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Desirable Tevatron F0 straight optics for 150 GeV injection

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Introduction

The geometry and optics of the 150 GeV/c beam lines which connect the Main Injector to the Tevatron are highly constrained. It is implicitly assumed in the present design that the geometrical trajectory of the proton and pbar lines is mirror symmetric about a vertical plane which runs through MI-70, and the closest point of approach in the Tevatron, which here is called "TeV-70". See Figure 1. Consequently, for example, the roll angles of the tilted dipoles in the two lines are equal and opposite. So far, no demands at all have been placed on the optics of the Tevatron F0 straight into which the beam lines connect. Table 1 shows the beta and dispersion functions derived from the contemporary Tevatron lattice that were used to match the proton line.

β_X (m)	α_X	β_Y (m)	α_Y	η (m)	η'	η_N ($m^{1/2}$)	η_N' ($m^{1/2}$)
92.80	-.78	60.49	.10	3.16	.029	.328	.024

Table 1 Nominal optical parameters at TeV-70

Positive dispersion is radially out of the Tevatron, and positive azimuth is clockwise around the Tevatron.

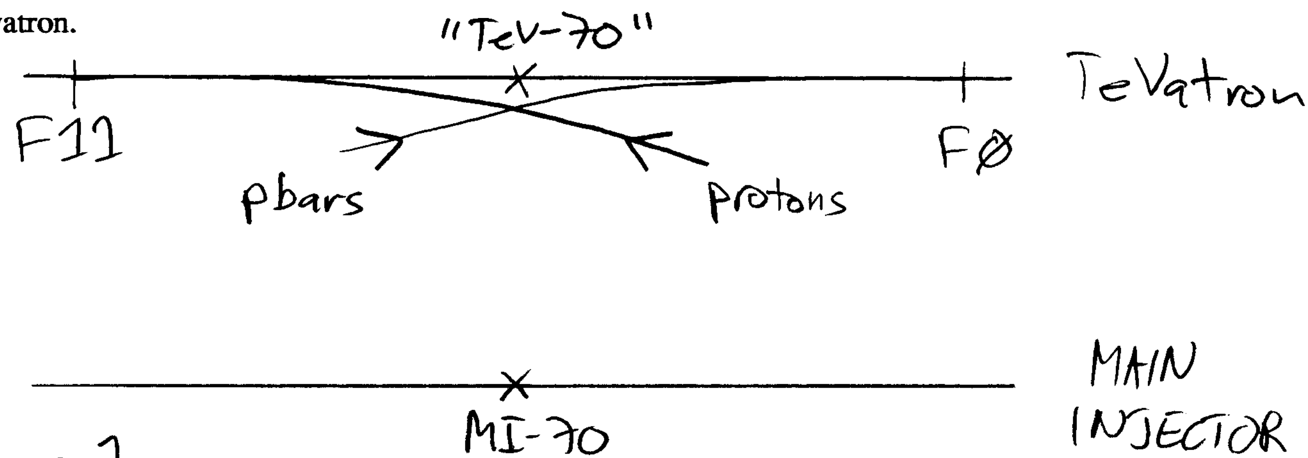

Figure 1

There are several reasons to make some demands upon the Tevatron optics at TeV-70.

1) Making the (relatively severe) request that horizontal dispersion be zero would greatly simplify the 150 GeV beam line layout, probably enabling the removal of 2/3 length dipoles.

2) Making the (relatively modest) request that optical symmetry be maintained at TeV-70, so that $\alpha_X = \alpha_Y = \eta_X' = 0$, would allow the beam line quadrupoles to have equal lengths, strengths, and identical locations in both beam lines. This would simplify the debate about number of power supplies versus number of quadrupole lengths.

3) Tevatron optics may change significantly over the next few years - possibly, for example, with the inclusion of D0 low beta optics. Beam lines designed to work well with the present Tevatron may not work at all with the Tevatron in existence when the Main Injector turns on. At the least, modifications of Tevatron optics need to be passively monitored.

4) In general, the rather severe constraints placed on the 150 GeV lines could be loosened by placing modest constraints on the F0 straight.

Below, we comment on these and other related aspects of the Tevatron F0 optics which should be considered as fully as possible in the amount of time available. We deliberately ignore the added complications of the mutual constraints of the 120 GeV and 150 GeV proton lines.

<u>Zero dispersion</u>

One of us (DEJ) spoke to Dave Finley and Karl Koepke about F0 straight designs, especially in regard to the possibility of reaching zero dispersion. Finley commented that he and Bob Siemann looked at non-zero dispersion in the Tevatron RF cavities as a possible emittance growth mechanism, but dismissed it as unimportant. An order of magnitude cost estimate for an F0 straight redesign is $150k per spool quad, and $250k per special quad. A more productive path (Finley said) is to look at injecting in the other plane (see below). Koepke said that, for zero dispersion, it looked like new 6.6 Tesla dipoles would be required in several cells on either side of the RF straight section. Bends would be removed in the adjacent cells to keep the total bend angle the same. New quad lengths would probably also be needed. Sounds expensive.

Aside from the expense of what is probably a major redesign of the F0 straight, making the dispersion zero would probably have a major impact on the geographical relationship between the Main Injector and the Tevatron. It is an implicit part of the current design that two Main Injector dispersion cells, followed by two regular cells, launch the horizontal dispersion with about the correct amplitude to match into the Tevatron. It is a fortunate coincidence in the present design that when the bend angle in these four cells is subtracted from the total beam line bend angle, there is an appropriate amount of bending left over for the C-magnet and (currently) horizontal bending Lambertsons. It is not trivially obvious how the bending cell structure would be rationally rearranged in a zero dispersion scheme. However, it is quite probable that either the dipole packing fraction would be significantly lower, and/or the half cell lengths would be different, and/or the cell phase advance would be different from the Main Injector.

Plane of injection

In the present injection scheme the final Lambertsons bend horizontally, leading to large aperture requirements in the Tevatron Lambertsons and kickers. It might be decided, upon further investigation, that it is necessary to modify the injection scheme so that the final Lambertsons bend vertically instead of horizontally. Although this change would have a significant impact on the proposed contents of the Tevatron, it would probably only have a minor impact on the geographical relationship between the Main Injector and the Tevatron. It would have almost no impact on the optical functions in the Tevatron which are being discussed here. Although the topic of plane of injection modification is a major one, it is almost completely orthogonal to the question of desired optical properties at TeV-70.

Conclusions: Symmetric optics and sensitivity analysis

It is natural that the normalized dispersion slope, η_N', is so small at TeV-70 (see Table 1) near the center of a straight. This near-symmetry has made it possible to concentrate on the design of only one of the two 150 GeV beam lines. In addition to a study of the optimum plane of insertion, we recommend that two optical studies proceed, that are related to each other, but which are formally independent.

First, possible ways to introduce fully symmetric optics in the Tevatron F0 straight should be investigated. That is, how difficult is it to make $\alpha_X = \alpha_Y = \eta' = 0$ at TeV-70? What range of betas and dispersion functions, β_X, β_Y and η_X, naturally result?

Secondly, what range of values of β_X, β_Y and η_X can be easily reached by symmetric 150 GeV beam lines? Such an analysis would have important practical consequences - for example, in establishing acceptable ranges for the evolution of Tevatron optics in the F0 straight. It would also respond to comments in the recent DoE review about the need for beam line sensitivity analyses.