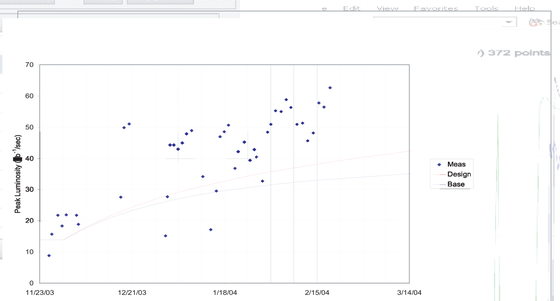
Sample of Beam Physics Results: Pbar Source, Main Injector & Tevatron

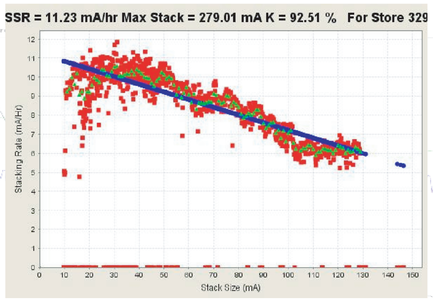
The following plots illustrate SDA capabilities.
This is not a comprehensive presentation of the RunII Accelerator performance.

Global "trending" Analysis

The store's peak luminosity during FY04 is compared to our baseline and the design

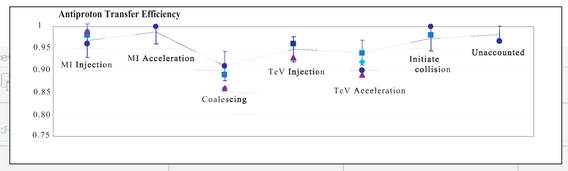


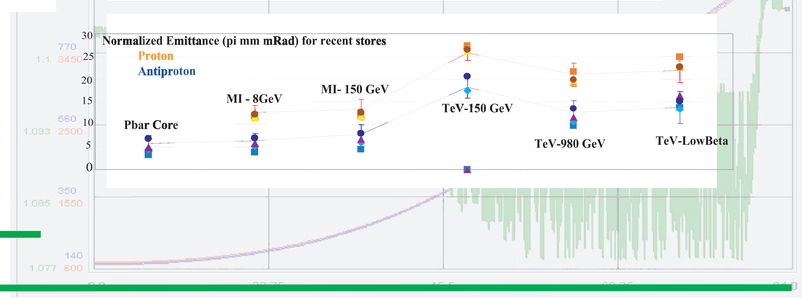
Courtesy of D. McGinnis



Antiproton stacking rate vs stack size, recent stores.

Anti proton accounting through the accelerator chain, Intensities & transverse emittances

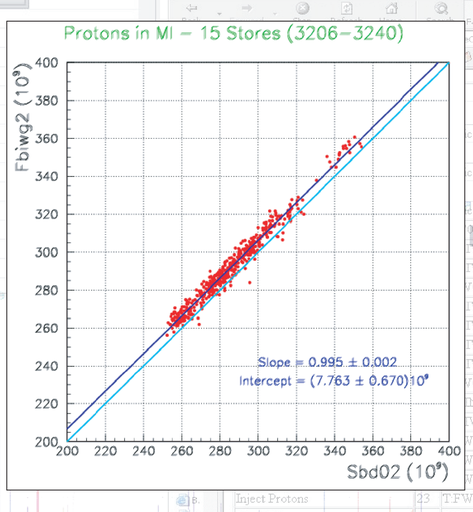


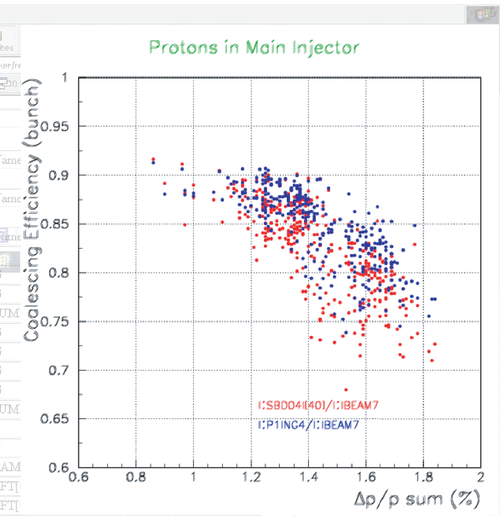


Instrument Calibration, M. I. Studies

The Main Injector beam intensities are measured by three devices. In the 1st plot, we compare the Fast Bunch Integrator(FBI) to the Sampled Bunch Display(SBD) , measured just after acceleration. (No DC beam left!)
In the 2nd plot, on the right side, the coalescing efficiency is shown vs the momentum spread, showing a significant drop if the longitudinal emittance is too large.

Courtesy of K. Gounder

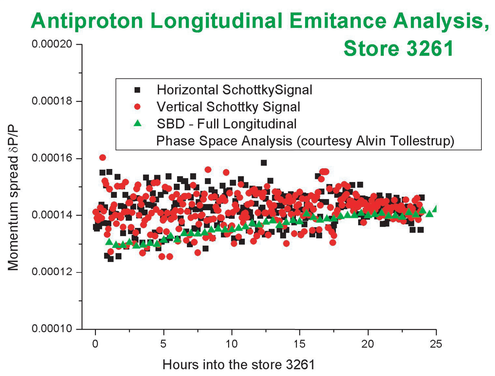


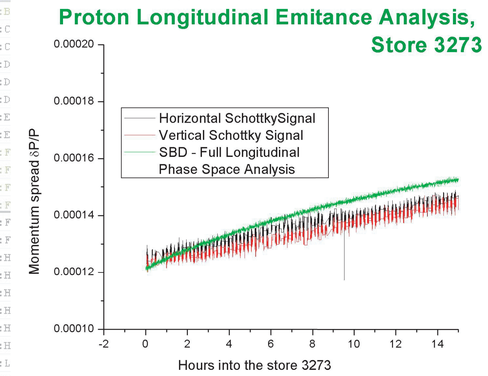


Recent Tevatron Instrumentation Upgrade: SBD and 1.7 GHz Schottky

The longitudinal emittance matters given the restricted dynamical aperture of the Tevatron for beams on the helices. Two independent devices measure the momentum spread : the 2 GHz SBD analyzes the pulse shape and reconstructs the longitudinal phase space for a stationary bucket. From this, we can extract the r.m.s. momentum spread for each bunch, in real time.

The 1.7 GHz Schottky sees the betatron sidebands quite clearly, allowing us to determine the tune, chromaticity and momentum spread. (In principle, one could also extract the transverse emittance, if the signal amplification is stable and well calibrated). This simple analysis compares the momentum spread, averaged over all bunches, using these two methods. When the Schottky signal is strong enough - after a few hours into the store- good agreement (~5 to 7%) is reached.



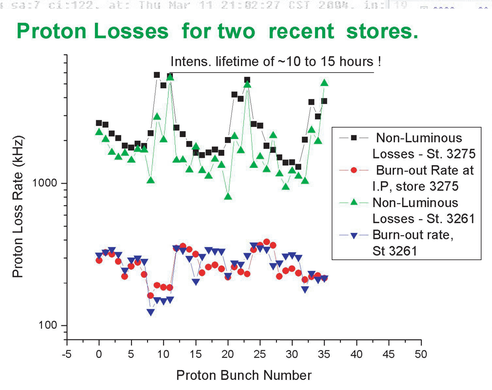


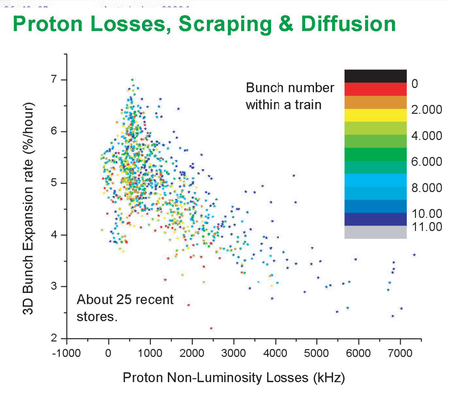
The 1.7 GHz Schottky measurement errors for antiproton are larger than those for proton, because the antiproton signal is weaker (It has both smaller emittance and beam intensity). In addition, the growth rates are different.

Courtesy of A. Tollestrup

Tevatron Beam Lifetime Analysis : No democracy among proton bunches!

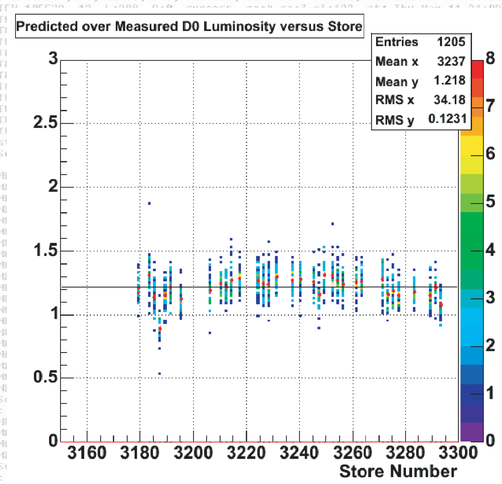
The integrated luminosity in a given store depends on the antiproton and proton beam lifetime. The contribution of proton lifetime to the luminosity lifetime is relatively small (typical proton lifetime is greater than 50 hours, while the luminosity lifetime is ~ 9 hours, at the beginning of the store) - for now! However, it is worth noting that (i) the burn-rate due to HEP collisions at the I.R. is a small component and (ii) the loss rate is not uniform at all along the bunch train, even though the proton bunch transverse and longitudinal emittances are fairly uniform at injection. This has been observed for many stores.
This loss is in fact consistent with scraping. We now look at the 3D Cartesian relative expansion rate of the proton bunch sizes observed with the Sync. Light and the SBD: Short-lived bunches tend to have a bunch-size growth rate less (by a factor 2 to 3) than the growth rate predicted by Intra Beam Scattering.

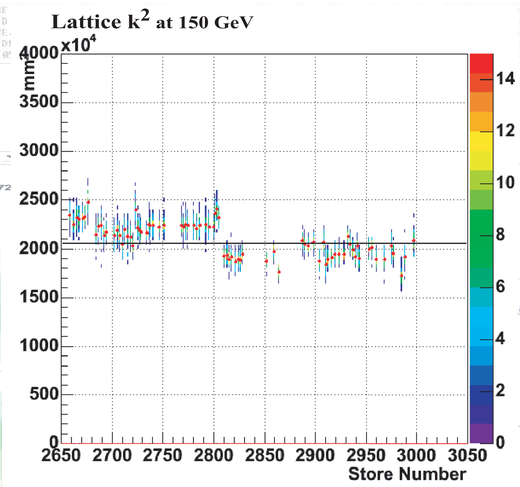




The correlation shown on the plot of the right side is a strong indication that we have both diffusion and scraping. Further work is on-going to characterize these mechanisms, including beam-beam effects.

Luminosity, bunch intensities & Emittance Studies at the Tevatron Collider





The luminosity can be calculated from bunch intensities, emittances and lattice parameters at the I.P.'s, and compared to the measured luminosity, based on a know cross-section. This is shown on the top plot where this comparison (ratio predicted over measured, at D0) agrees at the 10 to 20% level.

Improving the precision of such measurements strengthens our understanding of the machine. The horizontal beam width are measured at E11 and E17 by the flying wires. They are a function of the transverse emittance, the momentum spread and the lattice function β and the dispersion D at the two locations. The beam dependent quantities can be taken out by computing the combined lattice function

$$k^2 = (\sigma_{17}^2 - (\beta_{17}/\beta_{11})\,\sigma_{11}^2)/(\delta P/P)^2 = D_{17}^2 - (\beta_{17}/\beta_{11})D_{11}^2$$

A change in this k^2 value is an indication of a change in the lattice in the E sector. This analysis is done for each bunch, for numerous stores: these plots are 2D histograms where the color is mapped to the number of bunches in a given bin.

Courtesy of K. Genser