Fermi National Accelerator Laboratory

FERMILAB-Conf-92/372

The Fermilab Main Injector

C.S. Mishra

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

November 1992

Presented at the *Division of Particles and Fields Meeting*,
Fermi National Accelerator Laboratory, Batavia, Illinois, November 10-14, 1992

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

Disclaimer

The Fermilab Main Injector

C. S. Mishra
Fermi National Accelerator Laboratory
Batavia, IL 60510, USA

ABSTRACT

The Fermilab Main Injector is a new 150 GeV proton synchrotron, designed to replace the Main Ring and improve the high energy physics potential of Fermilab. The status of the Fermilab accelerator complex upgrade will be discussed.

1. Introduction

The Fermilab Tevatron is the highest energy proton-antiproton collider in the world today and it will remain so until either the Superconducting Super Collider (SSC) or Large Hadron Collider (LHC) is operational. At present Fermilab accelerator complex is in the middle of an upgrade plan FERMILAB III. This upgrade plan will slowly increase the luminosity in the Tevatron by at least a factor of thirty. Major components of this upgrade plan are installation of electrostatic separators in the Tevatron, installation of low β systems at the two collider detectors located at B0 and D0, antiproton source improvements, upgrading the linac energy from 200 MeV to 400 MeV, installation of cold compressors and fast kickers and the construction of a new accelerator, the Fermilab Main Injector.

This upgrade plan is designed to extend the discovery potential of the U.S. High Energy Physics program. Some of the physics goals of Fermilab III are to discover and study the properties of the top quark, the last unobserved fundamental particle; to provide a factor of two increase in the mass scales characterizing possible extensions to the Standard Model; high rate b-quark hadron production and decay experiments, perhaps leading to the study of CP violation in b-quark hadron, and to support new initiatives in the neutral kaon physics and neutrino oscillation investigations.

2. Status of Upgrades

At present, Fermilab is under collider operation Run 1a. This run is underway after the successful installation of electrostatic separators in the Tevatron. These separators create helically separated orbits in the Tevatron and keep proton and antiproton bunches separated everywhere except at the two collider detectors. Significant improvements have been made to the Antiproton source to increase the accumulation rate and reduce the emittance of a given stack size. During this run Fermilab has been making record in antiproton stacking. The new low β system is operational and has allowed the implementation of a second high luminosity interaction region. At present the Tevatron is running at a luminosity larger than 4.5×10^{30} and is slowly heading towards the goal of 6×10^{30}.

After this run, the linac upgrade will be completed by replacing the second half of the existing drift tube linac with a side coupled structure generating about 300 MeV in the same length. This increase in energy will improve the injection into the 8 GeV Booster due to the reduction in space-charge forces. This will also increase the proton transverse beam densities and will benefit antiproton production by increasing the proton flux through the Main Ring. Before the Main Injector, cold compressors and fast kickers will be installed in the Tevatron to increase the beam energy from 900 GeV to 1000 GeV and number of bunches from 6 to 36. These upgrades will provide at least a factor of two increase over current luminosity.

3. The Main Injector

The Fermilab Main Injector (FMI) is a new 150 GeV proton synchrotron designed to remove the limitations of the Main Ring in the delivery of high intensity proton and antiproton beams to the Tevatron and to increase the antiproton production rate. The Main Ring aperture (12π mm-mr) is about half the size of the current booster aperture. After the 400 MeV linac upgrade the booster aperture will increase to about 30π mm-mr. The FMI is designed to have a transverse aperture of 40π mm-mr . The FMI will increase the number of protons targeted for antiproton production from $5.0 \times 10^{15}/hour$ to $1.2 \times 10^{16}/hour$ and will be capable of efficiently accelerating antiprotons in larger stacks containing 2×10^{12} antiprotons for injection into the Tevatron collider. It will also increase the total number of protons which can be delivered to Tevatron to 6×10^{13}, with proton bunches containing up to 3×10^{11} protons. The FMI will be capable of supporting a luminosity of 5×10^{31} in the existing collider. A new added feature due to FMI will be intense slow extracted beams, 3×10^{13} protons every 2.9 sec with 33% duty factor, for use in the studies of CP violation and rare Kaon decays, and for experiments designed to search for neutrino oscillations. In a similar amount of running time with FMI, a state of the art Kaon experiment will improve the upper limits of rare decays by two orders of magnitude.

The FMI will be constructed using a newly designed conventional dipole magnets. The new dipole magnets are being build based on considerations of field quality , aperture and reliability. The FMI lattice has two different types of cells, the normal FODO cells in the arcs and straight sections and the dispersion- suppressor FODO cells adjacent to the straight sections to reduce the dispersion to zero in the straight sections. There are eight straight sections, at present four are being used for beam transfer and one for radio frequency (rf) cavities.

Two full scale prototypes of the FMI dipoles have been built and undergone an extensive measurements of their field quality[1]. Measurements show that these magnets meet the designed specifications and are well described by the computer models. In the FMI we have two different length dipole magnets 6m and 4m. Several iterations of the dipole end design have been made to reduce the change in the effective length of the magnet and the sextupole component of the dipole ends. The change in the effective length introduces closed orbit error[2]. We have also initiated a dipole power supply R&D program. The power supply and magnet systems are designed to allow a significant increase in the number of 120 GeV acceleration cycles for simultaneous operation of antiproton production and 120 GeV slow spill beam. Besides the newly constructed dipoles, FMI will use existing components including quadrupoles, and 18 rf systems from the Main Ring.

Accelerator physics studies are underway to understand the FMI better and also to improve its performance. These studies include incorporation of magnetic measurements into tracking studies, transition crossing studies, impedance budgeting, beam line design and study of slow extraction. Using the measurements of the two prototype dipoles, Main Ring dipoles and quadrupoles and PE2D static field calculations we have made a database for the systematic and random errors of FMI magnets[3]. This database is used in simulations of the dynamical performance of the FMI[4] and other studies such as power supply requirements, corrector strength etc.

Simulations results of the FMI at its most critical time, injection, when the beam is stored for approximately 35000 turns at an energy of 8.9 GeV is described here. The average RMS closed orbit errors is 5.0 mm and 3.9 mm in the horizontal and vertical planes respectively. The maximum corrector strength required to correct these orbit deviations is 150 *μradian* in both planes which is about 10% of the available corrector strength. The β function of the FMI changes around the ring from its nominal value, mainly due to the dipole and quadrupole random errors and magnet alignment errors. The sigma of these deviation is about 15%. We are in the process of developing a shuffling scheme for the placement of quadrupoles to reduce this variation. The dynamical aperture of the FMI at the injection energy of 8.9 GeV is predicted to be 22 $\pm$1.4 mm, corresponding to a normalized emittance of 59.2 $\pm$ 10.2π mm mradians. The dynamical aperture is limited by the detuning of the large amplitude particles, due to the presence of large octupole in the recycled Main Ring quadrupoles, and second order sextupole effects. In the lattice there are corrector octupoles, which will be used for slow extraction at 120 GeV. We have used these octupoles in the simulations to cancel the effect of the octupole due to quadrupoles, at 8.9 GeV. Such a correction scheme increases the dynamical aperture by about 5 mm. We can improve this further by utilizing a quadrupole shuffling scheme, which will help to reduce the effect of quadrupole random error. Study of the FMI dynamical performance at 120 GeV and simulation of slow extraction is in progress.

The FMI has approval to begin the Title II work, below and above grade construction at MI-60 straight section, where rf will be located. We are requesting approvals for copper coil, steel lamination and to start general site preparation. The scheduled completion date and commencement of operations is 1997.

1. D. J. Harding *et al.*, "Design considerations and prototype performance of the Fermilab Main Injector dipole", *Proc. of the 1991 IEEE Particle Accelerator Conf.*
2. C. S. Mishra , H. D. Glass and F. A. Harfoush, "Effective length of the Main Injector Dipole and its effect on the Main Injector", *FMI Internal Report 0072.*
3. F. A. Harfoush and C. S. Mishra, "Systematic and Random errors for the Main Injector Tracking", *FMI Internal Report 0066.*
4. C. S. Mishra and F. A. Harfoush, "Simulation of the dynamical performance of the Main Injector at 8.9 GeV", *FMI Internal Report 0070.*