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FNAL MAIN RING TO ENERGY SAVER ANTIPROTON TRANSFER SYSTEM FOR TEVATRON I

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Summary

A system for antiproton beam transfer from the Main ring to the Energy Saver for colliding beam operations has been designed and fabricated. The system is similar to the existing proton beam transfer system used for fixed target operation of the Energy Saver. Using a fast kicker in the Main Ring, one or several bunches of 150 GeV pbars will be kicked horizontally across the septa of two Lambertsons into a short transfer line. At the end of this line, they are injected into the Energy Saver through two more Lambertsons and kicked onto a closed orbit by a second fast kicker. For commissioning and tune-up, the system will be operated in reverse, extracting 150 GeV protons from the Energy Saver to the Main Ring. In addition to a description of the design of the system and its components, the status of the installation and commissioning will also be discussed.

Introduction

For colliding beam operation in Tevatron I,[1] 13 53 MHz bunches of 8 GeV $\bar{p}$'s will be injected into the Main Ring and accelerated to 150 GeV. These bunches will be coalesced into a single bunch; they will then have to be transferred to the Tevatron, where there may already be circulating proton (and $\bar{p}$) bunches. This paper will describe the components and the beam dynamics of the transfer (reverse injection) system. It will not discuss the beam synchronization system required for control of the azimuthal location of the transferred $\bar{p}$ bunches.

The general outline of the system is quite similar to the forward injection system. Pbars circulating in the Main Ring are kicked onto an extraction orbit by a kicker at E17. The kicked beam passes through the field region of two standard forward-injection-style Lambertsons, and is pitched down towards the Tevatron. As in the forward injection system, there are two trim dipoles and a lattice matching quadrupole in the transfer line; the beam is then pitched flat at Tevatron height by two more forward-injection-style Lambertsons in the Tevatron, and injected into the Tevatron aperture. It is kicked onto the closed orbit by a kicker at D48.

Main Ring Extraction

Prior to extraction at 150 GeV , correction dipoles in the Main Ring at D46 and E17 are ramped to produce an orbit distortion of -8 mm at the extraction point (E11). Another dipole at E12, together with the E17 dipole, produce a kicker-cancelling bump between E17 and E11. To extract the beam, the E17 kicker is fired to produce an additional -28 mm deflection at E11, causing the beam to cross the septum of the Lambertson at E11. The extracted beam is kicked downward by the Lambertson field into the transfer line to the Tevatron.

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Fig. 1 shows the calculated beam envelope for the circulating and extracted beams on the last turn before extraction. The size shown corresponds to that expected for antiprotons: a normalized emittance of 25π mm-mrad and a momentum spread of ± .115%.

Transfer Line

The transfer line elements are four Lambertsons, two trims and one quad. The quad is shared with the forward injection line. The layout is shown in fig. 2. Fig. 3 shows the horizontal orbits in the transfer line, relative to the Main Ring and Tevatron center lines. The horizontal trims are adjusted to create an orbit which goes through the center of the lattice matching quad (whose position is fixed by the forward injection system) and into the Tevatron Lambertsons aperture. The correct horizontal injection angle into the Tevatron is obtained by rotating the Lambertsons by 6.4 deg. To compensate for the field difference introduced by the rotation, a shunt will be used across the Main Ring Lambertsons.

Tevatron Injection

Fig. 4 shows the injected and circulating beam envelopes from D43 to E17. To clear the Lambertson septum after injection, the closed orbit is displaced about 8 mm from the Tevatron center line, using horizontal correction dipoles at D48, D49, E11, and E13.

Extraction System Components

The E17 kicker is a lumped inductance system, (similar to that described in ref. 2), which is driven to 5 kA by the discharge of a capacitor bank through a thyratron switch. The current waveform is a half-sine wave of duration 35 µsec, appropriate for single turn extraction of a single $\bar{p}$ bunch. The voltage requirement is ~5 kV.

The D48 kicker has substantially more stringent requirements. The time structure required for the kicker pulse must be such that it will not restrict the choice of whether protons or $\bar{p}$'s are first injected into the Tevatron. The worst case then occurs when 6 equally spaced bunches of protons are already in the Tevatron, and a $\bar{p}$ bunch must be injected into one of the gaps. Since only a single bunch is to be injected, the flat top can be very short; however, the sum of the rise and fall times must be less than the time separation between 2 proton bunches (3.5 µsec). Additionally, because of the relatively small phase advance between the injection point (D49) and the kicker, a large kick angle (0.9 mrad) is required.

In order the acheive this, the D48 kicker has been constructed as two 1.9m transmission-line style magnets, of impedance 5 ohms. The magnets are similar in design to the E17 forward injection kickers in the Tevatron.[3] However, in order to improve the frequency response, the magnet has been more finely segmented into LC cells, and the cells have been separated by air gaps to reduce the mutual inductance between them. The magnets are connected

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in parallel to a cable PFN through a thyratron switch (see fig. 5). The 2.5 ohm cable PFN is constructed of 10 reels of RG-220 cable in parallel, each roughly 300 m long. The system should be able to acheive a rise and fall time for the kicker field of better than 1.5 usec; the peak current in the magnets will be 5 kA, acheived with a voltage of 50 kV on the PFN.

The extraction/injection Lambertson magnets are identical in design to those used for the forward injection system.[4] They require roughly 1500 A, and will be ramped synchronously with the Main Ring.

Lattice Function Matching

The quadrupole in the transfer line is used to match the Tevatron and Main Ring lattices. This match is not perfect, but the resulting phase space dilution is small (0.9% in each plane). There is a very small horizontal dispersion mismatch (causing less than 0.1% dilution). However, there is a significant vertical dispersion mismatch. The additional vertical dispersion in the Main Ring produced by the new overpasses around the collider detector exacerbates the problem. With overpasses at both B0 and D0 as designed, the vertical dispersion mismatch at Tevatron injection will result in a 20% dilution of the $\bar{p}$ phase space. The corresponding reduction in collider luminosity will be 10%.

Commissioning

The system will be commissioned by extracting 150 GeV protons from the Tevatron to the Main Ring. A machine supercycle will be set up in which protons will be injected into the Main Ring, accelerated to 150 GeV, coalesced into a single bunch, and injected into the Tevatron. They will coast at 150 GeV for a few seconds while the devices associated with the pbar transfer line are activated. Then, the single bunch of protons will be extracted from the Tevatron. It will traverse the pbar transfer line in the direction opposite that of pbars, be injected into the Main Ring and aborted. The reverse injection system will be tuned to minimize injection oscillations in the Main Ring.

A similar procedure will be used to test the pbar transfer system before each attempt to transfer pbars from the Main Ring to the Tevatron.

References

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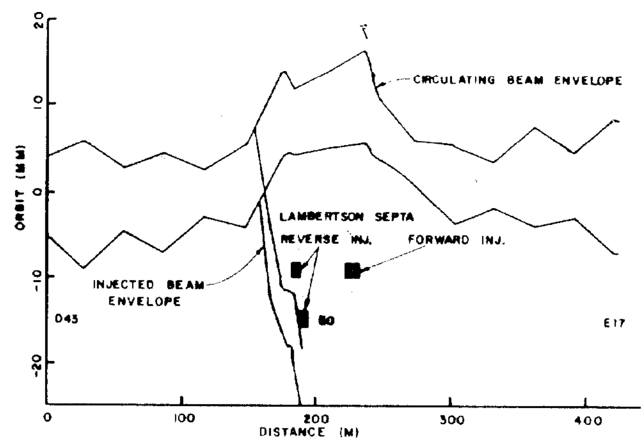

Fig. 4 Calculated beam envelopes of circulating and injected 150 GeV $\bar{p}$ beam near E0 in the Tevatron. The kicker is at D48.

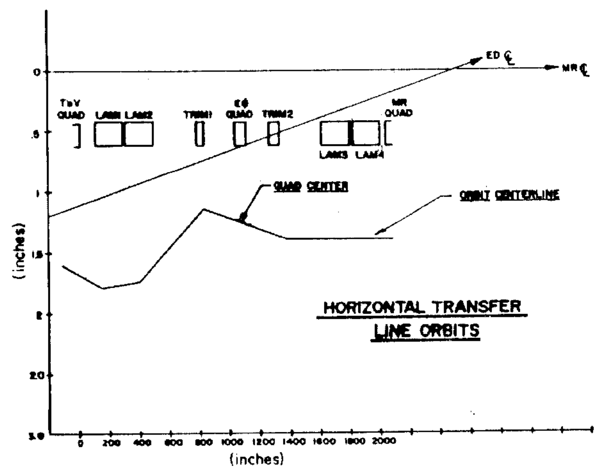

Fig. 3 Horizontal transfer line orbits for the reverse injection system at E0.

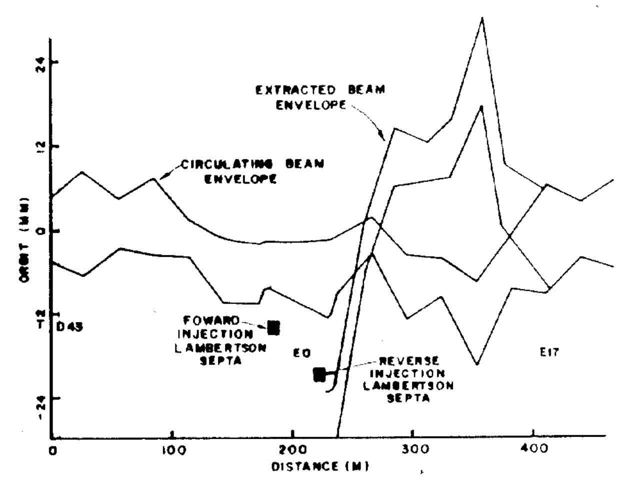

Fig. 1 Calculated beam envelopes of circulating and extracted 150 GeV $\bar{p}$ beam near E0 in the Main Ring. The kicker is at E17.

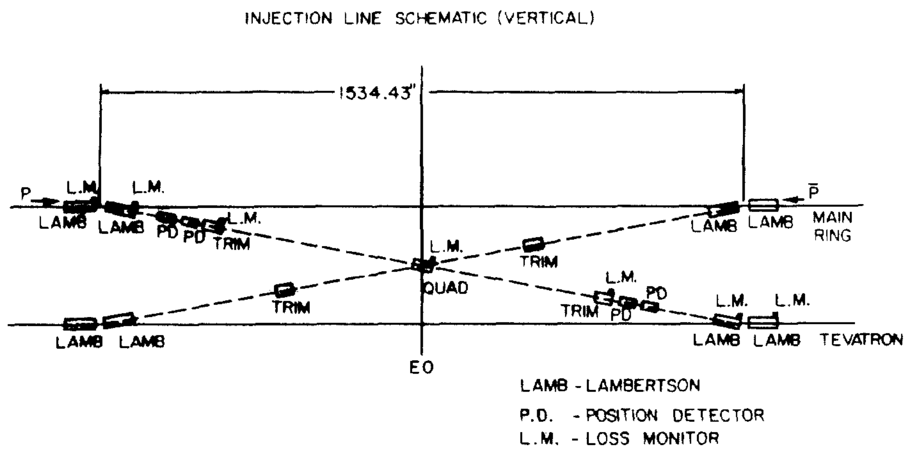

Fig 2 Layout of the forward and reverse injection systems at EØ.

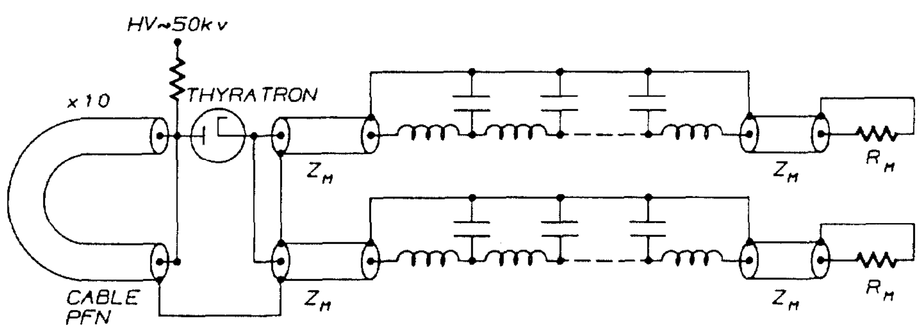

Fig. 5 Circuit diagram of the D48 kicker system for Tevatron $\bar{p}$ injection. The magnets are shown as distributed LC systems, with Z_m=5Ω. The load resistor R_m=5Ω. The cable PFN has Z_o=2.5Ω (10 double-ended 300 m cables).