A Design for a Beam Halo Scraper System for the Tevatron Collider

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ABSTRACT

The next Tevatron Collider run will have higher luminosity than the previous run as well as separated beams. In order to achieve a low beam halo background rate in both collider detectors, the beam scraper system has been greatly expanded. In the previous run, only one beam scraper was used, and it was only used at the beginning of stores. For the next run, eight scrapers will be available. Because of the seperated orbits, protons and anti-protons must be scrapped independently. There are scrapers for both vertical and horizontal planes. For every primary scraper, there is a secondary scraper to catch particles scattered back out of the edge of the primary scraper.

INTRODUCTION

In hadron collider storage rings without synchrotron radiation damping of the transverse emittance, there will be particles with transverse emittance at the smaller of the physical or the dynamic aperture. These beam tails are populated by a variety of mechanisms. Regardless of how the tails are populated, they will cause background problems and even radiation damage problems for the particle physics experimenters who want to have detectors close to the beam and have strong quadrupoles to make low beta at the interaction point. These strong quadrupoles typically have very large beta only a modest distance from the detectors. It is thus desirable to remove all particles with transverse emittance of more than about 5 σ. This can be done by moving a block of metal, called a beam halo scraper, into the physical aperture until the undesired beam particles are removed by interacting in the scraper. A problem with this single-scraper method is that a significant fraction of the beam particles that hit the scraper merely multiple-coulomb scatter back out of the surface without undergoing nuclear interactions. These particles scatter out to larger emittances and cause the very background problems the scraper has been created to eliminate. An improvement over this state is to install a second scraper downstream of the first at a phase advance such that particles that scatter out of the first scraper will hit the second. The second must be kept further away from the core of the beam than the first so that only particles which have scattered out of the first to larger emittance will strike the second. Typically the first would be set at 5 σ from the beam with the second set at 5.5 to 6 σ. The phase advance from the first to the second should be of the order of .4 or .9 of an oscillation[1]. Figure 1 shows the phase space projection of the 5 σ edge of the beam at the second scraper for protons in the horizontal plane in this Tevatron design. The line of x's at the upper right represents particles scattered from the edge of the first scraper. The units are meters and radians.

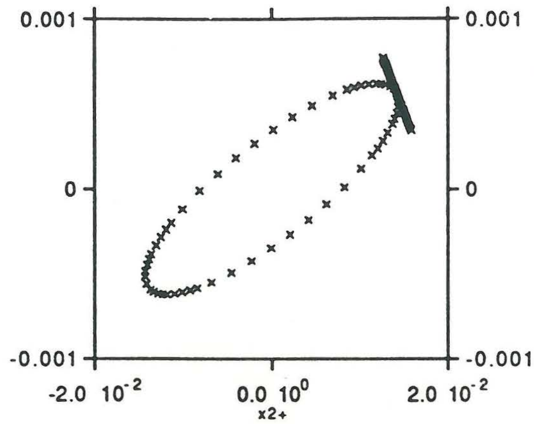

Figure 1. Phase space projection from primary scraper at clean-up scraper.

MECHANICAL DESIGN OF SCRAPERS AND MOTION CONTROL AND READBACK

Each beam halo scraper consists of an 'L' shaped steel block with separate horizontal and vertical motion control and readback at each end.[2] The position readback uses LVDT's (linear variable differential transformers) with a least count of .001". The motion control least count step is nearly an order of magnitude smaller than this so the software control allows "move to position". Some of the scrapers are 60" long, but because of the limited space available three short 24" scrapers have been made. This still allows alignment of the angle of the surface of the scraper relative to the beam to better than 50 microradians. The scraper surfaces are smooth and flat to .001". Calculations suggest that Tungston would be a better materail than steel in that the scrapers could be made shorter and have smoother, flater surfaces. We have chosen to use steel for reasons of economy and speed of frabrication. If, as the luminosity of the Tevatron is increased the experimental backgrounds become excessive, this system could be improved by replacing the primary scrapers with Tungston.

LATTICE DESIGN

The Tevatron lattice was not originally designed for operation as a collider. Modifications have been made to the lattice to add two matched low beta insertion regions, but no modifications have been made for beam halo scrapers. Over 94% of the circumference of the Tevatron is cold beam pipe and even small beam loss in these regions can cause quenches. Most of the warm regions are filled with other devices such as collider detectors, RF, electrostatic separators, injection and aborts. This left a very limited collection of location slots into which one could insert scrapers. Some of the design criteria which went into the selection of scraper locations were 1)The primary and secondary locations should be seperated by about 0.4 or 0.9 oscillations (plus some number of whole oscillations if necessary). 2)In the horizontal plane scrape from the radial inside (i.e. the low energy side). This not only takes advantage of any energy lost in scatters in the primary scraper to produce greater displacement at the secondary scraper, but also allows the primary scraper to serve as the momentum space aperture stop for particles that are lost from the RF bucket and very slowly lose energy through synchrotron radiation. 3)It was desirable to use the existing scraper at D17 which is used for the fixed target extraction clean-up. This was chosen to be the primary proton scraper for both the horizontal and the vertical planes. 4)It is desirable to use both surfaces of the 'L' and scrape both a horizontal and a vertical beam edge at a given location. Because the horizontal and vertical phase advances between two points of the Tevatron are different, it is not possible to use the same pair of locations for the the primary and secondary scrapers of a particular particle in both the horizontal and vertical planes. It was, however, found possible to put the primary anti-proton scraper for the vertical plane at the same location as the clean-up scraper for the protons in the horizontal plane. The primary p-bar scraper for the horizontal plane was placed at F17 to take advantage of the large dispersion there. A short slot at E0 between devices used for beam transfer from the Main Ring to the Tevatron was found to have acceptable phase advances from both the p-bar primary scrapers and so a special, short (24") scraper is being built for there. The only slot with the proper phase advance from the proton vertical primary was found between the F49 quads and so another special short (22") scraper is being built for this location. Table 1 below shows the locations chosen and their lattice functions.

TABLE OF SCRAPER LOCATIONS AND LATTICE FUNCTIONS

loca-tion	pur-pose	β_x	β_v	X_p	Ψ_x	Ψ_v
D17	p h	76.4	38.41	4.3	18.042	18.010
A0	p h	63.4	156.1	1.5	6.371	6.480
					8.91 advance	
D17	p v	76.4	38.41	4.3	18.042	18.010
F49	p v	168	42	2.4	6.321	6.365
						8.945 advance
F17	p-bar h	65.4	44.55	5.2	3.879	3.847
E0	p-bar h	76.3	67.60	2.7	0.007	0.030
					3.87 advance	
A0	p-bar v	63.4	156.1	1.5	6.375	6.479
E0	p-bar v	76.3	67.60	2.7	0.024	0.030
						6.45 advance

Figure 1 below is a schematic diagram of the scraper location which also indicates their function. Note that protons circulate clockwise while p-bars circulate counter-clockwise. Outside the circle represents the radial plane, while inside the circle represents the vertical plane with radial out representing up. The beam seperation is indicated.

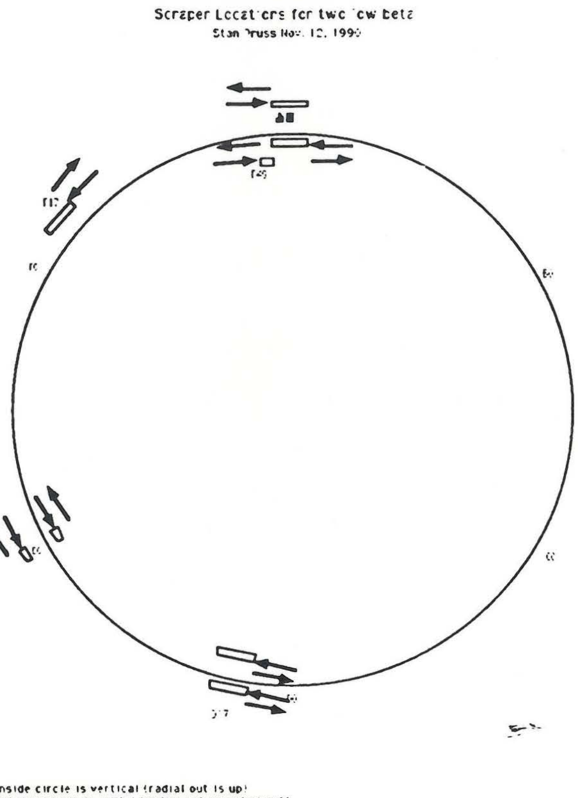

Figure 2. Tevatron scraper locations

REFERENCES

(1) J.B.Jeanneret, "Phase Difference Between Collimators in a Collider," CERN, Geneva, Switzerland, SL/EA/Note 90-01, 1990.

(2) S.Lackey,M.Coburn,C.Crawford,J.Elseth, and W.Knopf, "Motion Control System for the Fermilab Electrostatic Septa," in 1987 IEEE Particle Accelerator Conference, Washington, D.C., March 1987, pp. 617-619.