BEAM INTENSITY UPGRADE AT FERMILAB*

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Abstract

The performance of the Fermilab proton accelerator complex is reviewed. The coming into operation of the NuMI neutrino line and the implementation of slip-stacking to increase the anti-proton production rate has pushed the total beam intensity in the Main Injector up to ~ 3×10^{13} protons/pulse. A maximum beam power of 270 kW has been delivered on the NuMI target during the first year of operation. A plan is in place to increase it to 350 kW, in parallel with the operation of the Collider program. As more machines of the Fermilab complex become available with the termination of the Collider operation, a set of upgrades are being planned to reach first 700 kW and then 1.2 MW by reducing the Main Injector cycle time and by implementing proton stacking.

INTRODUCTION

The Fermilab accelerator complex has recently seen substantial improvements in proton throughput.

The short-baseline neutrino oscillation experiment MiniBoone has accumulated in the last few years 7.2×10^{20} protons from the Booster.

In 2005 the Main Injector (MI), a 120 GeV proton synchrotron, has started operation for the NuMI long-baseline neutrino facility [1], achieving a maximum delivered beam power of 270 kW. The anti-proton source, part of the Tevatron Collider complex, has witnessed a steady increase in proton intensity. Up to 8×10^{12} protons/pulse (ppp) have been delivered on the anti-proton target by means of slip-stacking [2] two Booster batches in the Main Injector. Implementation of slip-stacking over multiple batches will increase the beam power on the NuMI target to 350 kW.

The future experimental neutrino program [3], devoted to long-baseline electron-neutrino appearance searches, will require a substantial upgrade in proton beam power.

With the conclusion of the Collider program, several machines will become available to be used, in conjunction with the Booster and the Main Injector, to increase the beam power delivered to the NuMI facility.

We foresee a first stage up to 700 kW beam power, which makes use of the Recycler ring as a proton pre-injector to the Main Injector, and a second stage up to 1.2 MW by adding in the chain the Accumulator ring, presently part of the anti-proton source, to perform momentum-stacking of several Booster batches.

THE ACCELERATOR COMPLEX

A sketch of the Fermilab accelerator complex is shown in Figure 1 .

The Booster is effectively the proton horsepower of the complex. Fed by 400 MeV H^- ions from the Linac, it accelerates protons to 8 GeV kinetic energy at 15 Hz rate. Booster batches (set of proton bunches accelerated in the Booster, typically up to ~5×10^{12} protons) are transferred through the MI8 line into the Main Injector or sent to the MiniBoone neutrino target.

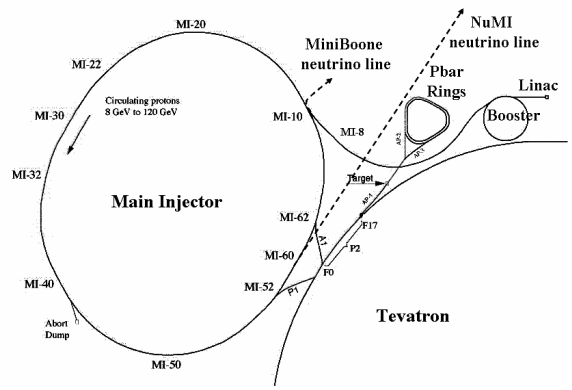

Figure 1: The Fermilab accelerator complex.

The Main injector is seven times the circumference of the Booster. Six Booster batches are required to fill up the machine, leaving one seventh of the circumference available for the rise-time of the extraction kicker. Table 1 summarizes the MI parameters.

Table 1: Main parameters of the Main Injector

Circumference (km)	3.319	Harmonic number	588
Injection momentum (GeV/c)	8.9	RF frequency at injection (MHz)	52.8
Extraction momentum (GeV/c)	120	RF frequency at extract. (MHz)	53.1
Transition gamma	21.8	Maximum RF voltage (MV)	4.3

The Main Injector is the central machine of the complex, equipped with a complex set of injection and extraction lines to connect to the other machines of the complex. It provides protons for anti-proton production, it has a dedicated extraction to the NuMI line and it is connected to the Tevatron for proton and anti-proton transfers.

An additional machine, an 8 GeV anti-proton storage ring, denominated Recycler, is located in the Main Injector tunnel above the MI ring and with the same basic cell geometry. Antiproton transfers in and out of the Recycler Ring take place through two transfer lines connecting the Recycler to the Main Injector. Figure 2 shows the Main Injector tunnel in the MI-60 region, where the NuMI extraction is located.

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