Fermi National Accelerator Laboratory

FNAL/C--96/301
~~FERMILAB-Conf-96/301~~
CONF-960812-26

The Fermilab Main Injector: Current Status and Future

C.M. Bhat

Main Injector Department, Accelerator Division,
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

September 1996

MASTER

Presented at the *1996 Annual Divisional Meeting (DPF 96) of the Division of Particles and Fields of the American Physical Society*, Minneapolis, Minnesota, August 10-15, 1996.

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

THE FERMILAB MAIN INJECTOR : CURRENT STATUS AND FUTURE

C. M. BHAT
Main Injector Department, Accelerator Division,
Fermi National Accelerator Laboratory,[a] P.O. Box 500, Batavia,
IL 60510, USA

The Fermilab Main Injector is a 8-150 GeV proton synchrotron being built as a high intensity injector to the Tevatron. The design incorporates many novel features to achieve $p\bar{p}$ luminosity in the Tevatron exceeding 8×10^{31}cm^{-2}sec^{-1}. An overview of the Main Injector project, current status and future prospects will be discussed.

1 Introduction

The Tevatron at Fermilab, with 1.8 TeV center of mass energy, is presently the highest energy $p\bar{p}$ collider in the world. The Fermilab accelerator complex has a chain of accelerators- a 400 MeV Linac, an 8 GeV proton synchrotron (Booster), a 150 GeV synchrotron (Main Ring) and the Tevatron. The $\bar{p}$ storage ring comprises of an 8 GeV Debuncher and an 8 GeV Accumulator.

Fermilab has a goal of upgrading the $p\bar{p}$ luminosity in the Tevatron collider in excess of 20×10^{31}cm^{-2}sec^{-1}, in order to increase its potential to investigate elementary particle physics beyond the standard model. This luminosity will be about ten times more than that achieved during the last collider run. The major limitation to reach this goal arises primarily from the intensity limitations of the Main Ring. The new 150 GeV synchrotron, the Main Injector[1], being built in a tunnel separate from the Main accelerator eliminates the bottleneck for high intensity and will replace all functionalities of the Main Ring. This will also provide additional capabilities for the fixed target programs.

2 Overview of the Main Injector

The Main Injector has a sheared oval shape and has two fold symmetry. The accelerator tunnel is being built south-west of the Tevatron and its circumference is 3.319 km, about half the circumference of the Tevatron.

The Main Injector operates between 8 GeV and 150 GeV. The lattice is based upon a 90° FODO cell, with zero dispersion at all of its straight sections. The normalized transverse admittance is $\geq 40\pi$ mm mr and the longitudinal

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

Table 1: Main Injector Acceleration cycles.

	Cycles	Time (sec)	Mode of Extraction	Beam Energy	Beam Intensity
1	$\bar{p}$ Production	1.467	Single turn	120 GeV	5×10^{12}p/cycle
2	MI Fixed Target	2.867	Slow spill	120 GeV	3×10^{13}p/cycle
	"	1.867	Fast spill	120 GeV	3×10^{13}p/cycle
3	Tevatron Collider	4	Single Turn	150 GeV	33×10^{10}p/ bunch (3 cycles of 12 bunches)
	"	"	Single Turn	150 GeV	$\approx 6.6\times10^{10}\bar{p}$/ bunch (9 cycles of 4 bunches)
4	Fixed Target	2.4	Single turn	150 GeV	3×10^{13}p/cycle (2 cycles)

admittance is $\geq$ 0.5 eV-s. The quantity β_{max} is 58 m, indicating stronger focusing than Main Ring. The maximum dispersion is about 2 meters.

The transition γ for the Main Injector lattice is 21.838 and there is no special transition crossing scheme in the basic design of the Main Injector.

The four basic types of acceleration cycles of the Main Injector and some characteristics are listed in Table I. The quantity $\frac{dp}{dt}|_{trans}$ during acceleration is selected to be 240 GeV/c-sec and the repetition rates of the acceleration cycles are about 40% faster than that for the Main Ring. There will also be a deceleration cycle in which the unused $\bar{p}$s from the Tevatron at the end of each collider run will be reverse injected into the Main Injector at 150 GeV, decelerated to 8 GeV and transferred to a $\bar{p}$ Recycler Ring[2]. The cycle time for this is estimated to be ≈10 sec.

The Main Injector has several beamlines for the purposes of : injection of 8 GeV protons from Booster, two beamlines for proton and $\bar{p}$ transfer to the Tevatron at 150 GeV, two beam lines at 120 GeV for extraction of protons for $\bar{p}$ production and existing switch yard, one beamline towards external beam abort (which has a potential for future high intensity K-physics program) and one beamline for extraction of 120 GeV protons for long baseline neutrino oscillation experiments (towards the MINOS/COSMOS and Soudan-II detectors). The 150 GeV proton transfer line has additional functions such as transferring 8.9 GeV/c $\bar{p}$s from the Accumulator to the Main Injector. There will be two more 8 GeV beamlines for the purpose of transferring $\bar{p}$s to and from the 8 GeV Recycler Ring[2].

The 8 GeV proton transfer line from Booster to Main Injector will be built using permanent magnets. These magnets are similar to the ones to be used in the Recycler Ring. We have planned to commission the beam line about a year before the completion of the Main Injector project.

2.1. Beam Instability Issues

Extensive studies have been carried out to examine beam instabilities at different stages of acceleration cycles in the Main Injector. Dynamics of high intensity beam bunches have been simulated by incorporating space charge forces and beam impedances arising from various accelerator components. These studies show that for beam longitudinal emittances in the range of 0.10-0.35 eV s and bunch intensities shown in Table I Main Injector will perform efficiently.

2.2. Project Status and Schedule

The Main Injector and the 8 GeV beam transfer line tunnels are complete. About half of the 344 Main Injector dipole magnets are installed in the accelerator ring already. During a nine-month shutdown in 1998 all RF cavities and 128 quadrupole magnets from the Main Ring will be recycled and will be used in the Main Injector. Civil construction to connect the Main Injector to the Tevatron will also be done during that time. Commissioning the accelerator will begin in summer 1998. Expected project completion date is March 1999.

3 Luminosity Goal During the Main Injector Era

Peak $p\bar{p}$ luminosity during the last collider run was in excess of $2\times10^{31}\text{cm}^{-2}\text{sec}^{-1}$. The Main Injector alone is designed to increase the peak luminosity by a factor of five. Our conservative estimates of luminosity during the Main Injector era is in excess of $8\times10^{31}\text{cm}^{-2}\text{sec}^{-1}$.

Other luminosity upgrades include construction of an 8 GeV Recycler Ring using permanent magnets for $\bar{p}$ storage. This synchrotron will fit into the Main Injector tunnel and also acts as a super-accumulator ring for $\bar{p}$s. The expected collider luminosity with Recycler Ring is in excess of $20\times10^{31}\text{cm}^{-2}\text{sec}^{-1}$.

The author would like to thank D. Bogert, S. D. Holmes and P. Martin and other colleagues in the Main Injector Department for inputs and comments.

References

1. Fermilab Run II Hand Book (1995).
2. Fermilab Recycler Ring Technical Design Report (1996).