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STATUS OF EFFORTS TO IMPROVE THE TRANSVERSE PROPERTIES OF THE FERMILAB BOOSTER

C.W. Owen, B.C. Brown, J. Crawford, J. Garvey, H. Gerzevske
J. Lackey, K. Meisner, R. Rice
Fermi National Accelerator Laboratory*
P.O. Box 500
Batavia, Illinois 60510

Abstract

Recent changes in the injection beam line and the injection and extraction long straight sections of the Fermilab Booster have resulted in both larger apertures and simpler operation. These have facilitated further studies of the aperture limitations in the Booster. We will summarize our studies and results and indicate present aperture limitations. Operational benefits and transmission effects will be discussed.

Introduction

A long-standing problem in the Fermilab Booster has been the vertical aperture limitation imposed by the extraction septum. A solution originally suggested in the 1968 design report[1] was implemented during the Summer of 1980. Improvements in a variety of other areas have resulted in significantly increased Booster reliability and operational reproducibility. This work has improved Booster transmission and beam quality and has made previously difficult studies of the aperture of the entire Booster ring feasible. These studies indicate that large magnet alignment errors and closed orbit distortions are limiting the Booster overall available aperture. These recent accomplishments and results of measurements are presented and future plans are discussed.

Low Momentum Deflection Magnets

The aperture problem in the extraction area is controlled by deflection of the beam below the extraction septum within the long straight section using four d.c. magnets. The design considerations are reported elsewhere.[2] Magnets with a gap of 5.97 cm and a steel length of 17.78 cm were installed. Twenty turn coils are excited to 1000 A (four magnets in series). The magnets are arranged in dogleg pairs and are placed at each end of the extraction long straight with members of the pair separated by 30.48 cm center to center. The injected beam center can be lowered by as much as 14 mm at the extraction septum by this combination. Any non-local orbit distortion caused by asymmetries in the magnets or installation can be corrected by separately powering one of the upstream magnets and by an appropriate change in current in the standard vertical trim dipole at the end of the long straight section. No such correction has been needed. The deflection magnets have significantly increased the available vertical aperture at the L13 extraction straight section. Figure (1) shows the increase in vertical aperture as measured by a 3-dipole bump centered at L13 for four values of current through the deflection magnets. (Positive current deflects the beam lower in the straight section and results in a larger useful aperture.) Figure (2) shows the increase in Booster transmission as the deflection magnet current is raised.

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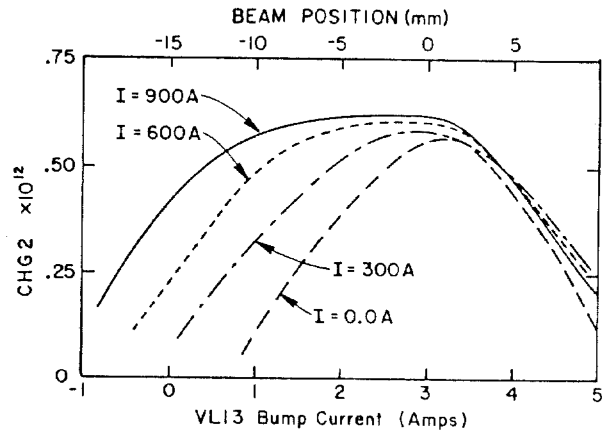

Fig. 1 Shows how L13 deflection magnet increases the available vertical aperture.

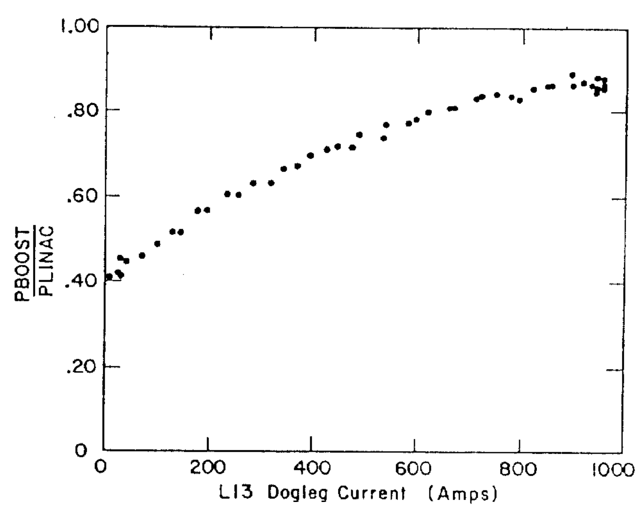

Fig. 2 Booster transmission vs. L13 deflection magnet current

General Improvements

Work on many systems has produced a Booster which operates reliably and in a manner which facilitates reproducible measurements. A low level RF system implemented in October of 1979 provides accurate control of the beam average radial position and machine tune.[3] This system allows better control of parameters affecting adiabatic capture of beam injected into the Booster and has greatly reduced errors in beam phase and momentum during extraction and synchronous transfer of the beam into stationary Main Ring RF buckets. Alignment errors in the 200 MeV transfer line between the Linac

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and Booster have been corrected to facilitate tuning for a good match of the injected beam to the Booster lattice and to provide a new stability in injected beam parameters. Wiring and position errors of ring correction quads and dipoles have been fixed and correction magnets with poor field quality have been replaced. Analog readbacks of the correction elements have been made more accurate and have been stabilized. Magnetic support brackets which distorted vertical correction dipole fields have been removed. The vertical fast transverse damper system[4] has been upgraded and optimized for increased suppression of vertical instabilities. Diagnostic and monitoring equipment (wire scanners, toroids, etc.) have been installed, repaired in some instances, and calibrated to provide precision tuning of injection into the Booster. These projects are good examples of many efforts to maximize the Booster operational reproducibility. The culmulative effect has been to increase the Booster transmission while injecting a better quality beam into the Main Ring accelerator. An important additional benefit is that the operational environment now allows closer scrutiny of properties of the transverse aperture and beam instabilities.

Aperture Measurements and Improvements

Aperture measurements using local 3-magnet bumps have been made using charge transmission as an indication of available local aperture. A typical transmission plot is shown in Figure (3). Note the separate points for charge immediately after injection (CHG1) and for charge accelerated to extraction energy (CHG2). To infer the largest region available for beam we have measured (using CHG1) the displacement limits at zero remaining charge using an appropriate conversion from bump magnet current to position. Figure (3) was taken after long periods of operation in which local bumps and average radial position were empirically tuned to achieve optimal overall Booster transmission for injection into the Main Ring.

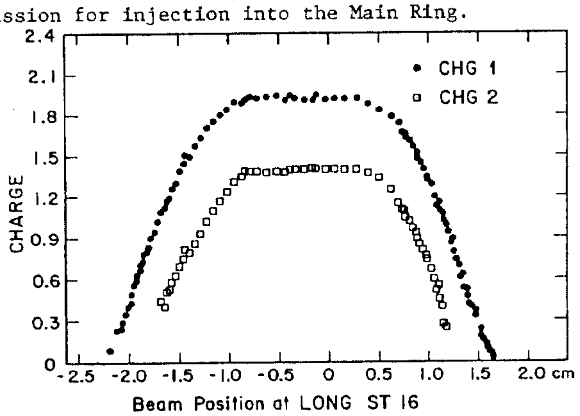

Fig. 3 Typical scan to measure local aperture.

Many aperture measurements have been made with all dc correction dipoles turned off. These plots are similar to Figure (3) except that aperture centers for CHG1 and CHG2 often are not at the same position, and seldom are the center positions symmetric around zero bump current. These aperture measurements, along with optical survey data, indicate severe closed orbit distortions and Booster ring magnet alignment errors. Vertical survey data show that significant tunnel movement has occurred since the last major alignment effort of 1973. A trial program of magnet moves was begun in 1980 to correct some of the worst vertical closed orbit errors. These few magnet realignments resulted in improved vertical aperture, increased transmission without using dc vertical correction dipoles, and reduced amplitude vertical dipole corrections after empirical orbit bump tuning to optimize transmission. Figure (4) shows data taken before and after the vertical aperture improvements. Both sets of data were taken after tuning to optimize transmission. An attempt to correct the horizontal orbit by realigning magnets resulted in the predicted orbit changes but did not clearly improve horizontal aperture or transmission. Orbit corrections at the point of interest also produced smaller orbit shifts throughout the ring. Closed orbit distortions in the horizontal plane appear so severe that small changes throughout the ring make effects on the overall aperture extremely difficult to predict. Further aperture improvements will require careful evaluation of complete survey data in combination with aperture measurements and beam detector closed orbit measurements. An analysis of empirically derived correction magnet current values may also provide useful information on the low field closed orbit distortions. A program for attacking the aperture problems is planned for the 1981 Summer facility shutdown.

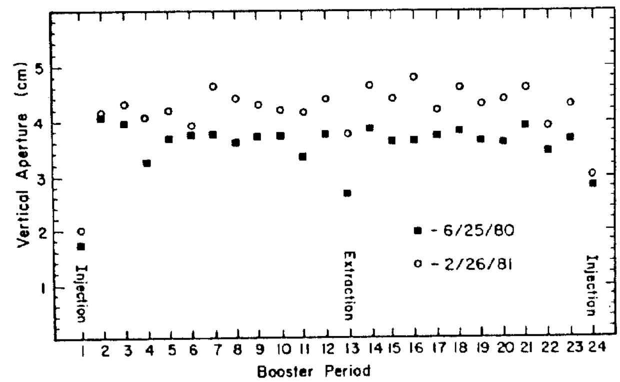

Fig. 4 Comparison of local vertical aperture before and after L13 deflection magnet installation and ring magnet realignments.

Recent Results on Beam Transmission and Emittance

Results have been presented[5] on Booster transmission vs. injected charge, and on emittance measurements of the Booster beam at high intensity[6]. Recent transmission results are presented in Figure (5). The transmission at low intensities is at least as good as ever. Significant improvements have been made at high intensities. During the first two months of 1981, the Booster and Main Ring operated at record intensities. The Booster has operated stably at more than 3.5×10^{13} protons per Main Ring cycle (13 Booster pulses) while the Main Ring has delivered more than 2.5×10^{13} protons per cycle. Peak intensities of 3.7×10^{13} from the Booster and 2.9×10^{13} from the Main Ring have been reached.

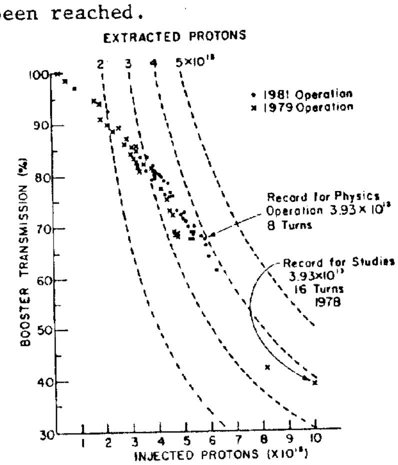

Fig. 5 Booster transmission vs. injected charge (PLINAC)

Conclusions and Acknowledgements

The most serious remaining transverse limitations in the Booster are clearly the result of large horizontal magnet misalignments.

We expect to complete the realignment program during the Summer of 1981.

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Many of the programs described in this paper were started during the time when Dr. Charles Ankenbrandt was Booster Group Leader. His continued support and cooperation as Main Ring Group Leader have been very helpful.

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