REVIEW OF RECENT TEVATRON OPERATIONS*

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Abstract

Fermilab's Tevatron proton-antiproton collider continues to improve its luminosity performance at the energy frontier √s = 1.96 TeV. The recent Tevatron operation will be reviewed and notable tasks leading to advancements will be highlighted. The topics to be covered include: work performed during the 14-week shutdown in 2006, improved helical orbits, automatic orbit stabilization during high-energy physics (HEP) stores, optics corrections, improvements in the quench protection system, and avenues to maximizing the integrated luminosity delivered to the CDF and D0 experiments.

INTRODUCTION

The Tevatron has now delivered over 3 fb^{-1} of luminosity to both CDF and D0. (see Fig. 1). The goal is to deliver 8 fb^{-1} to the experiments before the end of Run II which is currently scheduled for October 2009. The current running period began in June 2006 following a 14-week shutdown for planned upgrades and maintenance throughout the accelerator complex. Since that shutdown ended, the Tevatron has doubled the total integrated luminosity by delivering > 1.5 fb^{-1} to both experiments. Since June 2006, the peak luminosity has increased from 180 to 292 $\mu b^{-1}/s$ (1 $\mu b^{-1}/s = 10^{30}$ cm^{-2} s^{-1}) and the best weekly and monthly integrated luminosity have increased to 45 pb^{-1} and 167 pb^{-1} respectively.

SHUTDOWN 2006 TASKS

The 2006 shutdown was used for installing the last new components for the remaining Tevatron Run II upgrades as well as the usual maintenance and repair tasks. Two new electrostatic separators (used to keep the two beams on distinct helical orbits) were installed, and three others with higher than desired spark rates were replaced. The second Tevatron Electron Lens (TEL-2) was installed while the first electron lens (TEL-1) was repaired. Reshimming of the remaining 228 dipoles whose cryostats were sagging and causing coupling was also completed. A ring-wide hydrostatic level sensor system was finished, and the second plane of an Ionization Profile Monitor (IPM) was installed [1]. Cables were pulled in preparation for new sextupole circuits to correct second order chromaticity. To address a reliability concern, approximately 1200 helium relief valves on all magnets were replaced following two rare failures that required the replacement of two dipoles several months prior to the shutdown.

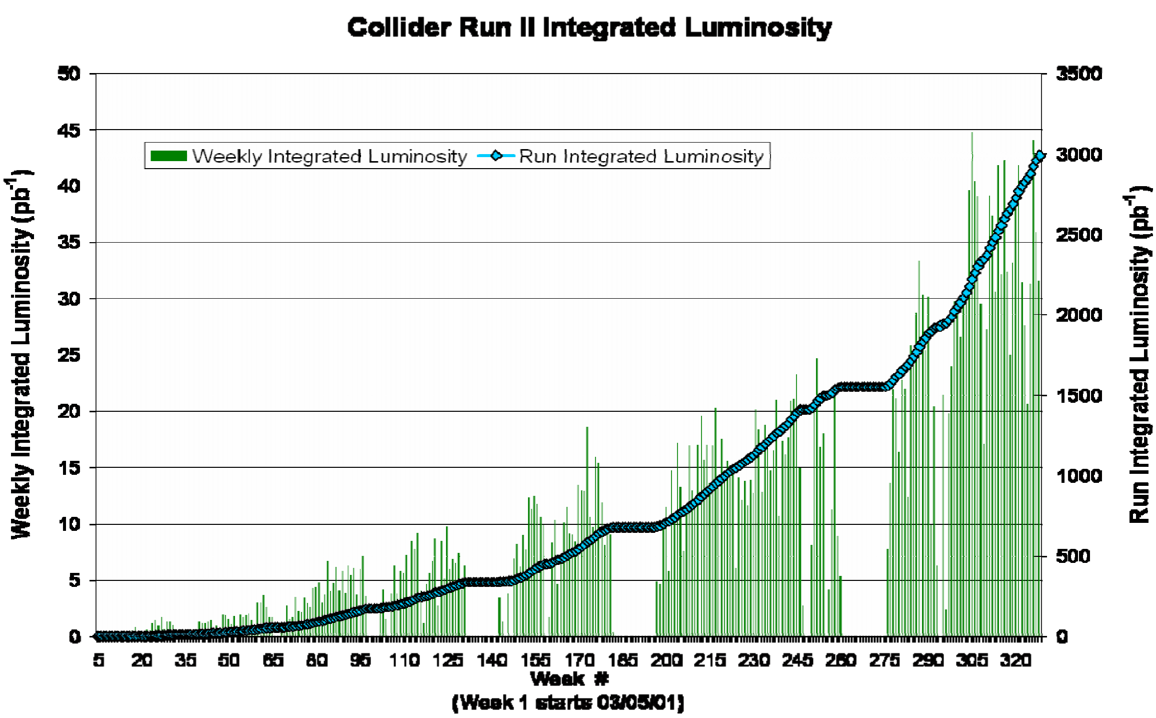

Figure 1: Weekly and total delivered luminosity during Tevatron Run II.

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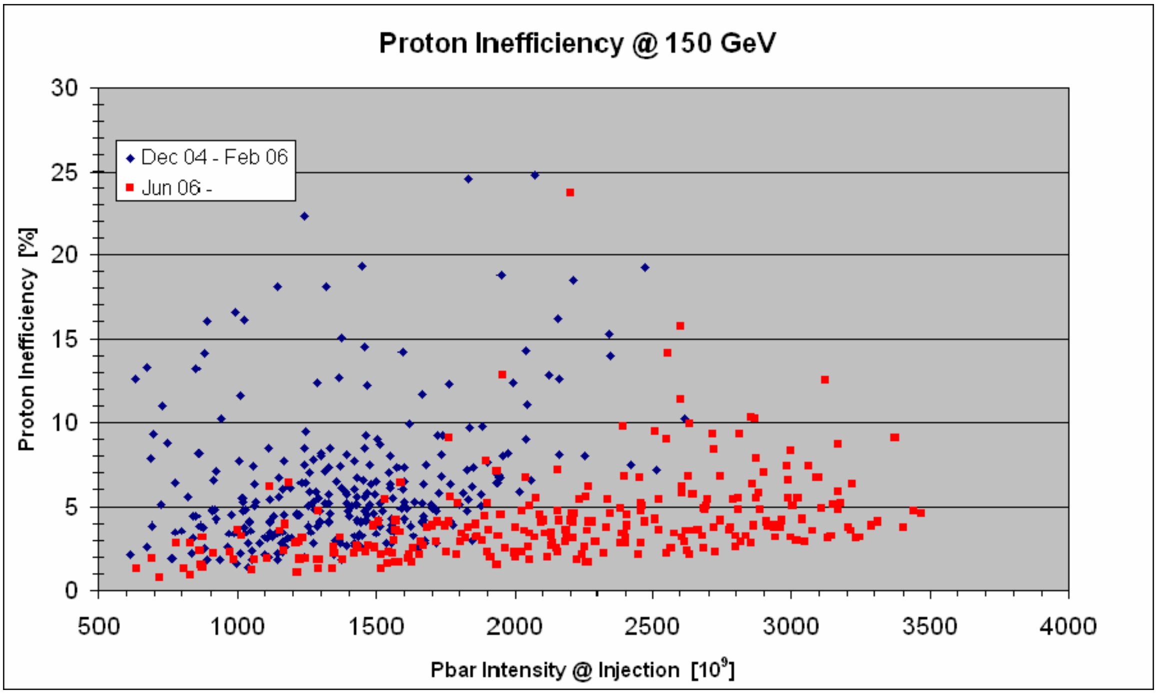

Figure 2: Proton inefficiency versus injected antiproton intensity while at 150 GeV in the Tevatron.

OPERATIONS

Recent Highlights

The higher luminosities achieved since the shutdown are due mainly to increased antiproton intensities with smaller emittances [2]; the antiproton intensities at the start of high-energy physics (HEP) stores has increased 45%. In addition, proton intensities have increased 10% thanks not only to injecting more protons, but also improving the proton lifetime during antiproton injections at 150 GeV. Fig. 2 demonstrates the benefit of implementing a new helical orbit after the shutdown; the beam separation at one particularly bad parasitic crossing point was increased and the resulting detrimental beam-beam effect reduced.

The luminosity lifetime also benefited from increased beam separation thanks to the two new separators installed during the shutdown. Beam separation at the upstream parasitic crossings nearest to the interaction points (59 m away) increased 20%. Comparing stores before and after the shutdown that have similar initial luminosities, the luminosity lifetime increased ≈15%, thus improving the integrated luminosity per HEP store.

The newly installed TEL-2 electron lens has been successful commissioned. TEL-2 has been used to remove unwanted beam from the abort gap (as a spare for TEL-1) and has demonstrated beam-beam compensation on protons [3]. Having both TELs functional allows flexibility in conducting beam-beam compensation studies and maintaining a clean abort gap.

An improvement to the orbit stabilization scheme used during HEP stores has allowed greater operational stability and reproducibility. Now, soon after collisions begin, the orbit is smoothed automatically to our desired positions. Then, every 30 seconds throughout the store, the orbit is smoothed again to account for short-term changes mainly caused by slight, thermally-induced, changes in the girders supporting the low-beta quadrupoles in the collision halls. Small variations in the position, roll, or pitch of those quadrupoles can lead to observable orbit deviations in the arcs; orbit stabilization uses dipole correctors near the interaction points to minimize such orbit changes.

The leveling of antiproton bunch intensity from the Recycler has benefited the Tevatron and the experiments. Previously, the differing antiproton bunch intensities would cause up to a factor of 5 variations in the bunch-to-bunch luminosities and complicate operation of the experiments' trigger and data acquisition systems. Moreover, the head-on beam-beam tune shift seen by the protons would vary dramatically too, making it difficult to find an optimal tune setting for all bunches. The intensity leveling in the Recycler has reduced the typical intensity spread to 20-25%.

Challenges

Beam-beam effects remain a hurdle for increasing peak and integrated luminosity [4]. The recent helical orbit improvements have helped, but beam-beam effects can cause 10% or more loss in the delivered luminosity during an HEP store [5]. Typically, the antiproton lifetime is dominated by burn-up from luminosity alone, but the proton lifetime is now degraded by non-luminous losses arising from beam-beam effects with the larger antiproton intensities – see Fig. 3. Without careful control of the tunes, the proton losses can be large enough to cause a quench.

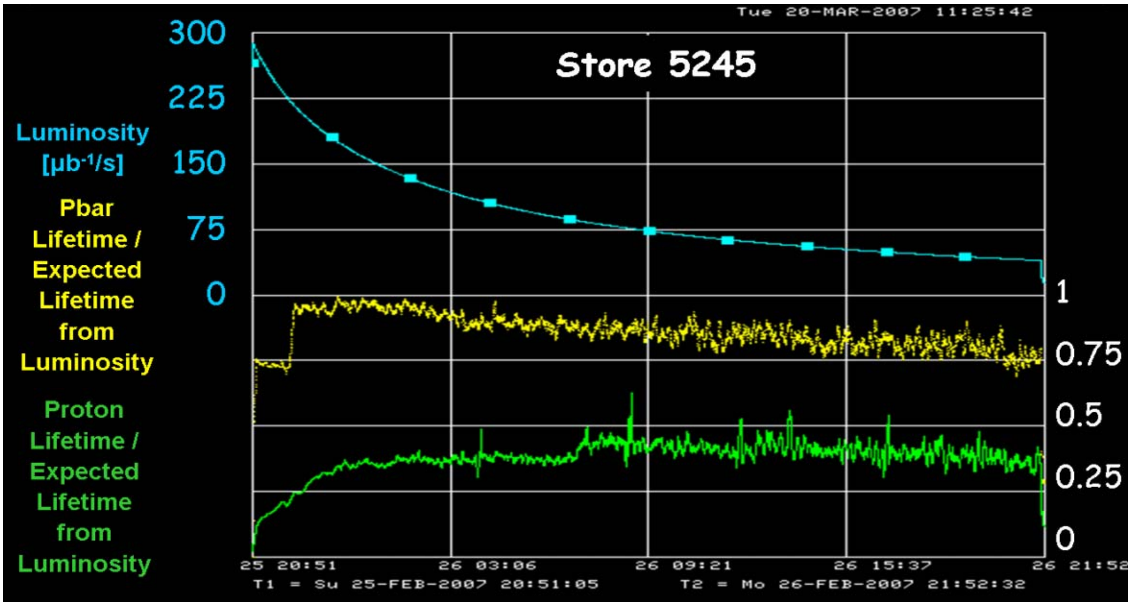

Figure 3: Typical proton and antiproton lifetimes relative to those expected from luminosity during HEP.

Reliability

Since June 2006, there have been over 280 HEP stores, 70 of which were terminated unintentionally; the 75% intentional termination rate is slightly better than the 72% Run II historical average. Including two failures resulting in more than 3 weeks of downtime, the Tevatron is averaging ≈105 HEP store hours per week in fiscal year 2007 which began on October 1.

Improving machine reliability remains a focus for the Tevatron. In addition to the previously mentioned Kautzky valve replacement, the quench protection system is being modified to allow faster quench detection so that the beam can be aborted more quickly upon a quench; the abort can be pulled within ≈350 μs (17 beam orbits) of the quench event, an improvement of 150 μs. Furthermore, the antiprotons are now cogged out of abort gap for acceleration to prevent unnecessary quenches. Previously, if there was an abort during the ramp, there would surely be a quench since the 3 antiproton bunches sitting in the abort gap would get kicked into cryogenic components.

Upgraded beam loss monitor (BLM) electronics are being commissioned currently. The new electronics should allow finer time resolution of loss patterns and greater flexibility and robustness for implementing aborts based on high beam losses prior to a quench of the superconducting magnets.

PLANS

Although increasing the antiproton production rate remains a priority for increasing luminosity, there are other Tevatron-specific topics to pursue to help push toward our deliver 8 fb^{-1} integrated luminosity goal. Notably, the new sextupole circuits to correct second-order chromatic effects have recently been commissioned [6] and their effects on lifetimes are being evaluated. These new circuits are also a prerequisite for pursuing a possible new working point near the ½ integer which should allow higher beam intensities.

Other possible improvements under investigation include: injecting and scraping higher intensity protons prior to injecting antiprotons to yield brighter protons for HEP stores while reducing beam loss during acceleration and the low-beta squeeze; different cogging of antiprotons during injection to reduce beam-beam effects by changing the location of long-range crossings; using the electron lenses to improve the lifetimes of particular proton bunches by raising their tunes away from the 7/12 resonances; measuring turn-by-turn quadrupole oscillations during beam injection to identify and correct lattice mismatches with the transfer lines. Each of these topics could help increase luminosity by a few percent.

CONCLUSION

The Tevatron performance has improved greatly over the past year thanks to increased antiproton intensities and improved lifetimes in the Tevatron. The Run II total integrated luminosity now exceeds 3 fb^{-1}. All major Tevatron upgrades are effectively complete, although the full benefits for some are still being realized. Additional smaller improvements are being pursued to reach for the 8 fb^{-1} luminosity goal before the end of Run II.

REFERENCES

[1] A. Jansson et al., FRPMS008, these proceedings.
[2] K. Gollwitzer, WEZAKI01, these proceedings.
[3] V. Shiltsev et al., TUOCKI04, these proceedings.
[4] V. Shiltsev et al., Phys. Rev. ST Accel. Beams 8 (2005) 101001.
[5] A. Valishev et al., TUOCKI03, these proceedings.
[6] A. Valishev et al., FRPMS015, these proceedings.

