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An Update on the Tevatron Collimator System for Collider Run II

M. Church, Fermilab†, PO Box 500 Batavia, IL, 60510

Abstract

This paper updates the reader on progress since the last report on this subject[1]. The new beam halo collimation system to be installed in the Tevatron for Collider Run II is nearing completion. All collimators have been completed, and 6 out of 13 collimators have been installed in the Tevatron and are currently being tested. All controls have been installed and software algorithms are being developed for both beam halo scraping and proton removal. The remainder of the collimators will be installed by April 2000 and will be fully commissioned with colliding beams during the engineering run between May 2000 and November 2000.

1 INTRODUCTION

The Tevatron is a proton-antiproton storage ring which will be operated at 1 TeV beam energy during Collider Run II. There are two interaction regions, located 1/3 of the ring apart, which will service colliding beam detectors. The primary purpose of the new collimation system is to reduce the detector backgrounds due to beam halo. This is expected to be a serious issue, since the luminosity will be 10 times higher than in Collider Run I. In addition, some of the collimators will be used to remove the proton beam at the end of a store, so that the antiprotons can be decelerated and extracted back to the Recycler Ring for recooling and reuse.

2 DESIGN AND LAYOUT

The collimation system is a two-stage system. Primary scattering targets are followed by secondary absorbing collimators at an appropriate phase advance downstream. The principle behind this system has been described elsewhere[2]. The locations of the targets and collimators in the Tevatron are based on tracking and beam loss simulations by Drozhdin, et. al.[3] and on other constraints imposed by an already existing machine. The layout finally arrived at is shown in Fig. 1. There are a total of 12 targets/collimators to be used for beam halo removal -- a primary target and two associated secondary collimators each for low momentum protons, for high momentum protons, for low momentum antiprotons, and for high momentum antiprotons. There is one additional collimator to be used for proton removal only.

The only locations in the Tevatron with non-zero horizontal dispersion are at the IR's, and therefore momentum collimation and transverse collimation are necessarily mixed in the horizontal plane. There is limited available warm space in the Tevatron, and this puts severe constraints on where the collimators and targets can be located in the ring. Depending on beam conditions and location, the beam sigmas range from .25 mm to 1 mm. During beam halo removal, we anticipate moving the primary targets to within 5 beam sigmas from beam center and the secondary collimators to within 6 beam sigmas from beam center.

It is difficult to make significant changes in the Tevatron lattice (and, indeed, in any already existing machine) in order to modify phase advances, beam separations, dispersion functions, and beta functions. However, a small (~20°) local phase bump will be implemented in part of the ring in order to obtain better vertical beam separation between the protons and antiprotons at the F17 collimators. This will be done by reconfiguring the existing six tune quadrupole circuits and powering some additional quadrupoles independently in order to match to the IR inserts. Table 1 shows the beta functions, dispersion functions, beam separations, and phase advances from primary target to secondary collimators.

3 MECHANICAL DESCRIPTION

The collimator consists of 2 pieces of stainless steel, 1.5m long, bolted together in an L-shape configuration. These pieces are machined and ground to ±25μm tolerance and then electropolished. This assembly is welded inside a stainless steel box with bellows on each end. The bellows are connected to stationary beampipe on either end. The entire assembly is supported by two cradles which can be moved independently in both the vertical and horizontal directions by stepping motors. The limit on the motion is ±25.4mm, and currently the smallest step size is 25.4μm, although this could be reduced to 3.2μm if necessary. The support system and bellows are such that each end of the collimator can be moved independently to opposite ends of its range of motion with no mechanical binding. Position readback is provided by LVDTs (linear differential voltage transformers), and mechanical damage is prevented by limit switches on all degrees of motion. The stepping motors each develop 1125 in-oz (.81 m-kg) of torque and are geared such that one motor turn corresponds to 1.27mm in collimator translation. The maximum speed is

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

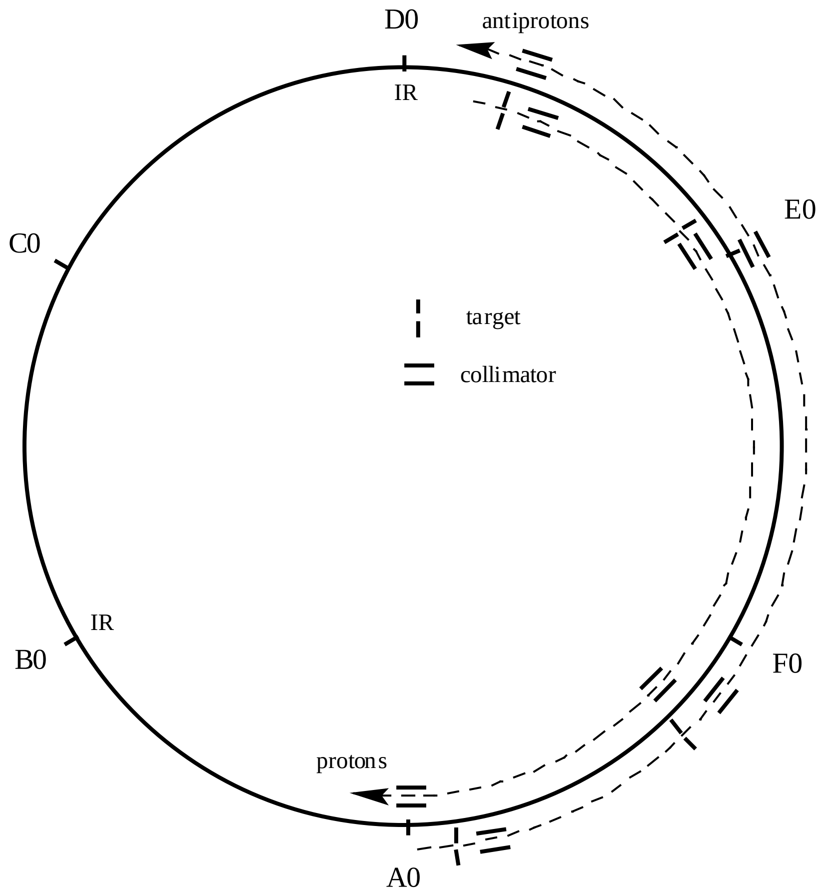

Figure 1: Layout of Tevatron beam halo targets and collimators for Run II.

	protons		antiprotons					beam separation	
collimator	ϕ_x (deg) (mod 360)	ϕ_y (deg) (mod 360)	ϕ_x (deg) (mod 360)	ϕ_y (deg) (mod 360)	β_x (m)	β_y (m)	D_x (m)	x (mm)	y (mm)
D17 target	0	0	326	349	87	34	5.7	4.4	1,9
D17(2)	6	12	320	337	63	47	4.9	3.5	2.7
D17(3)	8	14	318	335	58	52	4.7	3.2	2.9
D49 target	171	187	156	153	88	75	1.8	5.0	3.1
E0(1)	183	195	143	142	59	94	1.7	3.6	4.1
E0(2)	213	225	112	123	96	59	2.3	2.2	4.4
E0(3)	214	227	111	121	99	59	2.4	2.1	4.4
F17(1)	148	167	177	182	91	32	5.9	5.6	1.0
F17(2)	149	169	176	179	85	35	5.7	5.4	1.2
F17 target	156	180	170	168	61	50	4.9	4.6	2.1
F48	312	302	14	46	99	29	1.8	5.7	1.4
F49 target	326	349	0	0	179	40	2.5	7.9	1.3
A0	331	14			160	61	2.6	7.4	3.2

Table 1: Beta functions, dispersions, phase advances from target, and beam separations at collimators.

currently set at about 1.2 turns/second which translates to 1.5mm/sec of transverse collimator speed. The maximum speed is actually limited by the inductance of the motor coils, which broadens the stepping pulse width and causes them to overlap in time at too high a stepping rate.

The primary targets are similar to the collimators, except the stainless steel L-assembly is only .06m in length, and the entire assembly is supported on only one movable cradle. The scattering targets are tungsten wings, 5mm thick, which are bolted to the L-assembly and protrude .6mm further into the aperture than the stainless steel.

4 BEAM STUDIES

During the current fixed target program, there has been some limited opportunity for dedicated beam studies with the collimators. This time has been used to understand collimator alignment issues, understand collimator mechanical tolerances, understand beam loss limits, develop automated scraping algorithms, and generally "get the bugs out" of a new system. To date, all of these studies have been done at 150 GeV.

For beam halo scraping, when the collimators are moved from the full out position to within 5-6 beam sigmas from the beam, their motion will be controlled via fast feedback from local loss monitors and a global beam current monitor. This feedback loop is in the locally controlling cpu and can occur at up to 720 Hz. It has been successfully tested at low intensity. The algorithms for sequencing the motion of the 12 targets/collimators are also being developed and tested. Future studies will also be done at 800 GeV.

5 PROTON REMOVAL

In the future, it will be required to remove the protons from the machine at the end of a collider store in order to efficiently decelerate the antiprotons for reuse. In order to do this quickly and without quenching the Tevatron, four normal conducting dipoles (old MR B2's) have been installed in the E0 long straight section of the Tevatron and powered in a dogleg configuration. During proton removal, this dogleg will be turned on, and a special collimator with tungsten wings bolted to each end will be gradually inserted into the proton beam between the first and second dipoles (see Fig. 2). The scattered particles will be mostly pointing toward the tunnel wall away from the superconducting magnets. In addition, two more collimators just downstream of the dogleg will help shield the superconducting magnets from particle spray. This will allow for rapid extinction of the proton beam, without danger of quenching. This procedure has been tested successfully at low energy and at low intensity, and it will be tested at higher intensity and higher energy in the near future. It appears likely that the entire proton beam (10^{13} particles) can be cleanly removed from the machine in about 120 seconds.

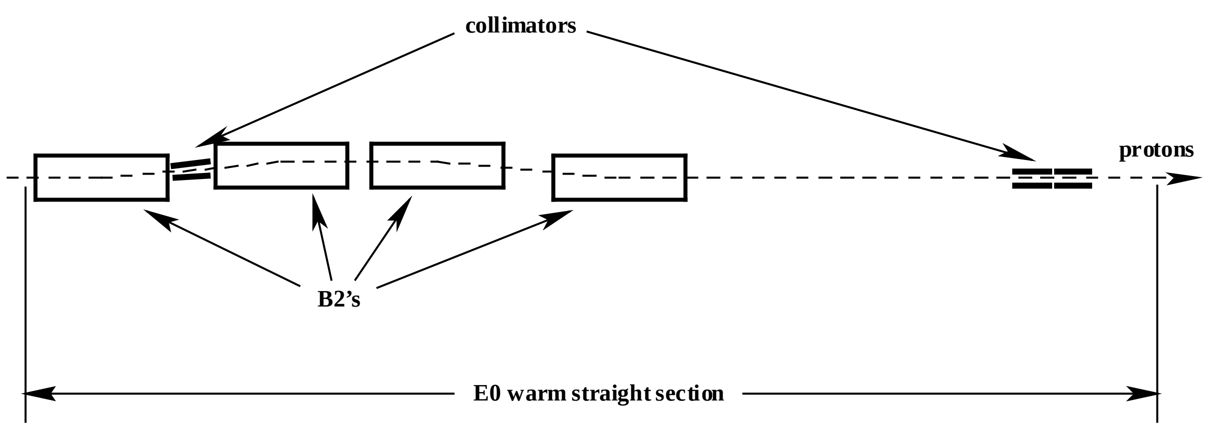

Figure 2: Proton removal dogleg at E0 straight section.

6 ACKNOWLEDGEMENTS

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