Fermilab Accelerators: Status and Plans

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Abstract

The performance of the Fermilab accelerator complex, which has led to the recent discovery of the top quark, will be presented. The performance of the Tevatron will be discussed, as will progress in the performance of the proton and antiproton sources. The status of the Main Injector project and its incorporation into the accelerator complex will be presented. It is expected that these improvements will result in a factor of five increase in the luminosity to 2×10^{32} cm^{-2} s^{-1} at the end of the next collider run. In addition, the Main Injector will provide a high intensity 120 GeV proton beam to allow for a search for neutrino oscillations (NuMI). Activities under consideration beyond the next collider run will be discussed which can lead to a peak luminosity of 1×10^{33} cm^{-2} s^{-1}.

1 CURRENT PERFORMANCE

Highlights of Collider Run I

The discovery of the top quark was based on the data from Collider Run I.

The integrated luminosity delivered to CDF was just shy of 150 pb^{-1} and was at a center of mass energy of 1.8 TeV. The collider operated with 6 proton and 6 antiproton bunches on helical orbits. The collider reliability was such that 72.6% (421 of 580) of the stores were ended intentionally. See Dan Wolff's presentation at this conference for more information.

An irritating feature of the collider run was the fact that one of the low beta triplet quadrupoles at CDF was inadvertently rolled by 7 mrad. This resulted in a reduction in the luminosity by about a factor of two at CDF and lesser amount at D0. Once this error was corrected, the luminosity reached it expected value.

The Main Ring bunch coalescing system was improved near the end of the run and this resulted in an increase in luminosity of about a factor of 1.3 as expected. The improvement relied on higher voltage cavities.

We are still in a region where the luminosity is proportional to the total number of antiprotons in the Tevatron. A luminosity of 2×10^{31} cm^{-2} s^{-1} has been typically achieved with 7×10^{10} antiprotons in each of 6 bunches.

Plans for Fixed Target

The beam energy for the upcoming fixed target run will be 800 GeV. The intensity goal is 3×10^{13} protons per pulse, with reliable delivery of 2.5×10^{13}. The slow resonant extraction spill length is 20 seconds with a Tevatron cycle time of less than 60 seconds. Some of the beam will be resonantly extracted in a fast mode which takes the beam out in about 1 msec. Several of these fast pulses will be interspersed in the slow spill.

The intensity goal is ambitious but probably not unattainable. The previous best intensity was only 1.8×10^{13}, with reliable delivery of 1.5×10^{13}. There are two known instabilities in the Tevatron which, if not controlled, will limit the intensity. A coupled bunch instability is associated with the RF cavities and appears at 1.4×10^{13}. Another horizontal instability would limit the intensity to 1.6×10^{13}, but can be controlled with a beam damper. It is expected that other instabilities must be controlled in order to achieve the intensity goals.

Status of the Fixed Target Run

The turn on of the fixed target run began in May, 1996. Beam operation has alternated with the civil construction for the new 8 GeV beam transfer line between the Booster and the Main Injector. The Booster operated at nights and weekends when the construction work was paused. Startup proceeded smoothly for the most part.

One unusual feature of the startup was to run 150 GeV beam to the E815 target train to help align it. For this special mode, beam was extracted from the Main Ring, injected into the Tevatron and extracted to the Switchyard after passing through only 2/3 of the Tevatron.

It is intended to operate this fixed target run for a total of 13 months before the shutdown scheduled for February 1998 to the complete the Main Injector. This fixed target run represents the end of an era which started in 1983 with the first extracted beam from the Tevatron.

2 COLLIDER RUN II

Overview

The plan is to finish the Main Injector in March 1999, and collide beams at 2 TeV in the center of mass shortly thereafter. Run II is to deliver 2 fb^{-1} on tape to each of CDF and D0. It will start with 36 bunches per beam with a minimum spacing of 392 nsec, and may finish with as many as 108 bunches per beam with a minimum spacing of 132 nsec. See Dixon Bogert's and Peter Bagley's presentations at this conference for more information.

The Main Injector project is progressing very well. The ring enclosure is complete; dipole magnet production is 54% complete; installation has been initiated and more than 77 of the 344 dipoles are in place along with various parts of other subsystems. As of April 1996, the project had obligated $132M out of $229.6M, and had an unallocated contingency of $27M.

Energy

The goal for Run II is 1 TeV per beam. During a study period in Collider Run I, a proton beam was stored at 980 GeV. During the present fixed target startup (taking advantage of the periods when beam operation is prevented due to the civil construction) the upper limit of the Tevatron energy was pursued. At the present time the limit is 1.01 TeV without beam. Further improvements in energy are expected as inadequately performing magnets are identified and either replaced or swapped with other magnets. Because the total cooling capacity is limited, it is desirable to operate some cryogenic loops colder than others to favor weaker magnets. The swapping technique takes optimum advantage of temperature differences in the various cryogenics loops. These differences are due to deliberately running various cryogenic loops colder than others, or due to the temperature profile within a cryogenic loop. Superconducting magnets perform at a higher current when they are colder.

Antiprotons

The typical antiproton stacking rate near the end of Run I was 6 x 10^{10} / hour; Run II will require 20 x 10^{10} / hour. In order to provide for this increase several improvements are planned for the Antiproton Source. A beam sweeping system will be built so that the antiproton production target can handle the higher protons intensities from the Main Injector. The Debuncher (which is the first stage of stochastic cooling will have a cycle time commensurate with the Main Injector) will have an upgrade which includes further cryogenic cooling of the electronics and which provides for pickups and kickers with gaps which dynamically vary with the transverse beam size. The Accumulator will have an upgrade to the stacktail system and its lattice. See Steve O'Day's presentation at this conference for more information.

These improvements will allow for an increased production of antiprotons. However, one should realize that in Collider Run I, more than half of the antiprotons remained at the end of collider stores and they were simply dumped. An idea for recovering these antiprotons has lead to the concept of a ring to recycle a large fraction of these antiprotons.

The Recycler Ring

The Recycler is an 8 GeV antiproton storage ring to be installed above the Main Injector. Since the beam enclosure is designed for 150 GeV, it is possible to use low field magnets for an 8 GeV ring. Since it is also a storage ring, it is possible to use permanent magnets. This ring will allow for the recovery of antiprotons from the Tevatron, and it is expected that this will raise the luminosity from about 0.8 to 2.0 x 10^{32} cm^{-2}sec-1. If successful, it can also form one basis for raising the luminosity to the range of 10^{33} cm^{-2}sec-1.

It has been suggested to use part of the Main Injector contingency to fund the Recycler, but this has not yet been approved by the funding agency. It is intended to install it at the same time as the Main Injector. It is possible that there will be an initial cooling system based on the proven technology of stochastic cooling. If so, it is expected to replace it or augment it with electron cooling when the R&D has proven out on this newer technology.

3 OTHER ACTIVITIES

Near Term

There are four major R&D efforts in accelerator science at Fermilab. The superconducting magnet effort is included in the interaction regions for the LHC. The permanent magnet effort is the basis for the 8 GeV injection line from the Booster to the Main Injector and for the Recycler's combined function gradient magnets. Electron cooling is being developed for the Recycler ring. The Fermilab Test Facility (FTF) is producing a long pulse photoinjector for TTF (TESLA Test Facility). See Howie Pfeffer's presentation at this conference for more information about the modulator developed for the rf source for this photoinjector. In addition, we are considering a demonstration of staged laser acceleration at the FTF.

There are two Fermilab based medical applications of accelerators. The Neutron Therapy Facility has been treating patients for some time. A second short term project is in place to produce an RFQ to accelerate ^{3}He for use in PET (Positron Emission Tomography).

The superconducting magnet R&D effort at Fermilab is aligned on the LHC. It is intended to fabricate and test low beta quadrupoles. Fermilab is the host laboratory for the US members of CMS.

It is intended to begin civil construction on the NuMI (Neutrinos with the Main Injector) project in 1999. NuMI features a 730 kilometer baseline for measuring Δm^2 and looking for neutrino oscillations using the 120 GeV proton beam from the Main Injector.

Longer Term

It is essential for the future of High Energy Physics that R&D in accelerators be prudently planned and pursued. In addition, it is very desirable that students have means to grow; one such program is the Joint University-Fermilab Doctoral Program in Accelerator Physics. This program has graduated 15 students since 1987 and continues at a steady rate.

This summer's study at Snowmass will look at the US High Energy Physics program in the context of the international program. One issue is how to extend the energy frontier beyond the LHC. Some options to be considered in the Fermilab context include a low cost hadron collider, muon colliders and new accelerator techniques.

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