Booster Collimation Revisited:
A Beam Whacker as Primary Collimator

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Abstract

A novel solution for a primary collimator for fast-cycling synchrotrons is proposed. A similar device, a so-called Beam Whacker that uses a motor from a personal computer hard drive, is now employed to measure the beam size and deduce the emittance in the Fermilab Booster. The name is derived from its passing resemblance to a Weed Whacker[1] a device for cutting weeds in a garden. The present proposal illustrates the basic principle of a rotating Beam Whacker collimator.

Introduction

Effective collimation is more difficult to achieve in an accelerator than in a fixed-energy storage ring because the horizontal and vertical positions and sizes of the beam change during acceleration; also the ideal thickness of the primary collimator increases with energy.

The present collimation system in the Fermilab Booster consists of two primary and several secondary collimators as shown in Figure1. All the present Booster collimators are passive devices with fixed geometry and position. This limits their effectiveness.

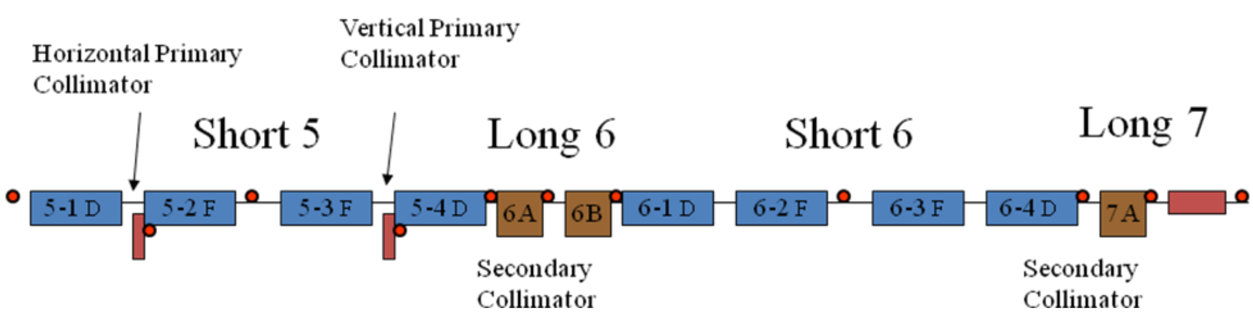

Figure 1. Blue boxes represent the main magnets; collimators are represented by brown boxes.

The beam half-height is physically larger at the injection energy (400 MeV) than at the extraction energy (8 GeV). Ideally, the relative position of the beam with respect to the primary and secondary collimators should be adjusted during the acceleration cycle to intercept the beam halo. Also, the primary collimator should grow in thickness during acceleration for fully efficient halo removal throughout the cycle.

Disk-drive Implementation of a Beam-Whacker Primary Collimator

Ideally, beam collimation in the Booster should be done in both planes and during the whole acceleration cycle. One impediment is that the Booster beam is moved in the horizontal plane differently from cycle to cycle for the purpose of cogging with the Main Injector. This makes it difficult to keep the beam at the desired position with respect to the horizontal collimators for the whole acceleration time. So we collimate in the horizontal plane only early in the acceleration cycle, before cogging begins, and rely on there being enough coupling between the two planes so that collimation in the vertical plane will result in clean beam also in the horizontal plane.

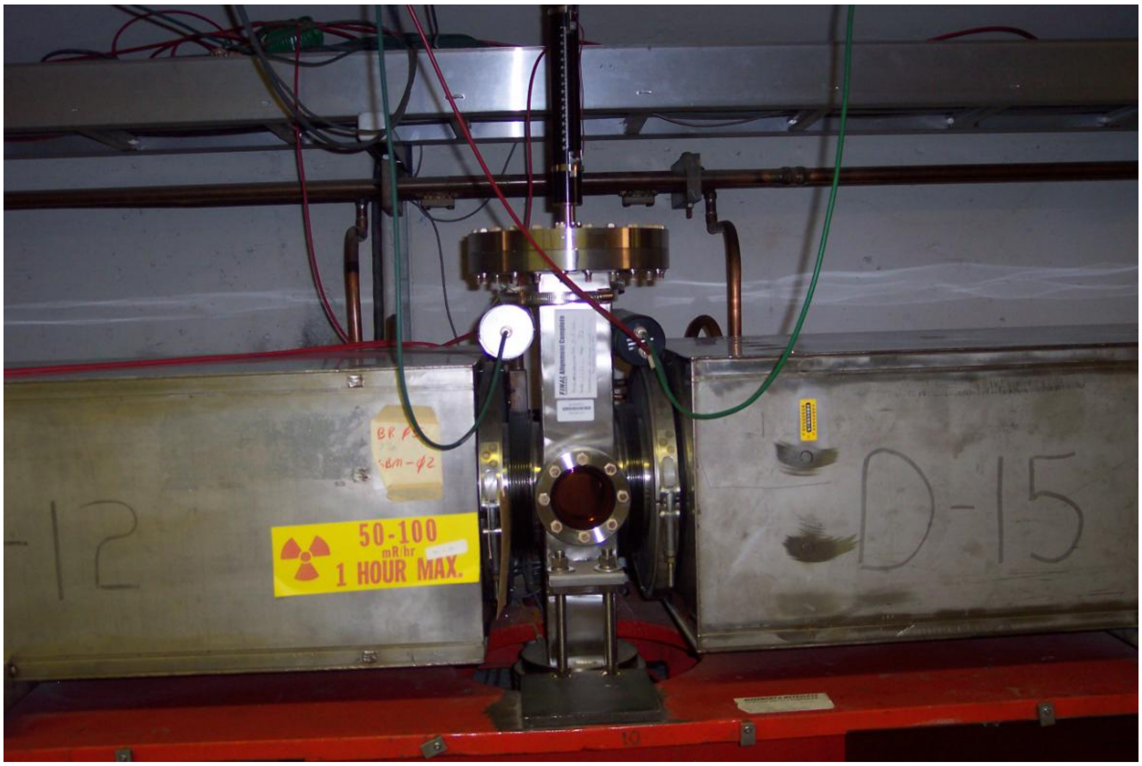

Photo 1. Primary Vertical Collimator.

The present primary collimator in the vertical plane in the Booster is shown in Photo 1. The Beam Whacker device that is being proposed to replace it is shown schematically in Figure 2. In this diagram, a compact disk drive from an ordinary personal computer has an oval plate with variable size and thickness attached to become the target that passes through the edge of the beam.

The motor with the disk plate is attached on a fork so that the whole assembly can be lowered into the beam. The exact shape of the oval disk will be determined using measurements performed by the Beam Whacker. Following the original design suggestions [2], the thickness of the primary collimator should be about 0.15mm of graphite for the injection energy and about 0.2 mm of tungsten for the extraction energy. To meet these requirements, we envision that the oval should be machined from a graphite disc whose perimeter on one side is 0.15mm thick. (If that is too thin to be practical, then about 0.3 mm of beryllium would also work.) The part of the oval that will intercept beam at the extraction energy (roughly 180 degrees away from the injection part of the oval) will be covered on one side of its perimeter with 0.2 mm thick tungsten. To provide the optimal amount of multiple Coulomb scattering at intermediate energies, there will be an annular region covered on the perimeter with about 0.2 mm of copper mounted on the other side of the disc. The azimuthal location of the copper foil will be about halfway between the thin graphite and the tungsten. These thicknesses are approximate and should be optimized via simulations. Because the beam is in the machine only half of the full rotation of the oval, the second part of the oval can have any thickness and can be used to insure the integrity of the plate.

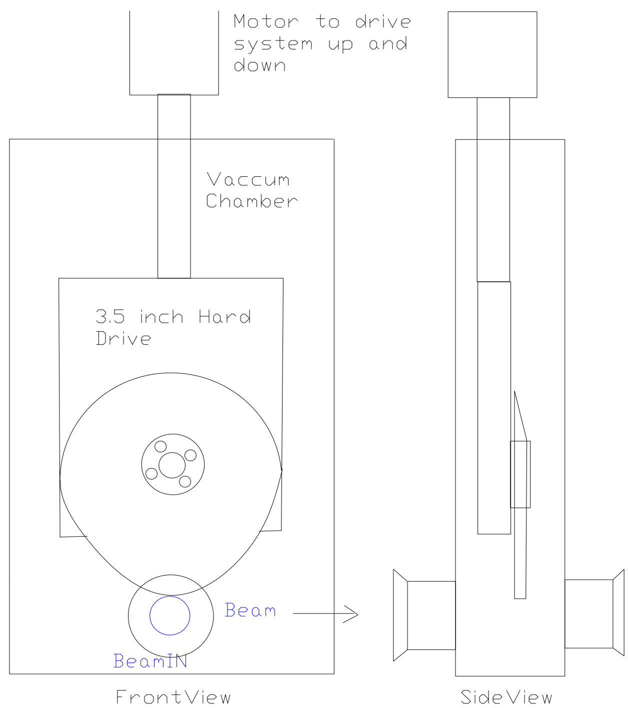

Fig.2: Conceptual picture of the Beam-Whacker based Primary Collimator

The purpose of the oval shape, of course, is to follow the desired position of the edge of the beam. It is possible that a circular disc would also work provided that appropriate time-dependent orbit control at the disc is implemented. In either case, the rotation of the disc is required because the optimal thickness in radiation lengths varies by a large factor during acceleration. We propose an oval shape because we believe that it is conceptually simpler for an orbit correction system to control the beam centroid rather than the location of its edge.

Operation of the Beam Whacker Collimator

When the collimator is not in use, the system is pulled up into a parked position with the plate out of the beam pipe. Once the motor is started, it takes about 30 seconds to achieve full speed (up to 7200 rpm). The Booster is a 15-Hz machine, so the Beam Whacker collimator will run at 900 rpm. The phase position of the plate must be synchronized with the beam injection time.

This procedure can take up to a couple of minutes. Once synchronization is achieved, the plate assembly can be lowered vertically into the chamber. A slow control loop will be needed to keep rotation of the collimator fully synchronized with the beam. Presently we have a similar rotating system with a commercial controller.

Acknowledgment

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References

[1] http://www.consumerdemocracy.com/phelp/cd4/listPosRevs2B.aspx?catId=148
[2] A.I. Drozhdin, P.H. Kasper, O.E. Krivosheev, J.R. Lackey, N.V. Mokhov, M. Popovic, R.C. Webber, Proc. of the 2001 Part. Accel. Conf., Chicago, June2001, p.2569.