STATUS AND PLANS FOR THE FERMILAB TEVATRON

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ABSTRACT

The Fermilab Tevatron is the world's highest energy accelerator system and the first large-scale superconducting synchrotron. Since Tevatron commissioning in July, 1983, the accelerator has operated in 1985, 1987 and 1990 with extracted beams of 800 GeV for fixed target physics; and in 1987, and 1988-89, with proton-antiproton colliding beams at a center-of-mass energy of 1800 GeV. This paper will review the current status of the Tevatron and the plans for its upgrades and future utilization.

Current Status

Approximately one year ago, the 1988-89 collider run[1)] of the Tevatron terminated with the delivery of almost 10 pb^{-1} of integrated luminosity to the CDF experiment. The peak initial luminosity achieved during the run exceeded $2x10^{30}/cm^2/sec$, more than twice the original design goal for the collider.

During the six month period following the run, a major repair program remedied a problem related to lead restraints in the ends of the superconducting dipoles in the Tevatron. Subsequently, the Tevatron was operated in fixed target mode (from February through August, 1990), and delivered an integrated intensity of about $1.85x10^{18}$ protons at 800 GeV to the experimental areas. The operational efficiency during the run was excellent, with many weeks over 70% efficient. Only one Tevatron dipole failed during the run; in contrast, during the 1987 run, the mean time between failures was about 6 weeks. Thus the repair of the lead restraint problem has indeed substantially improved the reliability of the Tevatron for fixed target operation.

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The Fermilab III Upgrade Program

The Fermilab III program is a major initiative of the laboratory which includes a program of accelerator upgrades[2)], aimed at an increase by a factor of 50 in Tevatron collider luminosity over the original design. This is accomplished in a phased manner over the next five years; the program is designed to minimize the disruptions to the ongoing physics program during this period. Figure 1 shows the luminosity progression as a function of time, in terms of the initial luminosity which can be expected vs. calendar year through 1996. The text at the bottom of

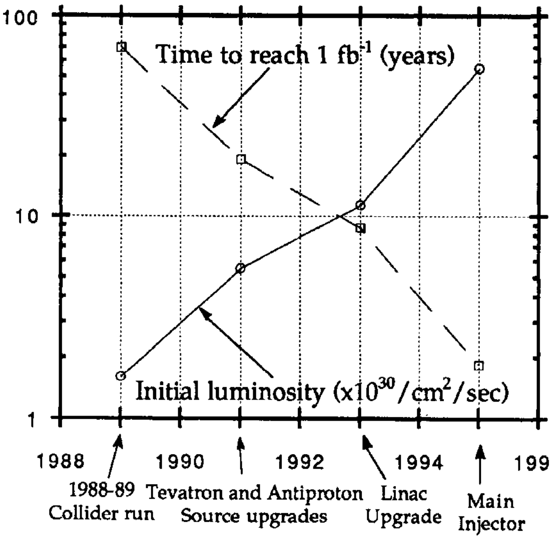

Figure 1: Fermilab III luminosity progression

the figure indicates the timing expected for each step in the upgrade.

Tevatron and Antiproton Source Upgrades

Significant improvements are being implemented in the Tevatron in preparation for the next collider run, which will begin in 1991. Two new low-β systems will be implemented: a new system at B0 to replace the old system used in the previous collider run, and a new system at D0 required by the advent of the D0 detector in 1991. The other major improvement for the Tevatron is a system of electrostatic separators which will separate the proton and antiproton beams everywhere except at the B0 and D0 interaction points. By reducing the number of beam-beam crossings with 6 bunches from 12 to 2, the beam-beam effects will be substantially reduced; these effects were a significant limitation to the luminosity in the last collider run.

In addition to improvements in the Tevatron, improvements have been implemented in the Antiproton Source. As shown in fig 1, the overall result of these improvements in the Antiproton Source and Tevatron is expected to be an increase in the initial luminosity to $>5\times10^{30}/cm^2/sec$ for the collider run starting in 1991.

Additional improvements planned for the Tevatron for subsequent collider runs include an improved antiproton injection kicker, which will allow operation with up to 36 bunches, and a system of cold compressors in the Tevatron cryogenics system. The cold compressors will reduce the Tevatron operating temperature by about 0.5^o K; this corresponds to an increase in the Tevatron energy from 900 GeV to above 1000 GeV.

Linac Upgrade

The Linac upgrade[3)] is a project to increase the Fermilab Linac energy from 200 MeV to 400 MeV by a replacement of the last four drift tube cavities in the present Linac with more efficient, higher gradient side-coupled cavities. This project is an approved line-item construction project, which started in October, 1989. The project is presently gearing up for full production of the required number of cavities. The schedule calls for installation of the new Linac cavities, and first operation at 400 MeV, in the fall of 1992. The motivation for this upgrade is to reduce the space-charge induced emittance growth presently suffered just after Booster injection at high intensities. The overall impact on collider initial luminosity, as shown in fig. 1, will be an increase to over $10^{31}/cm^2/sec$.

Main Injector

The principal limitation to the performance of the accelerator complex after the implementation of the Linac upgrade will be the Main Ring. This machine limits collider luminosity in a number of ways: the primary difficulties are its restricted transverse and longitudinal apertures, and its limited cycle rate. Additionally, the presence of the Main Ring beam in the vicinity of the collider detectors is a constant source of operational problems and dead time for the collider experiments.

The proposed solution to these problems is the Main Injector[4)]. This is a new 150 GeV synchrotron in a new tunnel, which replaces the Main Ring in all its functions. It will have a radius about half that of the present Main Ring, but will have adequate transverse and longitudinal acceptance to provide substantially increased proton intensities both to the

Antiproton Source for antiproton production, and to the Tevatron for collider operation. Moreover, it will be able to deliver intensities of 6×10^{13} protons/cycle to the Tevatron for fixed target operation. Finally, because it is in a separate tunnel from the Tevatron, it will allow 120 GeV test beams, and high intensity (3×10^{13}/cycle) 120 GeV production beams, to be delivered to the experimental areas year-round.

The overall impact of the Main Injector on collider performance is to increase both the proton and antiproton intensities sufficiently that the luminosity will exceed $5 \times 10^{31}/cm^2/sec$ (see fig. 1). The Main Injector project has been proposed to begin Oct. 1, 1991; if funded on the proposed schedule, it could be completed and operational by 1995.

Physics Reach of the Upgraded Tevatron Collider

In addition to the expectations for initial luminosity vs year, fig. 1 also displays another curve which shows the amount of calendar time (in years from the indicated date) required to reach an integrated luminosity of 1 fb^{-1}. This calculation folds in effects such as operational efficiency and luminosity lifetime, and is based on the experience of the 1988-89 collider run. It shows that within two years of operation after the Main Injector, the Tevatron collider could deliver 1 fb^{-1} of integrated luminosity. If the top quark had a mass of 250 GeV, this integrated luminosity would produce roughly 500 $\bar{t}t$ pairs. With detection efficiencies in the range of 5-10%, 25-50 top events would be seen, which would be enough to guarantee discovery. Since it is generally accepted that consistency with the Standard Model requires the top quark mass to be less than about 250 GeV, the absence of these top events would be direct evidence for a failure of the Standard Model.

Conclusion

The Fermilab Tevatron exceeded its design luminosity goal as a $\bar{p}p$ collider by more than a factor of 2 during the 1988-89 collider run; it has operated with excellent reliability during the present fixed target run. An upgrade program, called Fermilab III, has been initiated which will result ultimately in a 50-fold increase in the collider luminosity. This program, phased to provide a gradual increase in the luminosity over a period of 5 years, results in maximal utilization of the existing facilities for physics during this period. The major component of the upgrade is the Main Injector, a new 150 GeV synchrotron which will replace the Main Ring in all its functions. The upgrade will substantially benefit the Tevatron fixed-target program, and will provide a new source of high intensity 120 GeV beams at Fermilab. The result of the luminosity upgrade will be to provide integrated luminosities in excess of 1 fb^{-1} over a two-year period of operation following completion of the Main Injector. This will extend the mass reach for new physics by more than a factor of two. In particular, it will guarantee discovery of the top quark if its mass is within the range currently predicted by the Standard Model.

References

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