A Luminosity Upgrade for Fermilab

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This is the first in a series of reports describing Fermilab's plan to upgrade the TEVATRON, with the goal being to reach a luminosity of 5 x 10^{31} cm^{-2} sec^{-1}. (The luminosity is the product of the number of particles per second circulating in one beam and the average number of intercepted particles per unit transverse area in the other beam. When multiplied by the cross section for a given reaction, it gives the average number of events per second for that reaction.) The TEVATRON I Project (TeV I), which converted the superconducting TEVATRON into a collider, had a luminosity design goal of about 1 x 10^{30}. The machine was first commissioned for fixed-target operation in 1983, and the first 1.6-TeV center-of-mass colliding-beams events were observed in October of 1985 with a luminosity of about 10^{24}. Fermilab's Director, Leon Lederman, has remarked, "I believe it was the world's lowest recorded luminosity. . . It even beat the ISR because, when they first measured it in 1971, it was at least 10^{27}." Since that time, the luminosity has climbed by five orders of magnitude to 10^{29}. The proposed luminosity upgrade would give Fermilab a factor of 50 above the TeV I design goal.

There are a few issues that must be addressed in order to achieve this goal. The first is significantly reducing the beam emittance. The second is going from the present three-bunch operation to "multibunch" operation, storing about 100 bunches. Finally, the number of antiprotons must be significantly increased over the amount currently being produced. There are a few initial steps that Fermilab is proposing in order to reach the goal.

Initial steps toward multibunch operation are already under way. Studies of helically separated counter-rotating beams are currently in progress, with the intent of installing electrostatic separators in time for the 1989 run. The CERN experience with separated beams in the SPS provides valuable guidance in this work. The "6 on 6" bunch operation in the 1988 Collider run will be carried out without the benefit of beam separation.

A second significant step is the proposed upgrade of the existing Linac. The upgrade will elevate the energy of the Linac from its current level of 200 MeV to 400 MeV. This will involve replacing roughly half of the Linac with higher gradient structures, tripling the gradient in the later stages to 7.5 MeV per meter. This new configuration would enable the H^- ions to reach an energy of 400 MeV

before being injected into the 8-GeV Booster. The higher injection energy produces a greatly reduced dilution of the beam emittance in the Booster. This dilution is believed to be due to space charge effeets.

A third proposed step could be the addition of two new 20-GeV rings. The first 20-GeV synchrotron, called the Proton Super Booster (PSB), will be interposed between the 8-GeV Booster and the Main Ring. It will accept 8-GeV protons from the Booster, accelerate and inject them into the Main Ring at 20 GeV, with a significantly smaller beam emittance. Studies predict that this will produce a much improved Main Ring performance resulting from the combination of a smaller beam and better magnetic field quality. The second 20-GeV ring is called the Antiproton Super Booster (ASB). To reach the luminosity goal of 5×10^{31} it is necessary to increase the number of pbars in hand by about a factor of 10. In this new scenario, the Accumulator would continue in its present role, cooling and stacking pbars, then transferring them to the new ASB holding ring where they will be cooled and stored while the Accumulator stacks fresh batches. When a suitable number of pbars have been accumulated, they will be accelerated to 20 GeV and transferred to the Main Ring and ultimately to the TEVATRON. The ASB will also enhance pbar economy, offering the option of taking "old" pbars whose emittance was diluted by interbeam scattering out of the TEVATRON, decelerating them in the TEVATRON and Main Ring, and putting them back into the ASB to be used again.

Alternatives to the 20-GeV rings approach are also being considered. In particular, the Accelerator Division has begun to study a possible pp approach to higher luminosity.

In order to keep a vital colliding-beams physics program going, Fermilab must make significant improvements in the TEVATRON's luminosity. Initial steps of this program are already under way, with conceptual design reports being prepared. Portions of the project could conceivably be funded as early as 1990. This is an interim program that fills the gap between the TEVATRON and the SSC, and is a necessary evolutionary step to provide new physics opportunities in the intervening period.