y, and the dash-dot line dispersion.

3 Beta Functions Measurements

The tune shift ($\Delta\nu$) due to the quadrupole gradient change (ΔG) can be calculated from [2]

$$\Delta\nu = \frac{1}{4\pi}\int_0^C \beta(s)\Delta k(s)\,ds \qquad (1)$$

where

$$\Delta k = \frac{\Delta G}{B\rho}\ . \qquad (2)$$

Equation (1) is only a first order approximation, since

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the second and higher order terms in Δk are neglected. The terms neglected are important only when $\sin(2\pi\nu)$ is near zero. The Tevatron tune is about 0.4, thus the second order term is entirely negligible.

The beta function at the locations of the quadrupoles can be measured by varying the gradient of the quadrupoles. Assuming Δk and β do not vary over the length of the quadrupole, we get

$$\Delta\nu = \frac{1}{4\pi}\beta\Delta k\, l, \tag{3}$$

where l is the length of the quadrupole. If we plot $\Delta\nu$ over $\Delta k\, l$ the slope is $\beta/4\pi$. In figure 2 we plot the measurement at AQ7 and the TEVLAT [3] calculation.

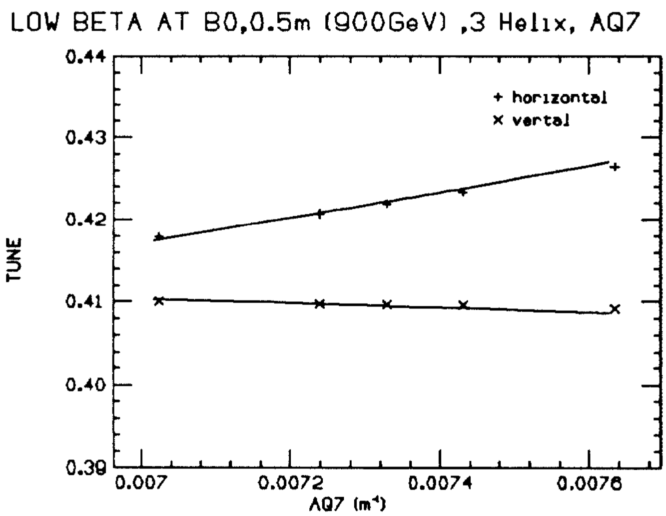

Figure 2: Tune vs. $\Delta k\, l$ at AQ7. The lines are the TEVLAT calculations.

The β functions were measured at the locations of the 7 correction quadrupoles of the B0 low β insertion. Measurements were first done for the injection lattice at 150 GeV/c. The beam was then accelerated to 900 GeV/c and two of the separators were turned on (flat top 1 helix). The beam was then squeezed to β^* of 0.5 cm. At low β the measurements were done with separators off (low β 0 helix) and with separators on (low β 3 helix).

The beta functions were also calculated using TEVLAT. The magnetic field of each magnet was measured as a function of current at Fermilab Magnet Test Facility. The MTF measurements were used in TEVLAT to compute the tune as a function of $\Delta k\, l$.

In tables 1 to 4 we tabulate the measured beta functions and the calculated beta functions at each quadrupole location. Note that since the measurements of small β function are difficult, the calculations and measurements are only given for the larger of horizontal (x) or vertical (y) β function at each location. The measured beta functions are consistently smaller than the calculations. Attempts are made to scale the strengths all low β quadrupoles in the computation to better fit the data. This *ad hoc* approach did not satisfactorily explain the disagreement though good agreement can be found.

4 Conclusion

The new Tevatron low β insertion at B0 is operational. The beta functions are measured at locations near B0. The difference between calculation and measurement need further investigation.

References

[1] A.D.McInturff et al., "The Fermilab collider D0 low beta system", in Proceedings of the European Particle Accelerator Conference, Rome, 1988, p.1264.

[2] E.D.Courant and H.S.Snyder, "Theory of the alternating-gradient synchrotron", Annal of Physics 3, pp.1–48, 1958.

[3] N.M.Gelfand, "TEVLAT", unpublished, 1991.

Table 1 : Low β 3 helix

location	measured (m)	calculated (m)	difference
B0QT6(β_y)	94.42	192.3	−103%
AQ7(β_x)	175.8	197.5	−12%
AQ9(β_x)	55.71	122.7	−120%
AQ0(β_y)	71.87	167.1	−131%
BQ7(β_y)	220.7	359.6	−63%
BQ9(β_y)	95.74	170.6	−82%
BQ0(β_x)	80.88	111.3	−38%

Table 2 : Low β 0 helix

location	measured (m)	calculated (m)	difference
B0QT6(β_y)	109.8	183.2	−67%
AQ7(β_x)	184.0	198.0	−8%
AQ9(β_x)	56.06	126.4	−116%
AQ0(β_y)	73.24	165.7	−126%
BQ7(β_y)	227.1	355.4	−56%
BQ9(β_y)	97.50	170.0	−74%
BQ0(β_x)	90.64	115.3	−27%

Table 3 : Flat top 1 helix

location	measured (m)	calculated (m)	difference
B0QT6(β_y)	106.0	120.8	−14%
AQ7(β_x)	153.8	170.1	−11%
AQ9(β_x)	93.17	103.1	−11%
AQ0(β_y)	78.54	72.17	+8%
BQ7(β_y)	215.6	276.2	−28%
BQ9(β_y)	111.9	119.6	−7%
BQ0(β_x)	93.51	88.34	+5%

Table 4 : Injection lattice 0 helix

location	measured (m)	calculated (m)	difference
B0QT6(β_y)	104.5	100.4	+4%
AQ7(β_x)	151.8	130.6	+14%
AQ9(β_x)	87.72	81.64	+7%
AQ0(β_y)	60.08	81.44	−35%
BQ7(β_y)	264.8	220.3	+17%
BQ9(β_y)	126.3	110.1	+13%
BQ0(β_x)	95.08	125.7	−32%