Accelerator Division Accomplishments in 1988

by John L. Crawford and David Finley

The year 1988 began with the Accelerator in the final phase of a fixed-target run which had commenced on June 15, 1987; before the run ended on February 15, the seventh and last TEVATRON dipole failure occurred on February 4. Despite the unfortunate spate of magnet failures, the run exceeded all expectations, with some 2.2 x 10^{18} protons delivered in nearly 2900 hours of operation. The peak extracted intensity for the run was 1.80 x 10^{13} ppp, not quite up to the 2.0 x 10^{13} we had hoped for, but the TEVATRON ran for extended periods at greater than 1.6 x 10^{13} ppp with excellent stability and reliability. Figures 1 and 2 summarize the 35-week fixed-target run.

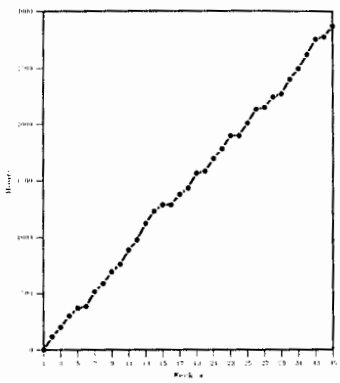

Fig. 1. *TEVATRON fixed-target operation, integrated HEP hours at 800 GeV*

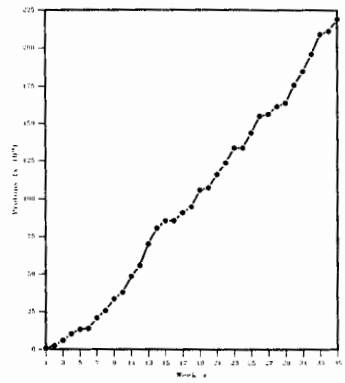

Fig. 2. *TEVATRON fixed-target operation, integrated intensity at 800 GeV*

Near the end of the fixed-target run, the Switchyard Beam Position Monitor system and associated application software was used as a position servo to maintain beam position through the Meson beamline. Once this system is made fully operational, it promises much improved position stability throughout the Switchyard.

On the Pbar Source front, an E-760 installation and study period was scheduled during which the gas jet target and detector were installed in the A50 pit;

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the jet was made operational and the detector saw $\bar{p}$-p collisions. Protons were decelerated in the Accumulator from 8900 MeV/c to 3500 MeV/c (through transition) via a γ t jump.

Following a two-week period of SSC-related studies, the Accelerator was shut down for three months of maintenance and development work. The Division's primary mission during this period was to inspect and repair as many TEVATRON dipoles as possible; inspection consisted of visually examining the magnet lead areas using a borescope and utilizing two industrial gamma-ray sources to take "x-ray" pictures of the magnet ends. The magnets were examined to see if the leads were properly tied down (to prevent flexing and strand breakage), if the G10 lead-clamping blocks were intact and were sufficiently far away from the end of the single-phase can, and whether the beam tube insulation was tied down. All magnets in A Sector, B1, and E1 were examined, with 138 out of 200 magnets undergoing some degree of repair. Seven magnets were found to have broken lead strands and so were replaced.

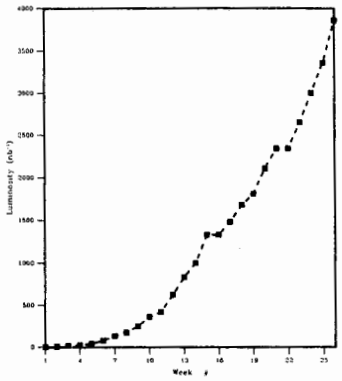


Fig. 3. TEVATRON Collider operation, integrated luminosity at 900 GeV.

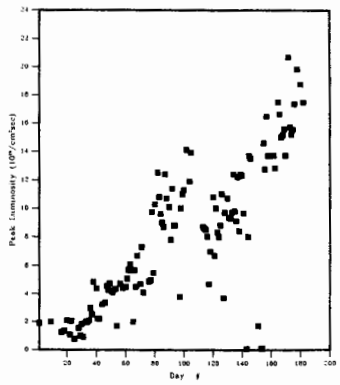


Fig. 4. TEVATRON Collider operation, peak luminosity/day.

A second major undertaking during these three months was the installation of a redesigned Main Ring overpass in the D0 interaction region. The original D0 overpass was installed in 1984 and was intended to be more of a "proof-of-concept" test bed than a permanent operational feature. A known shortcoming of the original design was an undesirable increase in the vertical dispersion function around the Main Ring and a dispersion mismatch between the Main Ring and the TEVATRON (leading to emittance growth in the TEVATRON). The new design lengthened the overpass by some 700 feet (although the height remained the same) and incorporated a near clone of the B0 "double dogleg" vertical bending system.

A 900-GeV ramp was established on May 26, 150-GeV circulating beam on May 27, and by May 29 the orbit was smoothed all the way to 900 GeV. Antiprotons were injected into the TEVATRON on June 6, and by June 12 we had our first 1.8-TeV 6 x 6 store with an initial luminosity of 4 x 10^{28} cm^{-2} sec^{-1}. (6 x 6 is shorthand for 6 proton bunches colliding with 6 antiproton bunches; all of the 1987 Collider run was 3 x 3.)

Collider operation was sporadic for the first four weeks, but by week six it had surpassed the integrated luminosity of the entire 1987 run. Since then the performance of the TEVATRON Collider has been nothing short of phenomenal - we reached 3 x 10^{29} cm^{-2} sec^{-1} (our "operational goal") on July 28, the design peak luminosity of 1.0 x 10^{30} cm^{-2} sec^{-1} was reached on September 7, an integrated luminosity of 1000 nb^{-1} (1 inverse picobarn) was delivered by September 24, 2000 nb^{-1} by November 5, and 3000 nb^{-1} by December 4. As this report goes to press, the integrated luminosity is nearing 4.0 pb^{-1}, the peak luminosity has exceeded 2.0 x10^{30}, and store duration is averaging 13.8 hours. Figure 3 shows the integrated luminosity through December 18, while Fig. 4 shows the progression of the peak initial luminosity. Figures 5 and 6 detail the weekly performance of the Collider.

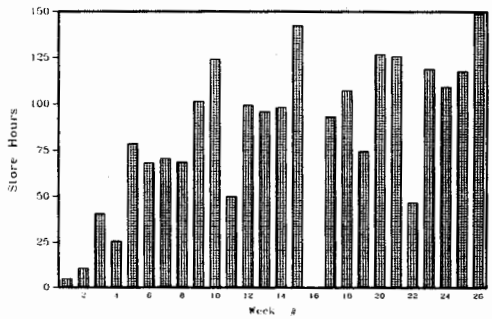


Fig. 5. TEVATRON Collider operation, integrated store hours/week.

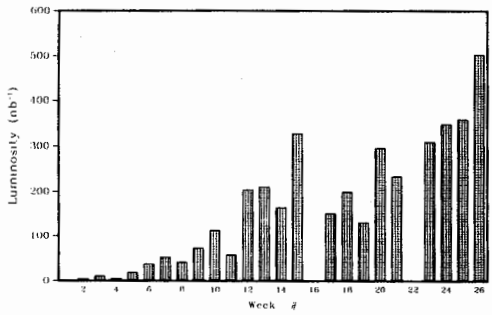


Fig. 6. TEVATRON Collider operation, integrated luminosity/week.

Meanwhile, the Pbar Source has not been resting on its laurels; its performance has also astounded accelerator aficionados. The peak stack achieved exceeds 81 x 10^{10} pbars, the number of pbars stacked in one week has reached 175.5 x10^{10}, the stacking rate per hour has been as high as 1.898 x 10^{10}, and as of this writing the Source has operated for 39 days without interruption. (As an aside, on November 9 a glitch on the commercial power grid caused the 81-milliamp pbar stack to be lost - some have suggested that this was the largest number of antiprotons annihilated in one fell swoop since the Big Bang.)

Why is the Collider performing so well? The present run is delivering integrated luminosity at a rate which is about 20 times greater than that delivered during the first Collider run. This spectacular difference is not (entirely) the result of luck. Indeed, by the time the first run ended in May 1987, the inter-meshing of improvements which were needed among all the accelerators had been clearly identified. During the intervening fixed-target run, the process of improvements for the second Collider run had already begun.

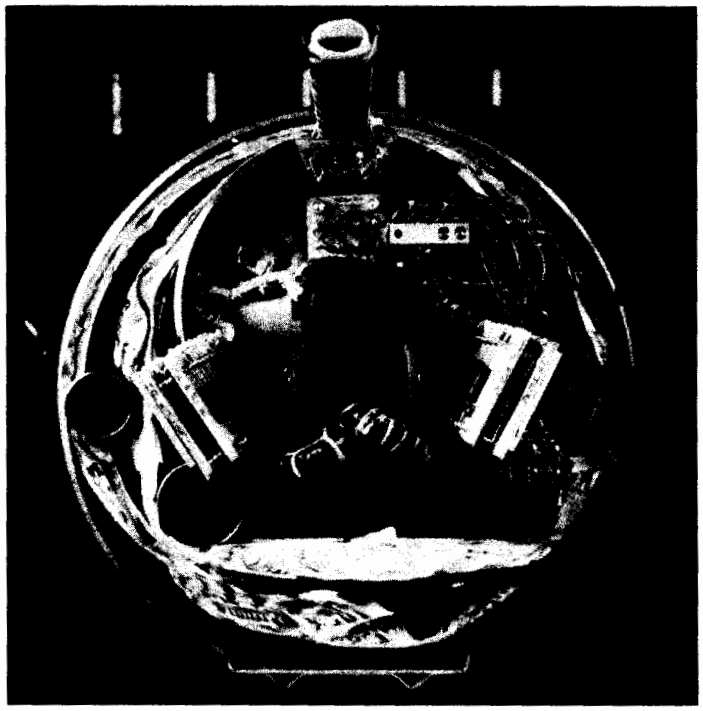
There are more antiprotons available this run. Main Ring and Accumulator improvements have resulted in a very much improved stacking rate. For instance, Main Ring intensity has averaged about 1.7 x 10^{12} ppp on stacking cycles, compared to 1.2 x 10^{12} last run; in the Pbar Source, the Accumulator aperture was increased to the design value and the horizontal dispersion in the low-dispersion straights was corrected, core cooling was improved due to the introduction of microwave mode dampers, and Debuncher betatron cooling times were reduced by the addition of optical notch filters. These improvements, coupled with improved TEVATRON reliability, have resulted in larger stacks. The larger stacks have made it profitable to extract bunches six times instead of only three times from the Accumulator. Once the bunches have been extracted, the improved Main Ring transmission and coalescing have resulted in higher intensity single bunches at 150 GeV. These improvements have resulted in an overall gain factor of about seven.

Getting the particles into a single high-intensity bunch in the Main Ring at 150 GeV is only part of what is required for large integrated luminosity. In the first run, one of the major problems was not being able to obtain sufficiently small beam sizes in the TEVATRON and, even if they had been small enough, not being able to keep them small during a store. The transverse emittances of the beams in the TEVATRON during the present run are half as large as in the last run. This is because the vertical dispersion match between the Main Ring and the TEVATRON was improved by the re-configuration of the D0 overpass, and because the compensation of the time-dependent higher order multipole fields in the TEVATRON magnets has been greatly improved. The abort kicker power supplies were identified as the primary source of the anomalous transverse emittance growth during the

last run; modifications to these supplies have resulted in an improvement in the luminosity lifetime by a factor of 2 to 3. Once these kickers were fixed, the full advantage of the "100% mini-beta" squeeze could be implemented and this reduced the beam size at the Collider Detector at Fermilab (CDF) even further. Without these improvements, the present Collider run's integrated luminosity would be disturbingly smaller by another factor of three.

There have also been operational improvements which are necessarily invisible if they are successful. These invisible improvements are nonetheless very important to the integrated luminosity. One of these items is the policy of relentless pursuit of things which kill stores. The improved diagnostics, controls, and applications software needed to accomplish this for each killed store involves the continuing efforts of many individuals. Without question, it is their constant effort which keeps the Collider functioning as well as it does.

Can a similar improvement factor be expected for the next Collider run? The answer is a resounding "no" - not without an upgrade program. Even now, the stacking rate drops steadily as the stack size grows, so that without improvements in the Pbar Source, peak stacks will probably be limited to less than 100 mA. (The pbar transfer efficiency also decreases as the stack size grows.) Creating more intense bunches or a greater number of less intense bunches is foiled by an effect called "beam-beam interaction"; the cure for this is separated beams - but all this sounds like a subject for Michael Harrison's article on the TEVATRON upgrade in the *Fermilab 1988 Annual Report.*



(Fermilab photograph 88-102-6)

End view of a Superconducting Super Collider (SSC) dipole on a test stand at the Fermilab Technical Support Magnet Test Facility. Two TEVATRON test stands have now been converted to accommodate full-length SSC dipoles. The second stand has an improved design, allowing the magnets to be operated at superfluid helium temperatures (1.8 K).

Since June of 1986, a series of eight coil assemblies has been delivered to Fermilab from Brookhaven National Laboratory. In the interim, an increasing number of diagnostic instruments, including strain gauges, voltage taps, temperature sensors, and deflection gauges, has been added in order to better understand magnet quench behavior. Additionally, full-length tooling, based on the proven design used for the TEVATRON, is under construction. The new tooling consists of full-length curing and collaring presses and a full-length press for applying the yoke and helium-containment skin. This tooling will provide high-precision coil sizing and uniformity for better magnet performance and reliability.