OPERATIONAL EXPERIENCE WITH USING COLLIMATORS TO REMOVE HALO IN THE TEVATRON COLLIDER

S. M. PRUSS, C. CRAWFORD, D. FINLEY and M. HARRISON
Fermi National Accelerator Laboratory*
P. O. Box 500, Batavia, IL 60510

Abstract

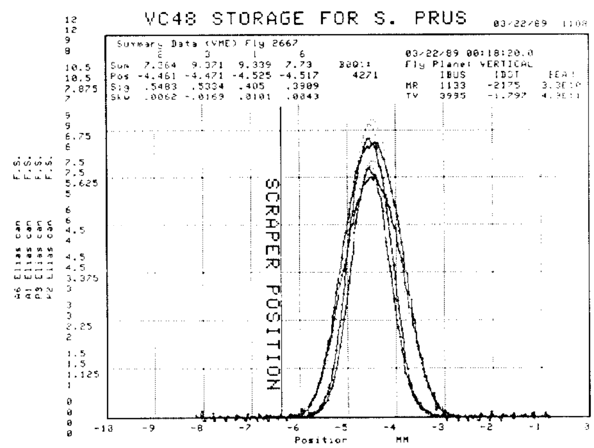
In every experiment it is desirable to have a high ratio of signal to noise. In the case of the Tevatron collider the signal will be proportional to the luminosity. One form of noise comes from large emittance particles interacting on the beam pipe walls near the experiment. Scraping these particles with a collimator may reduce the signal a little but can reduce the noise greatly. The key is striking a balance and scraping enough to reduce background without losing much luminosity. Operational experience with the Tevatron collider shows how this can be done.

Introduction

During a typical store there are several 10^{11} particles circulating at 47 kHz in the Tevatron. The experiments are sensitive to losses of a few thousand particles a second. Keeping the losses small requires that the beam must be smaller than the aperture and that it must remain so for the duration of the store. Stores are started by first injecting six bunches of protons into the Tevatron at 150 Gev . They are then blown up in emittance by injecting noise into the damper input until they fill the aperture. (This is done to reduce the variation of beam-beam tune shift over the anti-proton beam.) Then the antiprotons are injected, the beam is accelerated to 900 Gev, and the low β insertion at B0 is turned on. The proton beam typically has a normalized 95% emittance of 24 π mm-mr. The anti-proton beam has a much smaller emittance, typically 15π. This makes it possible to reduce the emittance of the protons with almost no antiproton loss.

There are two collimators installed in the Tevatron. These are 61" long, 'L' shaped blocks of steel inside the beam vacuum chamber in warm straight sections. They both scrape the beam from below and from the radial inside. They have remote horizontal and vertical position control at each end with a 2" range and have had their speed slowed to ~0.0026"/second to avoid loss rates high enough to quench the machine. The position readback and control is accurate and reproducible to about 0.001". One is located at the downstream end of the D0 long straight section where (for the low β lattice) both β_x and β_y are 120 m and the momentum dispersion is nearly zero. The second is located at the D17 medium straight section where β_x is about 70 m, β_y is about 50 m and the dispersion is about 6 m. There is a loss monitor near each collimator to indicate whether they are touching the edge of the beam and to warn of very high losses which might quench nearby superconducting magnets. The collimators are positioned about 0.6" (~10 beam σ at injection energy) from the center of the beam at injection.

There are two experiments normally running. These are CDF at the low β intersection at B0 and E735 at C0. Since there are typically five times as many protons as antiprotons in the collider and since the proton emittance is nearly twice that of the antiprotons, background from the protons is usually a greater problem for the experiments than that from the antiprotons. Since β_{max} near B0 is about 1500 while that near C0 is only 250, one would expect the background near B0 to be worse. In fact, perhaps because of the restricted aperture due to the abort system near C0, the backgrounds near C0 are usually worse. Typically, immediately after reaching low β, the background rates at B0 are in excess of 10kHz while those near C0 are near (or in excess of) 40kHz. Scraping is usually done using the D0 vertical scraper. The scraper starts at ~22 beam σ (σ ~ 0.027" at the scraper). As soon as it is moved toward the beam, the nearby loss monitor indicates an increase in beam loss. No perceptible decrease in beam intensity is seen until about 5 σ. The scraper continues to be moved into the beam until about 2% of the total beam has been scraped away. This is near 4 σ. The scraper is left in this position for about five minutes while the loss rates gradually decrease and become stable. Figure 1 shows the scraper position relative to the beam profile at this time.



An additional loss of beam of about 1% occurs during this time. (All of this reduction in beam intensity comes from the proton bunches.) The scraper is then withdrawn by about 1 beam σ. The loss at the local loss monitor drops by a factor of ~30. Almost no effect can be seen in the flying wire beam profiles before and after this procedure. The sigma of the gaussian fit to the proton profile decreases by 3 to 5%. Before scraping, the bunch intensity lifetime is several hours. After scraping, it is typically several hundred hours and the luminosity lifetime is entirely due to emittance growth. Care is taken to keep the scraper parallel to the beam to better than 50 μrad. (During the development of these procedures, a misalignment of 200 μrad after the scraper was withdrawn was observed to double the asymptotic loss rates at C0.) Over the next 15 minutes or so the loss rates on the loss monitor near the scraper will gradually build up by a factor of three and then stabilize. The background rates at B0 drop to ~2kHz when the scraper is pulled back from the beam and normally remain below 5kHz for the rest of the store. The loss rates at C0 typically drop below 10 kHz immediately after the collimator is withdrawn, but may slowly increase to 20kHz over the next half hour and then decrease very slowly thereafter.

As will be reported by D.A. Herrup et.al. in poster X12, "Luminosity Lifetime in the Tevatron Collider," the emittance growth rate is very small, ~1/2 π per hour. For the beam size to grow out to the scraper position, it would have to increase by 25%.

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This would require a 50% increase in emittance and would take 24 hours, and stores seldom last that long. This is what permits only one scrape at the beginning of a store to be adequate.

These scrapers have also been used to produce very small emittance beam (~5π) for E710, an experiment measuring very small angle elastic scattering and the total cross section. Figure 2 shows the decrease in transverse emittance as the collimator is moved into the beam. The emittances are larger than quoted above since this data was taken nearly 20 hours after the store started. Note that because of transverse coupling, the vertical collimation reduces both the vertical and the horizontal emittance. The longitudinal emittance was not changed during this procedure.

Emittance vs collimator position