Overview of Current Performance and Plan for FY03

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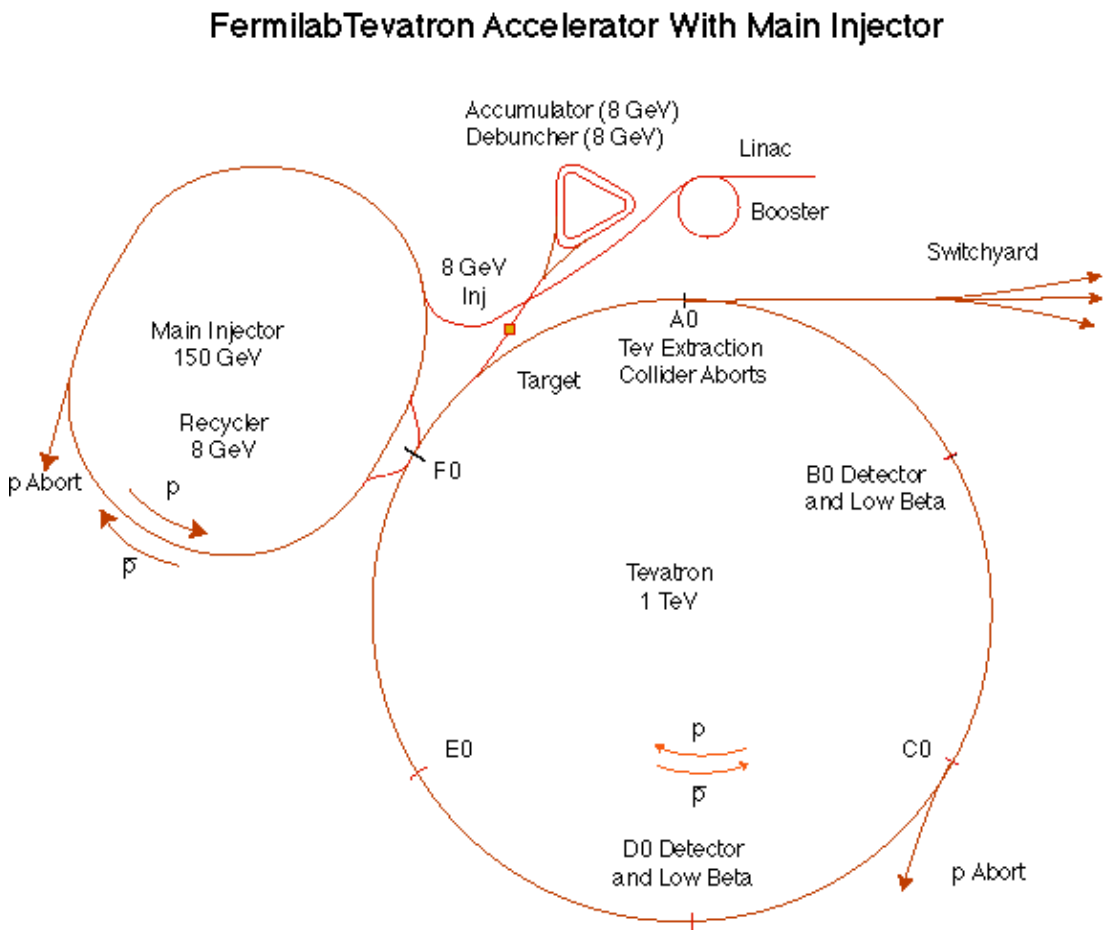
2/4/03 AAC Review

Accelerator Complex

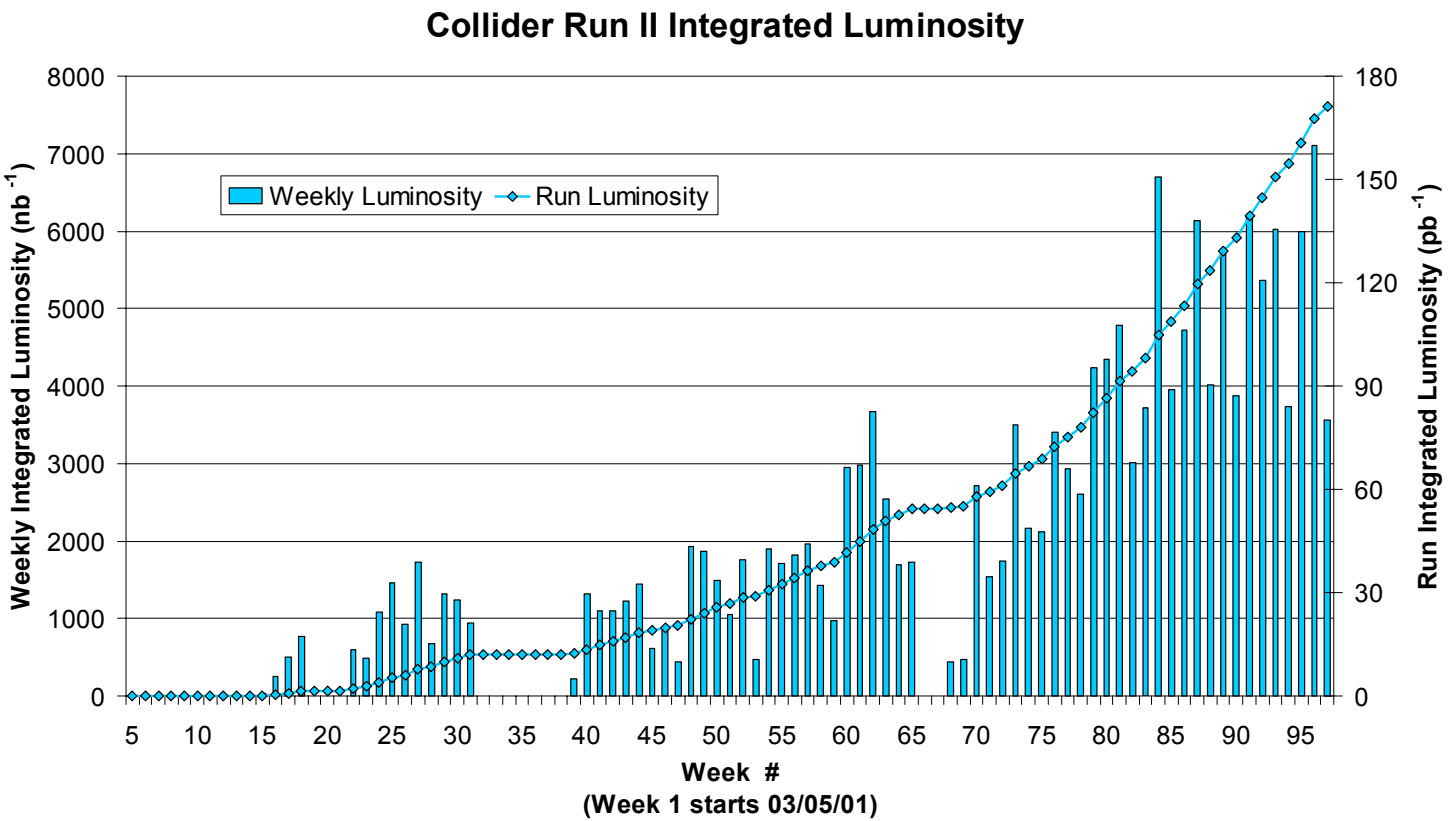


Operating Scenario

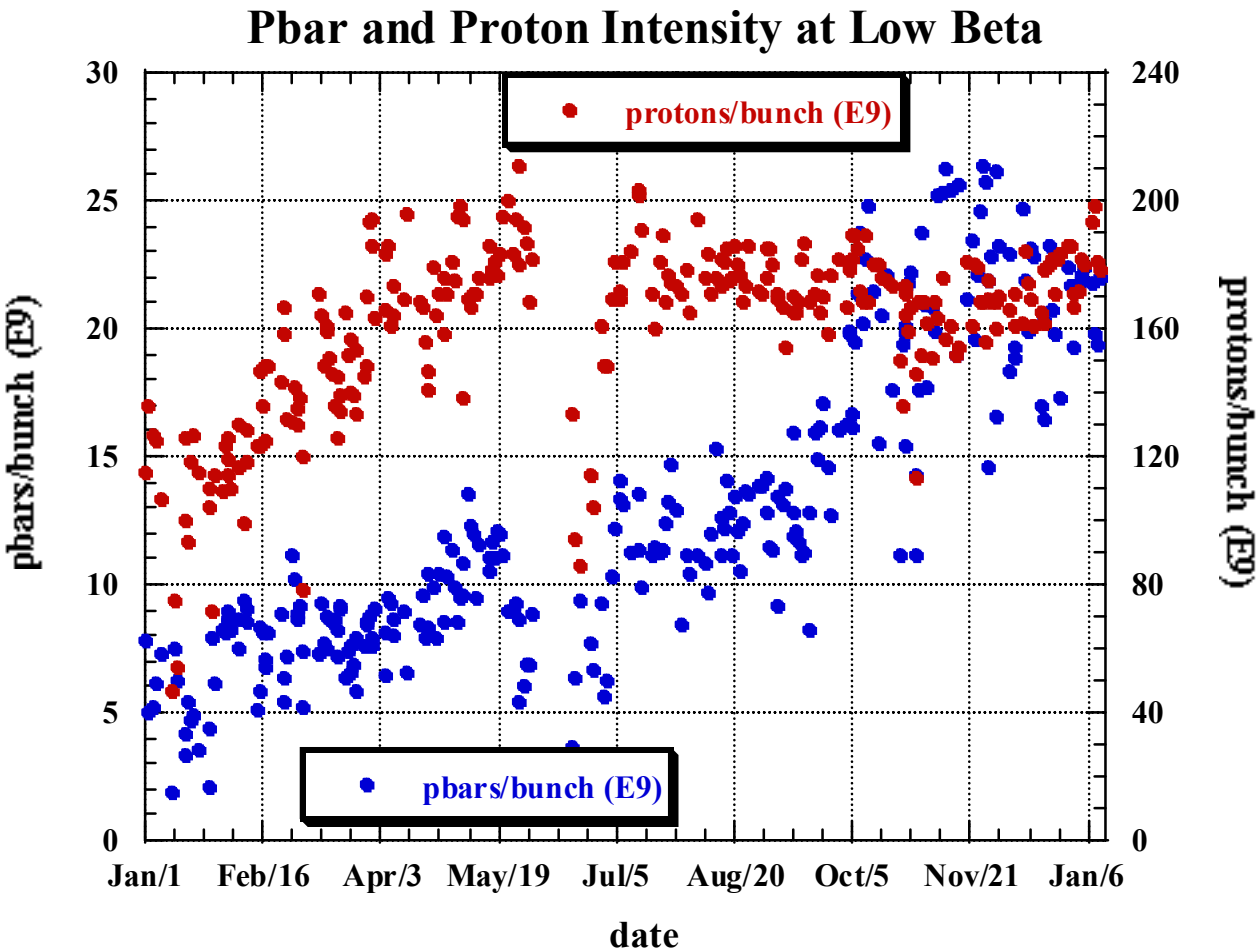
Antiproton Production: Every ~2.2 seconds a single batch of 84 proton bunches is extracted from the Booster and accelerated from 8 GeV to 120 GeV in the Main Injector. This beam is then extracted and targeted on the Antiproton Production Target. 8 GeV antiprotons from the target are collected and cooled in the Debuncher and then stored in the Accumulator stack. Antiproton production takes place continually during Collider stores.

A Collider shot is the process of loading protons and antiprotons into the Tevatron for a store. A batch of 7 proton bunches is injected into the Main Injector and accelerated to 150 GeV. These 7 bunches are then coalesced into a single bunch and injected into the Tevatron. This is repeated 36 times. The helix is opened in the Tevatron so that the protons and antiprotons circulate on separate orbits and do not collide. Then 4 batches of ~5-10 bunches of antiprotons is extracted from the Accumulator stack and injected into the Main Injector. These are accelerated to 150 GeV, coalesced into 4 bunches separated by 396 nsec, and then injected into the Tevatron. This process is repeated 9 times. When all 36 proton and 36 antiproton bunches are loaded into the Tevatron, the beam is accelerated to 980 GeV, and the low beta squeeze is initiated. In the low beta squeeze quadrupole currents and the helical orbits are changed so that the transverse beam size is reduced at the Interaction Regions (D0 and B0) and the protons and antiprotons are brought into collision there. A typical store lasts ~18 hours.

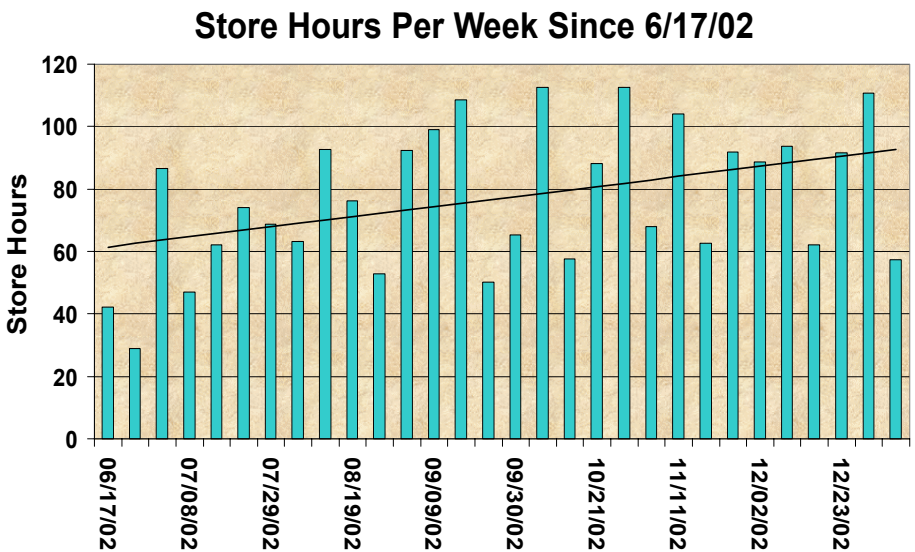
Integrated Luminosity History

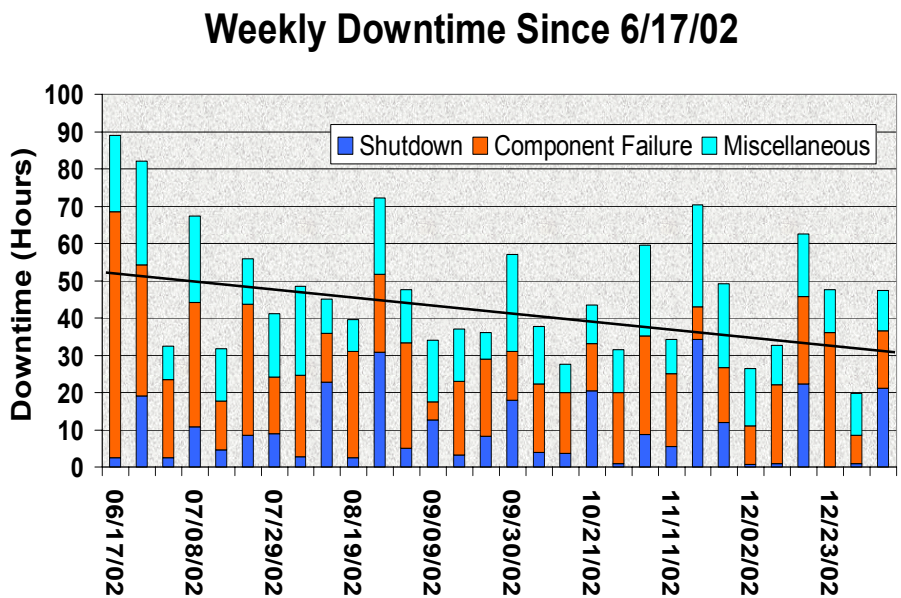


Peak Intensity History



Weekly Performance



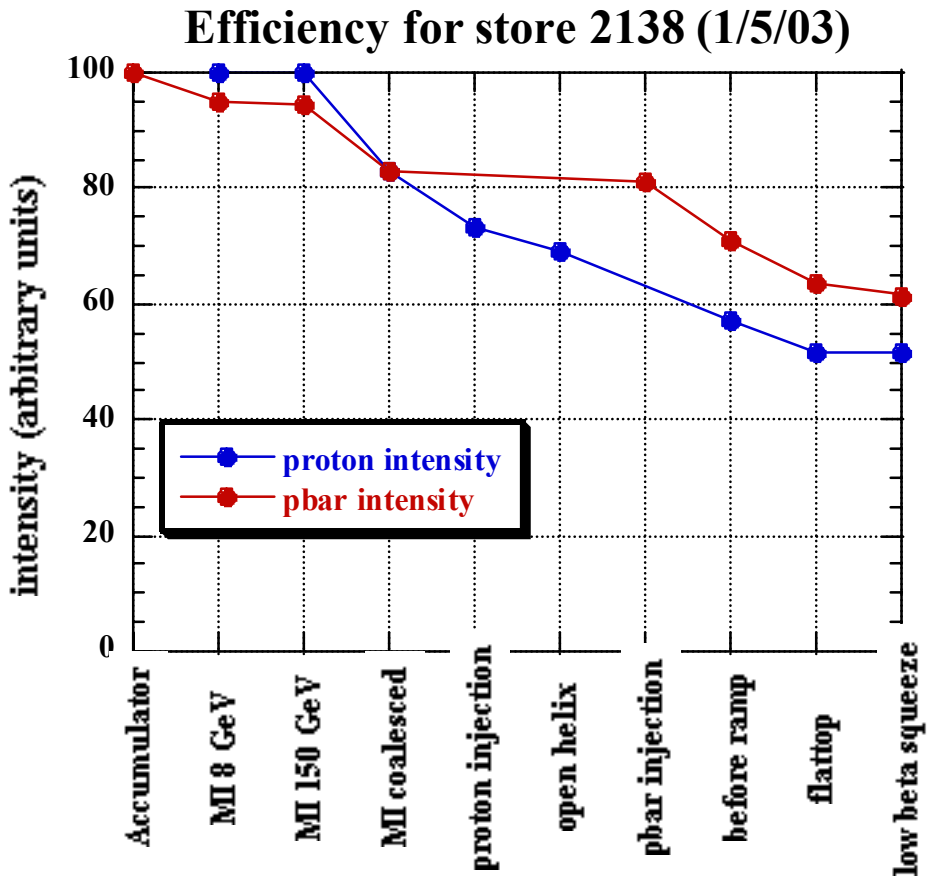


Status on Luminosity Parameters

	best parameters to date	highest luminosity to date	FY03 goals
max. antiproton stackrate (E10/hr)	13.1		18
max. antiproton stacksize (E10/hr)	213	167	200
pbar xfer eff.	.76	.60	.80
pbars/bunch at low beta (E9)	26.4	25.0	31.0
protons/bunch at low beta (E9)	211	163	240
emit. at low beta (π-mm-mrad) (average of p, pbar)	12.1	16.5	17.5
peak luminosity (E31 $cm^{-2}sec^{-1}$)		3.7	6.6

Intensity

- **Booster can produce adequate # protons for Tevatron FY03 intensity goals**
- **Accumulator can produce (almost) adequate # antiprotons for FY03 goals**
- **Emittance growth produces poor efficiencies**



Emittance (1)

- **Caveat: There are uncertainties in following numbers due to instrumentation errors and uncertainties in deducing phase space quantities from measured quantities.**

- **Proton longitudinal emittance:**
  - **Booster can produce <.15 eV-sec bunches at required intensity (5 dipole mode dampers are effective in controlling coupled bunch instabilities)**
  - **However, to control longitudinal instability in the MI the Booster emittance is intentionally blown up to ~.3 eV-sec/bunch (7 bunches)**
  - **After coalescing in the MI this is ~3.5 eV-sec (this is what Tevatron sees @ 150 GeV)**
  - **RMS bunch length at low beta is ~2 nsec (~4 eV-sec)**

Emittance (2)

- **Antiproton longitudinal emittance:**
  - **Accumulator core is kept at 25 eV-sec during shots, independent of stack size. This allows for extracting 90% of the core with …**
  - **extracted emittance of .8 eV-sec – 2.5 eV-sec /bunch with an average of ~1.25 eV-sec**
  - **MI measures ~1.5 eV-sec before coalescing, ~3.0 eV-sec after coalescing**
  - **Tev measures ~3.5 eV-sec @ 150 GeV, ~3.5 – 4 eV-sec at low beta**
- **Proton transverse emittance:**
  - **At Booster intensity of 4.2E12/batch, ε_H = 17 π-mm-mrad, ε_V = 14 π-mm-mrad @ 8 GeV**
  - **Coalesced beam @ 150 GeV in MI is ε_H = ~19 π-mm-mrad, ε_V = ~24 π-mm-mrad (large vertical emittance blowup may be instrumentation problem)**
  - **Tevatron measures ε_H = ~20-25 π-mm-mrad, ε_V = ~25 π-mm-mrad @ injection**
  - **"Calculated" emittance at low beta is ~20 π-mm-mrad. "Calculated" emittance uses measured luminosity, measured intensity, assumed bunch length factor of .6 and gives an estimate of average proton and pbar vertical and horizontal emittance – accuracy is ~25%**

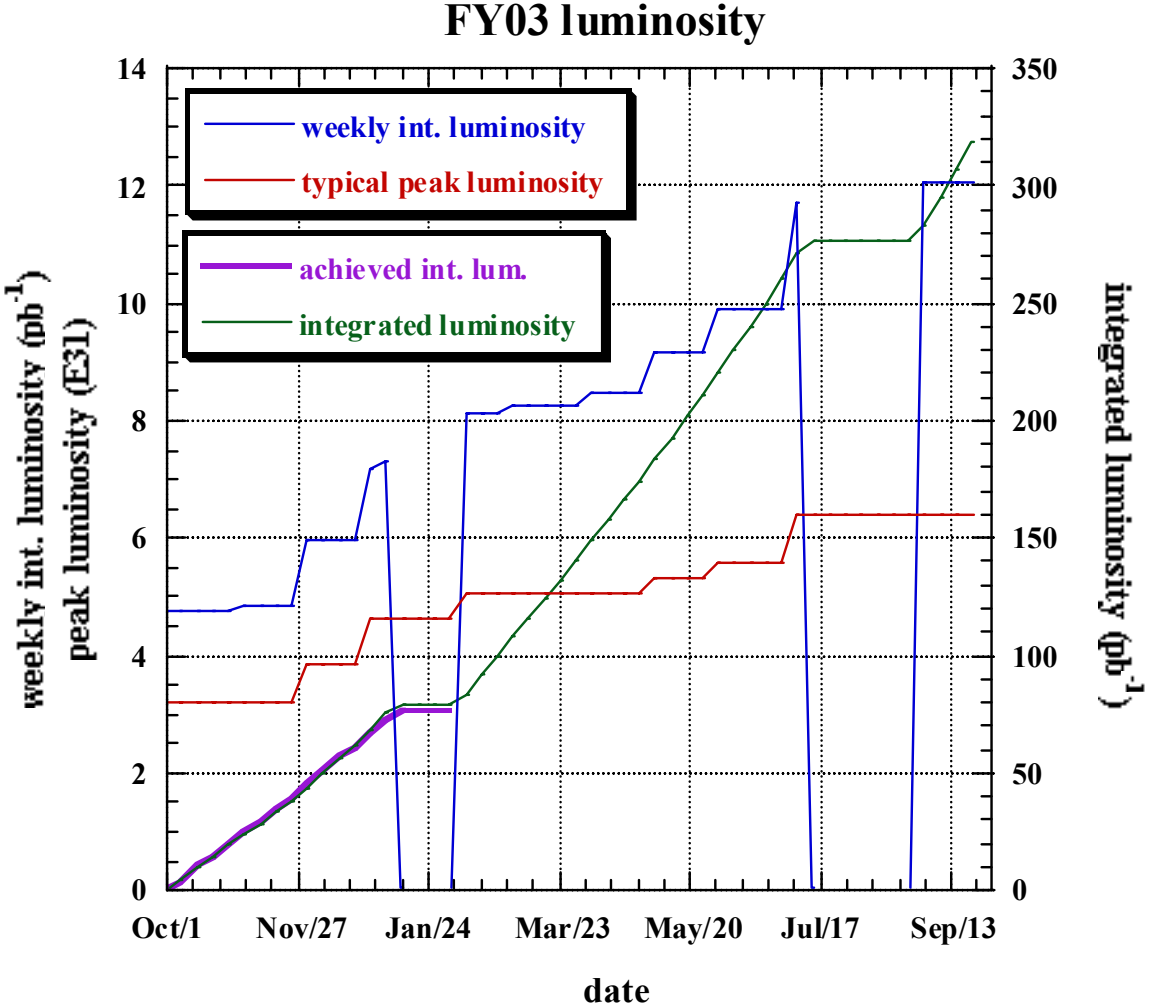
Emittance (3)

- **Antiproton transverse emittance:**
  - **Core transverse emittance grows linearly with stack size. $\varepsilon_{average}$ = 6 π-mm-mrad @ 140mA**
  - **At 8 GeV in MI, ε_H = 13 π-mm-mrad, ε_V = 10 π-mm-mrad, becoming ε_H = 14 π-mm-mrad, ε_V = 11 π-mm-mrad after coalescing**
  - **Tevatron measures $\varepsilon_H \sim 25$ π-mm-mrad, $\varepsilon_V \sim 21$ π-mm-mrad @ 150 GeV**
  - **RMS bunch length at low beta is ~2 nsec (~4 eV-sec)**

Agenda for FY03

- **3 week shutdown in January**
  - **C0 Lambertson removal; Recycler vacuum upgrades; Tevatron vacuum; CDF shielding; ….**
- **February to late-July**
  - **deliver luminosity; routine pbar shots to Recycler; up to 5 shifts/week dedicated studies; minimize shutdown days; …**
- **6 week shutdown in July**
  - **Recycler vacuum; e-cooling civil construction; A0 modifications; Tevatron collimators; NUMI installation work; (full scope of work not yet determined)….**
- **Continued running in Fall**
  - **same as Feb. - July**

Integrated Luminosity Performance and "Stretch" Goal for FY03



Critical Projects for Luminosity

- **A150/P150 beamlines – 20% in peak luminosity by 12/1/02** (missed)

- The original scope of the work -- reduction of injection oscillations and matching of beamlines has been done.
- This was thought to be the major source of the problem (emittance blowup), but this turns out not to be the case.
- Beam studies and calculations underway are aimed at understanding coupling and beam-beam effects in Tevatron as a source of emittance blowup.
- Progress possibly limited by lack of beam study time.

- **Tevatron transverse dampers – 20% in peak luminosity by 1/1/03** (missed)

- Transverse dampers have been completed.
- Dampers used at 150 GeV with positive effect – Tevatron can run with lower chromaticity @ 150 GeV.
- Dampers are not used on the ramp and squeeze because excessive coupling causes the dampers to anti-damp out-of-plane motion.
- ➔ proton intensity has not been increased, which was intended to be the source of the 20% improvement in luminosity.
- Progress possibly limited by lack of beam study time.
- The removal of the C0 Lambertsons will reduce transverse impedance, and that may make the beam more stable so that possibly the proton intensity can increased after the shutdown anyway!

Critical Projects (continued)

- **C0 Lambertson replacement – 10% in peak luminosity by 3/1/03**
  - Completed in January shutdown. Commissioning in progress.
- **Accumulator bands 2&3 equalizers – 5% in peak luminosity by 5/1/03**
  - Installed during the January shutdown. Will be commissioned in early February.
  - Expect 7% decrease in Accumulator core emittances during shots to Tevatron.
- **AP3 beamline – 5% in peak luminosity by 6/1/03**
  - Found a plastic magnet cap in the beamline in January shutdown (been there for ~20 years). Should give ~1-2π emittance reduction.
  - Future efforts will be directed toward 8 GeV transfer reliability and faster shot setups.
- **MI longitudinal dampers – 15% in peak luminosity by 7/1/03**
  - Cavity fabrication and FPGA programming is in progress.
  - High power amplifiers have been purchased.

Critical Projects (continued)

- **Reliability – 1.5%/month in integrated luminosity over 9 months**

- Projects are getting done.

- VFC replacement is 70% complete; cryo wet engine rebuild is complete.

- # store hours/week has been better than anticipated (averaging 86 hrs/week since 10/1/02)-- partly because of reduced study shifts, partly from less downtime.

- **Stacking upgrades – 1.5%/month in integrated luminosity over 9 months**

- Major emphasis has been on Debuncher momentum cooling, stacktail system, and yield into Debuncher (AP2 and target).

- No real stacking improvements since mid-November when peak stacking rate of 13.1 mA/hr was achieved.

- Since then, MI intensity has been lowered on stacking cycles to accommodate miniBooNE operation and to help keep Booster losses tolerable.

- Limited by study time.

Other Projects

- **Tevatron**

vacuum improvements; new Schottky detector; new (or modified) BPM's; A0 lattice modification; injection dampers; tune monitoring and feedback; collimators; TEL upgrade; instrumentation improvements; continuing beam studies and calculations on beam-beam and beam stability; ....

- **Main Injector**

continued coalescing improvements; continued beam-loading compensation improvements; instrumentation improvements; new BPM's; 2.5 MHz acceleration; ....

- **Pbar Source**

flying wires; quadrupole pickup; 1-q transverse damper; ....

- **Booster**

new extraction Lambertson; new collimators; ramped correctors; ....

- **Recycler**

vacuum improvements; new BPM's; lots of machine studies; instrumentation improvements; ....

Summary

- **Factor of 3.7 increase in peak luminosity in CY02**
- **Increased stacking rate and Accumulator stack size**
- **Significant improvement in Recycler operations**
- **Reduced downtime**
- **Progress on instrumentation**
- **Improvements in theoretical understanding of issues**

- **Plan of action for continuing improvements in luminosity**