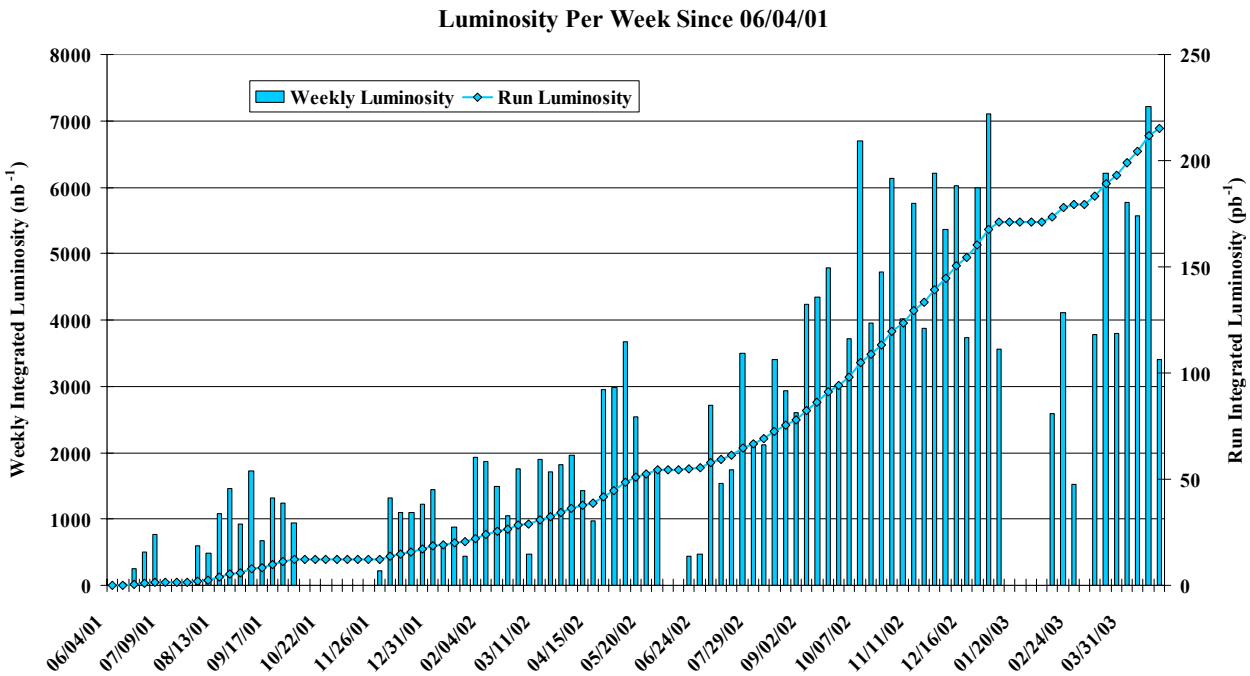
Run II Status

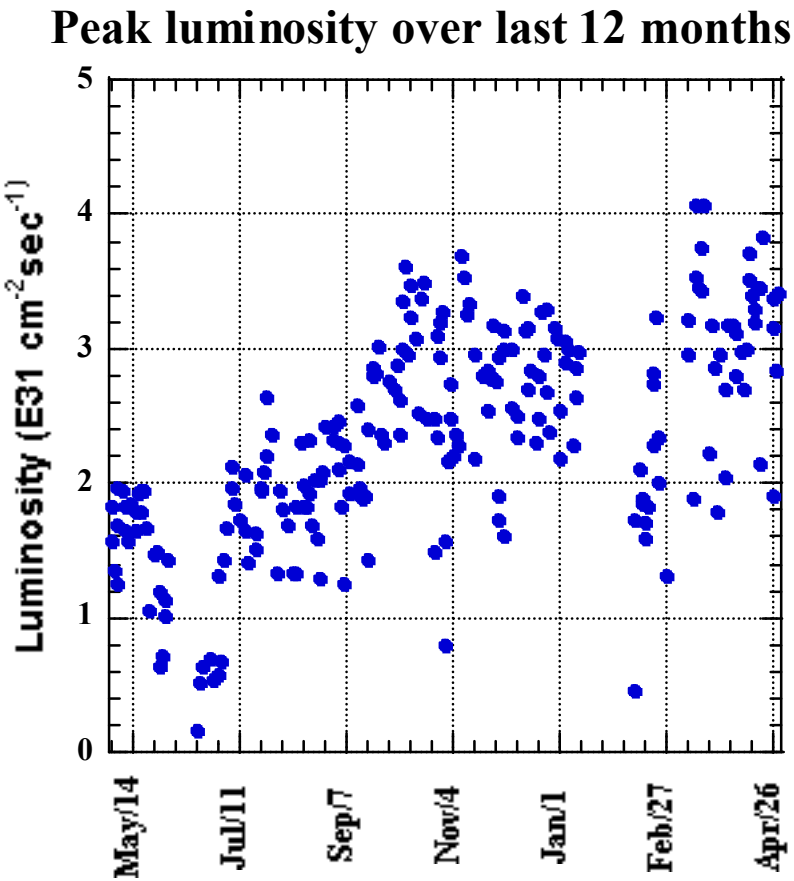
Mike Church
FNAL
5/05/03 Run II Director's Review

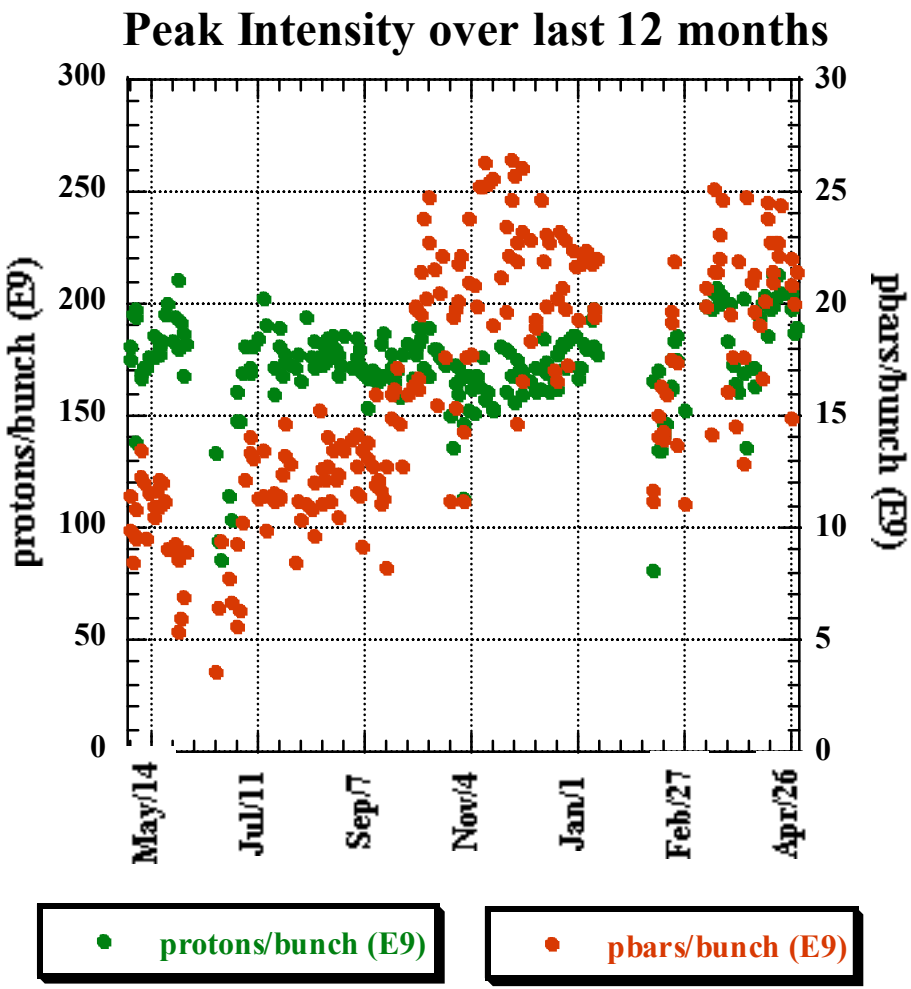
Integrated Luminosity History



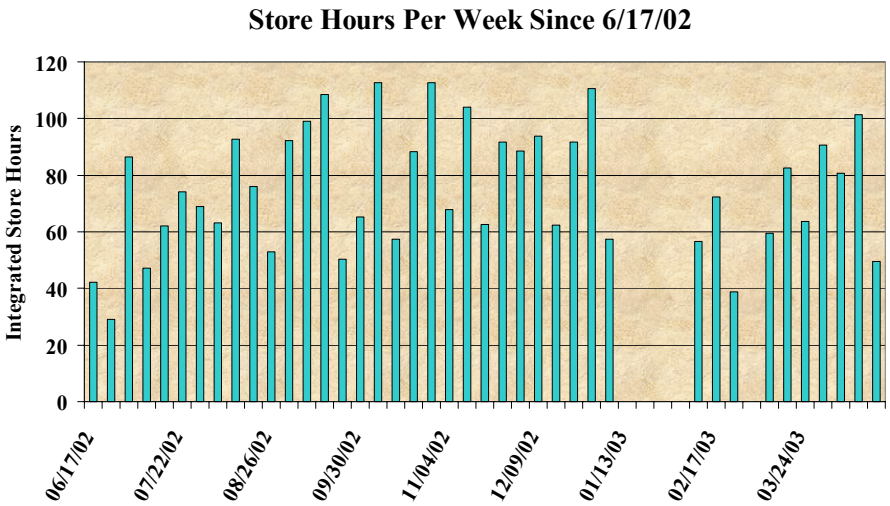
(Through week of 4/21/03)

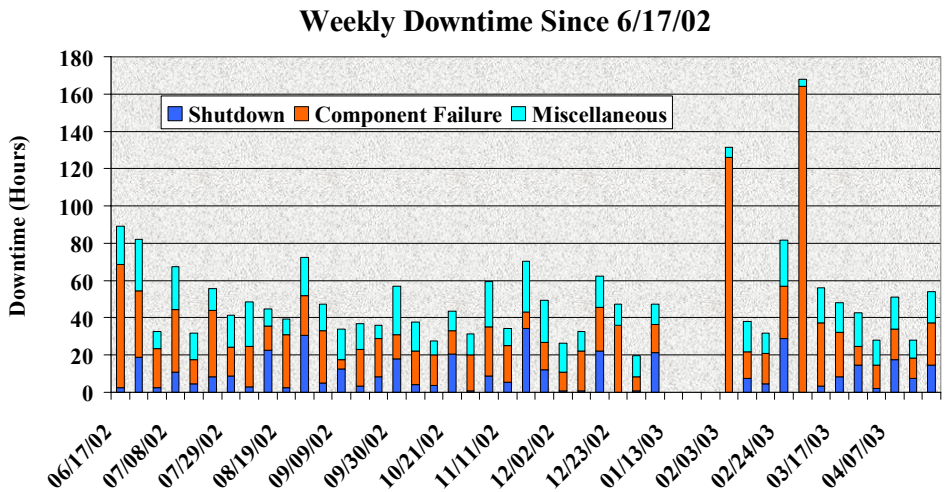
Peak Luminosity and Intensity History (Through 4/30/03)





Weekly Performance



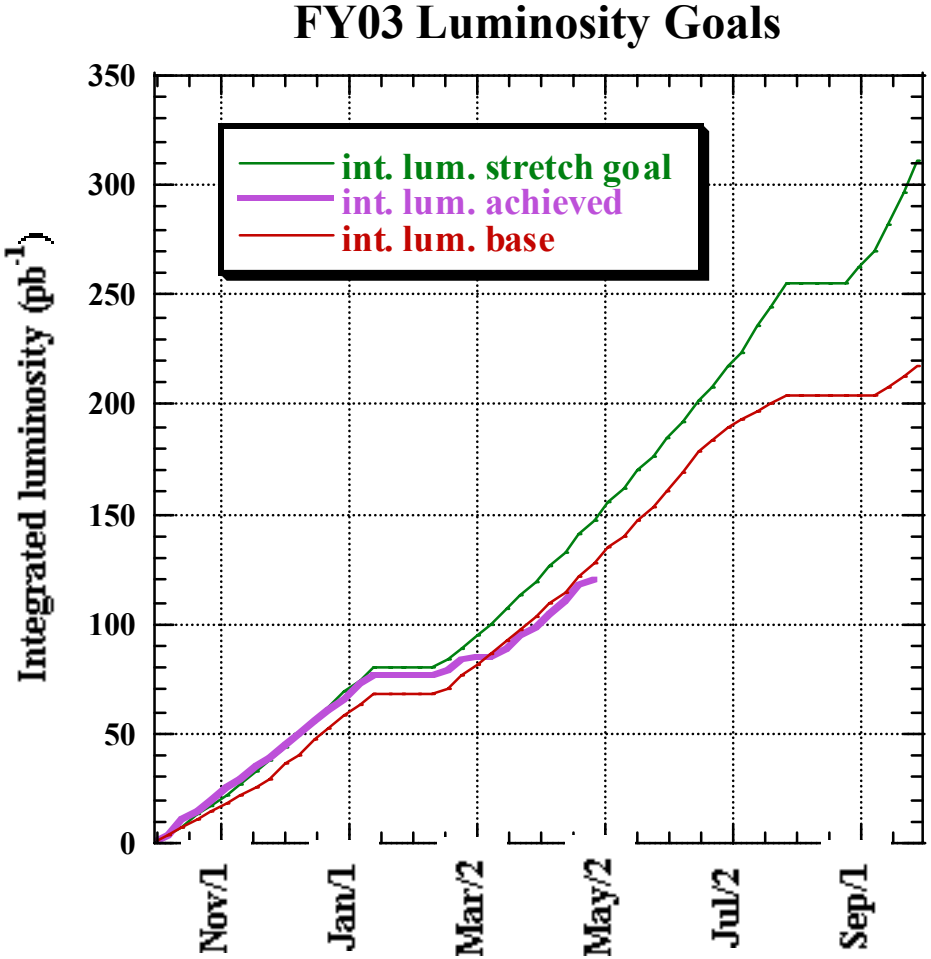


(Through week of 4/21/03)

Status on Luminosity Parameters

	best luminosity store 1 year ago	highest luminosity store to date	FY03 stretch goals ("routinely")
max. antiproton stackrate (E10/hr)	10.2	13.1	18
antiproton stacksize (E10)	113	143	200
pbar xfer eff.	.39	.66	.80
pbars/bunch at low beta (E9)	11.4	24.6	31.0
protons/bunch at low beta (E9)	181	196	240
peak luminosity (E31 $cm^{-2}sec^{-1}$)	1.83	4.23	6.6

Integrated Luminosity Performance and "Stretch" Goal for FY03



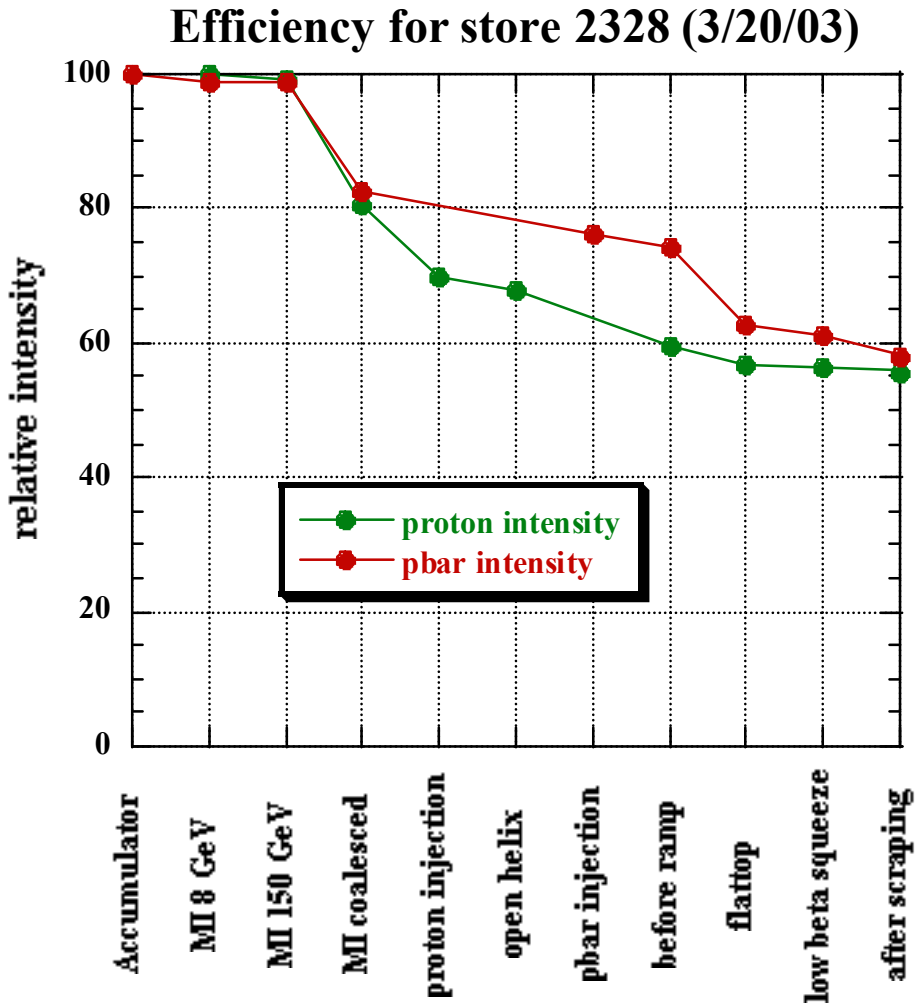
stretch goal (320 pb^{-1})

base goal (200 pb^{-1})

(Through week of 4/21/03)

Beam 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



Proton Longitudinal Emittance

- Booster can produce <.15 eV-sec bunches at required intensity (6 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 ~4.0 eV-sec.

  This contributes to poor coalescing, poor MI→Tev transfer efficiency, poor beam lifetime @ 150 GeV in the Tevatron, and poor acceleration efficiency

- At low beta longitudinal emittance is ~4+ eV-sec. Goal is 3 eV-sec.

-Longitudinal dampers will be installed in the MI in July.

-Beam loading compensation for 53 MHz RF cavities is being commissioned on the MI ramp

-"Selective" longitudinal fuzzer being developed for Booster

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 ~1.1 eV-sec @ 8 GeV

- MI measures ~1.5 eV-sec before coalescing (@150 GeV), ~3.0 eV-sec after coalescing

- Tevatron measures ~3.5 eV-sec @ 150 GeV.

- Tevatron measures ~3.5 – 4 eV-sec at low beta. Goal is 3 eV-sec.

- No single cure: Small emittance blowups during unstacking, transfers, acceleration and coalescing:

1) Feedforward beamloading compensation on the ramp on the 53 MHz cavities in the MI should help.

2) Higher voltage on Accumulator unstacking cavity should improve efficiency (fewer bunches to coalesce)

3) Long range beam-beam effects in the Tevatron may be contributing to emittance blowup??

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 = 17 π-mm-mrad
- Tevatron measures $\varepsilon_{average}$ = ~20-25 π-mm-mrad @ 150 GeV
- Tevatron emittance at low beta is ~20-25 π-mm-mrad. Goal is 20 π-mm-mrad.

-Again, no single cure:

1) Increased efficiencies may allow for lower initial transverse emittance (higher efficiency → fewer turns → lower emittance).

2) Injection dampers in MI and Tevatron will help. (1-2 π-mm-mrad per transfer)

3) Improved lattice match between MI and Tevatron will help.

4) Better vacuum in Tevatron will help. (long term project)

Antiproton Transverse Emittance

- Core transverse emittance grows linearly with stack size (this is the nature of stochastic cooling). $\varepsilon_{average}$ = 6 π-mm-mrad @ 150 mA

- At 8 GeV in MI, $\varepsilon_{average}$ = 8 π-mm-mrad, becoming $\varepsilon_{average}$ = 10 π-mm-mrad after coalescing

- Tevatron measures $\varepsilon_{average}$ ~ 20-25 π-mm-mrad @ 150 GeV and @ 980 GeV

Goal is 15 π-mm-mrad.

- **Major problem is the emittance blowup during the MI—>Tev transfer. Not understood, but under investigation.**

- **Improved helix in the Tevatron may also reduce pbar transverse emittance blowup(??)**

Agenda for FY03

- **3 week shutdown in January (complete)**
  - **C0 Lambertson removal; Recycler vacuum upgrades and instrumentation installation; Tevatron vacuum; CDF shielding; ….**
- **February to late-July**
  - **deliver luminosity; up to 5 shifts/week dedicated studies; minimize shutdown days; Tevatron requires ~1 shift/week of "maintenance"**
    (suffered 2 Tevatron magnet failures since shutdown)
- **6 week shutdown starting late July**
  - **Recycler vacuum; e-cooling civil construction; Tevatron F0 Lambertson modification; Tevatron collimator @A4; additional shielding for CDF detector; NUMI installation work; infrastructure maintenance (full scope of work not yet determined)….**
- **Continued running in Fall**
  - **same as February - July**

Critical Projects for Luminosity in FY03 (1)

- **A150/P150 beamlines**

- The original scope of the work -- reduction of injection oscillations and matching of beamlines to linear lattice has been ~completed.

- This was thought to be the major source of the problem (emittance blowup), but this does not seem 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.

- **Tevatron transverse dampers**

- Transverse damper installation is complete: dampers are used at 150 GeV with positive effect -- Tevatron can run with lower chromaticity @ 150 GeV with better lifetime.

-Transverse dampers are not yet used on the ramp and squeeze because excessive coupling causes the dampers to anti-damp out-of-plane motion (not understood).

- Injection dampers to be commissioned by July. Should reduce emittance growth by ~2 π-mm-mrad for pbars and protons.

- More studies required to understand interaction of dampers with coupling

Critical Projects (2)

- **C0 Lambertson replacement**

-Completed in January shutdown. New helix commissioning has started, but requires many study shifts (aperture scans, tune, coupling, chromaticity, feeddown corrections)

- The removal of the C0 Lambertsons has reduced transverse impedance, and has allowed the proton intensity to be increased since the January shutdown

- **Accumulator stochastic cooling bands 2&3 equalizers**

- Installed during the January shutdown.

-● **AP3 beamline**

- Found a plastic magnet cap in the beamline in January shutdown (been there for ~20 years).

- Beamline well-matched to MI lattice; injection oscillations contribute ~1 π-mm-mrad to emittance growth

- Future efforts will be directed toward 8 GeV transfer reliability and faster shot setups.

Critical Projects (3)

- **MI longitudinal dampers**

- Cavity fabrication and FPGA programming is in progress.

-High power amplifiers have been purchased. Beam studies in progress.

-Expect installation of new cavities in July

- **F0 Lambertson lamination shielding**

- Major source of transverse impedance in the Tevatron is now the F0 Lambertson magnets. Plan to shield the laminations during Summer shutdown. Should allow increase in proton intensity in Tevatron @ 150 GeV.

- **Reliability**

- VFC replacement is 95% complete; cryo wet engine rebuild is complete; compressor starter switch rebuild and cold compressor bearing replacement in progress

- Designing resonant abort kicker charging system to eliminate abort kicker prefires.

- New Tevatron magnet stands under fabrication

- Planning improved monitoring of Tevatron alignment

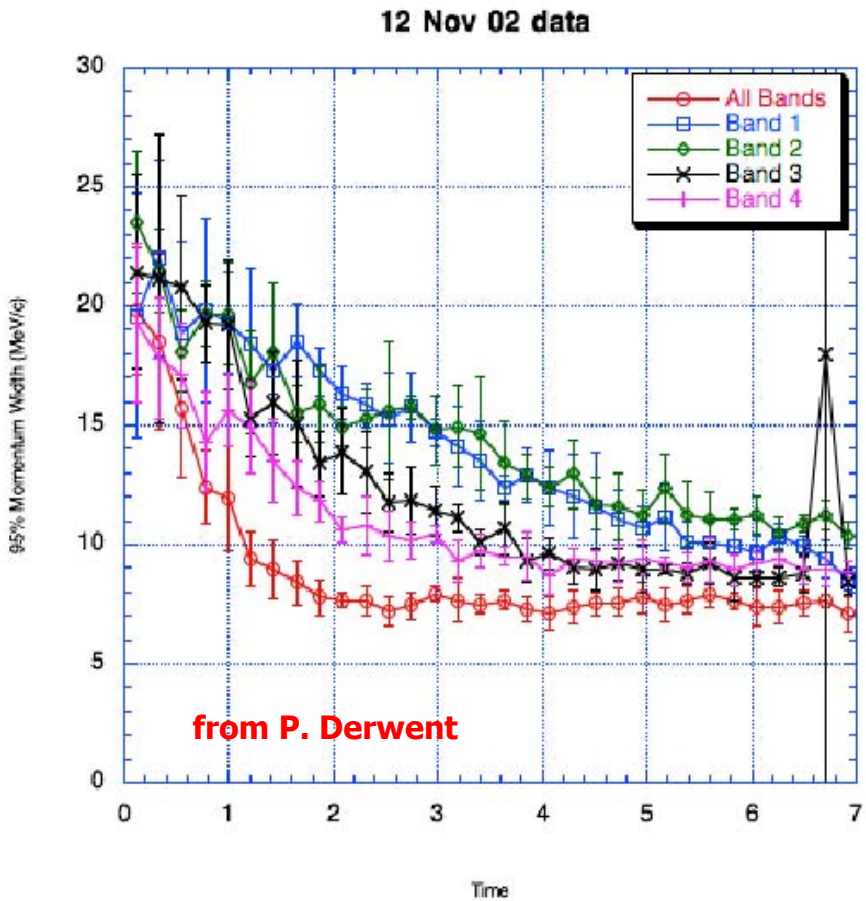
Critical Projects (4)

- **Stacking upgrades**

- Major emphasis has been on Debuncher momentum cooling, stacktail cooling 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.

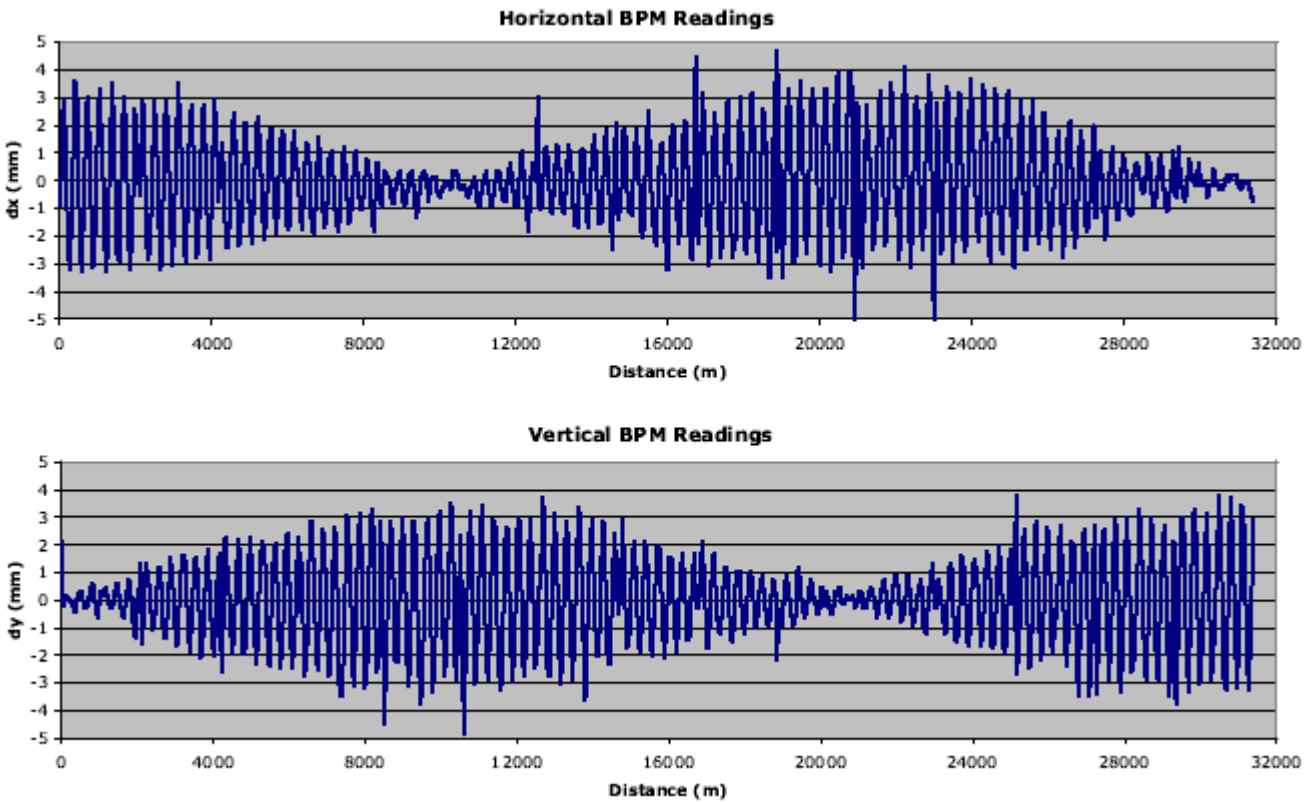
Debuncher momentum cooling



Tevatron coupling

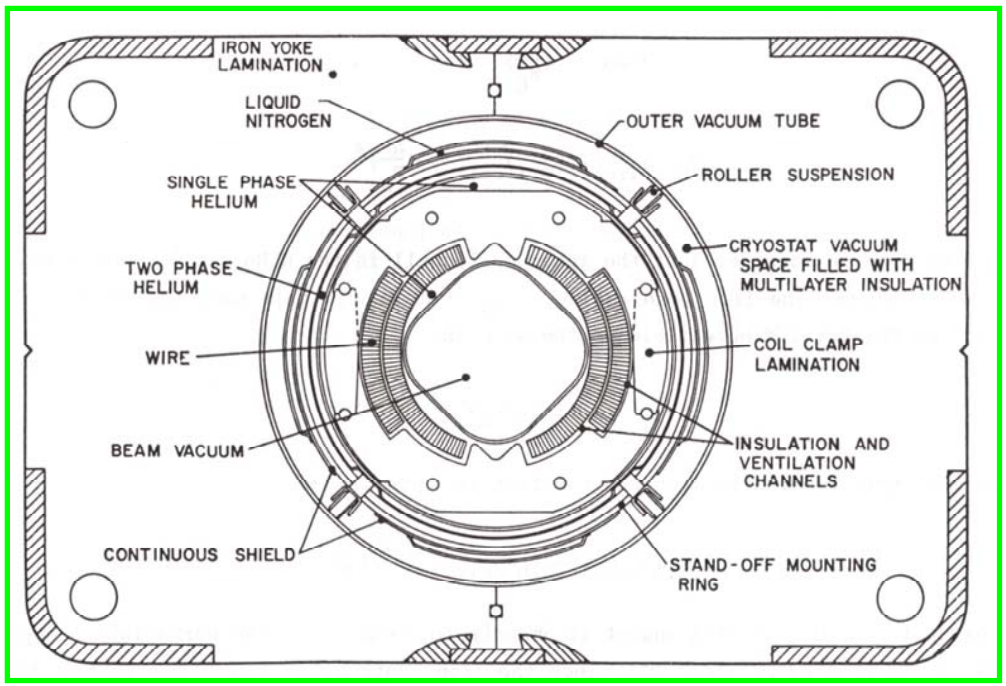
Data shows in-plane and out-of-plane difference orbits after single horizontal kick. Data is for 1st 5 turns in Tevatron.

(from M. Syphers)



Coupling in Tevatron is ~uniform around the ring and is consistent with ~1.5 units of a_1 per dipole. This is compensated by a distributed skew quad circuit of 42 elements.

Tevatron coupling (continued)

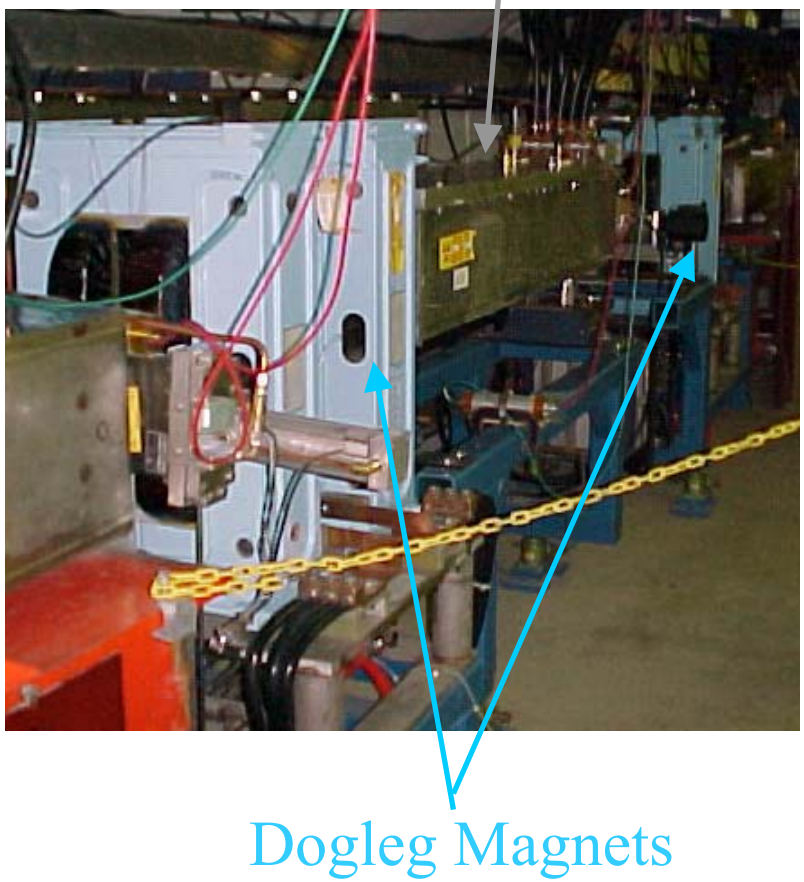


Tevatron dipole cross section (from P. Bauer)

Tevatron coil and cryostat assembly is held within the iron by 4 supports at 9 locations along the length of the magnet. Recent measurements of the "smart bolts" (upper supports) on 18 magnets in the tunnel, indicate that the coil assembly has sagged by ~2 mils from original. This is enough to produce ~1 unit of a1 per dipole.

In 1984, compensating skew quad circuit was running at ~2A. From 1995 compensating skew quad circuit has been running at ~24A (@ 800 GeV).

Booster Dogleg



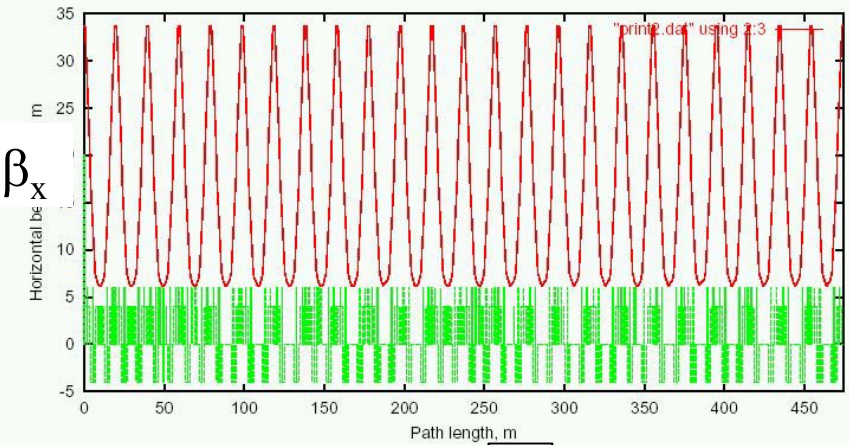
- Each of the two Booster extraction septa has a set of *vertical* dogleg magnets to steer the beam around it during acceleration.
- More powerful doglegs were installed in 1998 to reduce losses early in the cycle.
- These magnets have an edge focusing effect which distorts the *horizontal* injection lattice:
  - 50% increase in maximum β
  - 100% increase in maximum dispersion.
  - Harmonic contributions.
- Effect goes like I^2. Now tune to minimize.
- Recently got an unusual opportunity to explore potential improvements from fixing the problem.
- Working on schemes to reduce or remove problem.

(from E. Prebys)

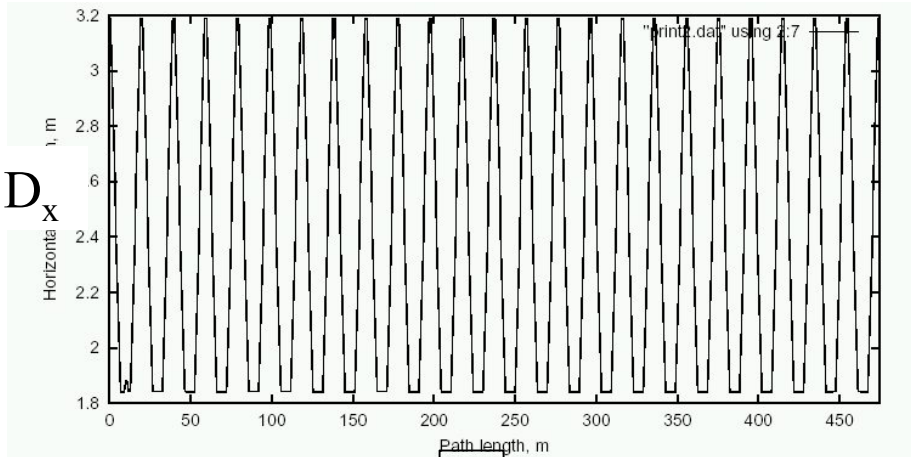
Booster Dogleg (continued)

Ideal Lattice

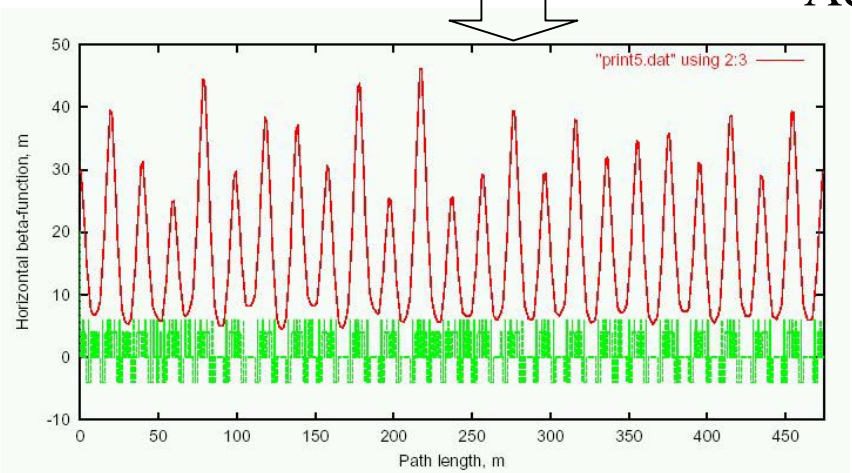
β_x



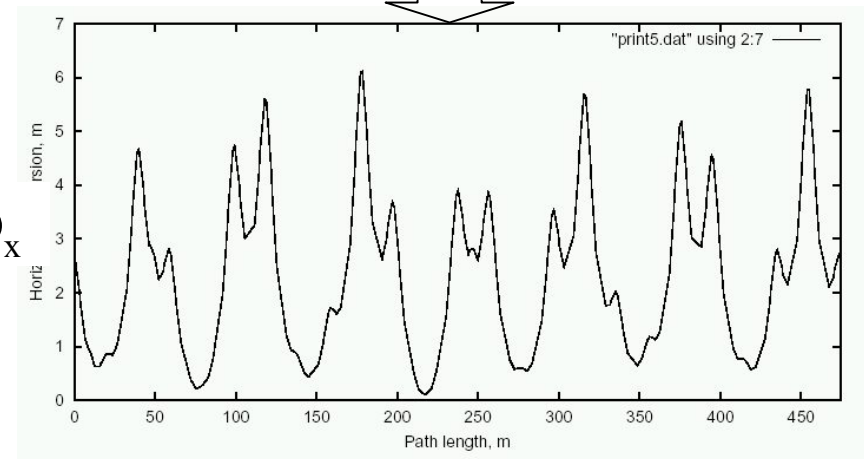
D_x



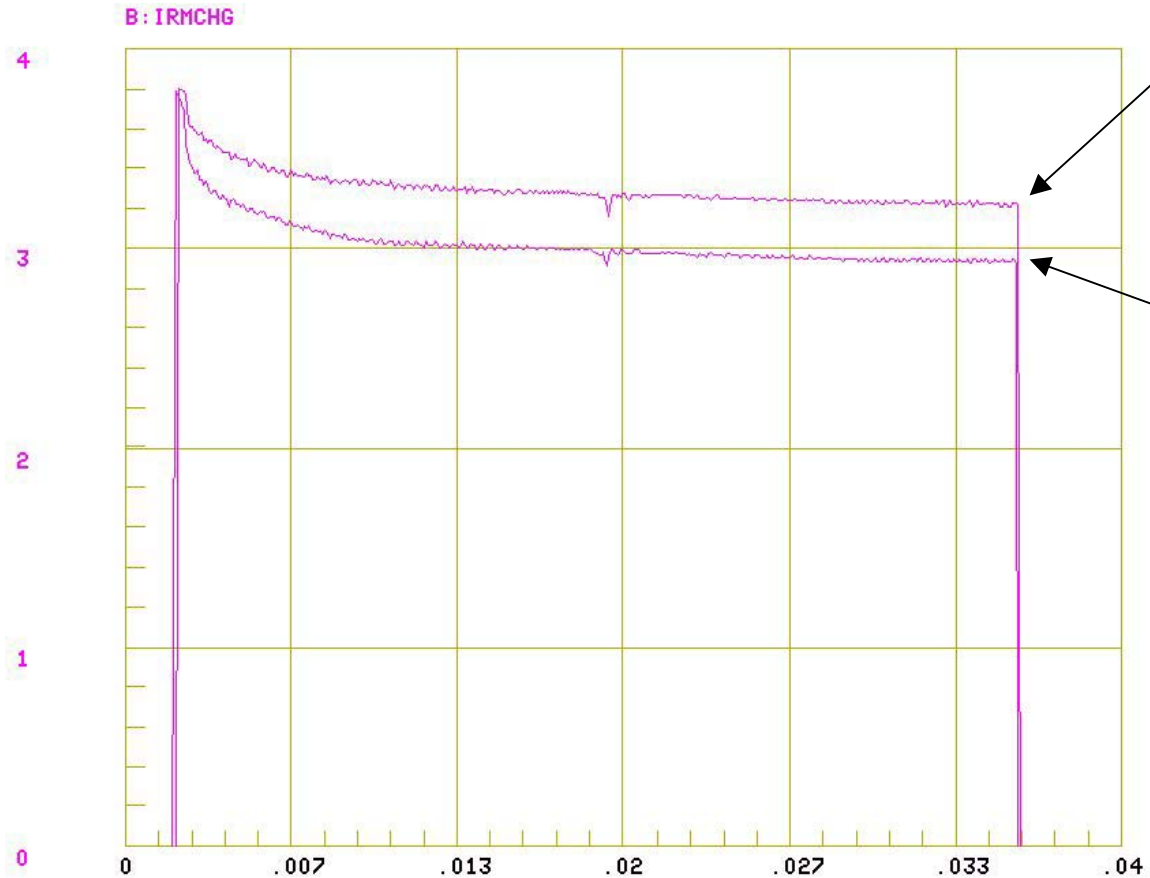
Add Doglegs



D_x



Booster Dogleg (continued)

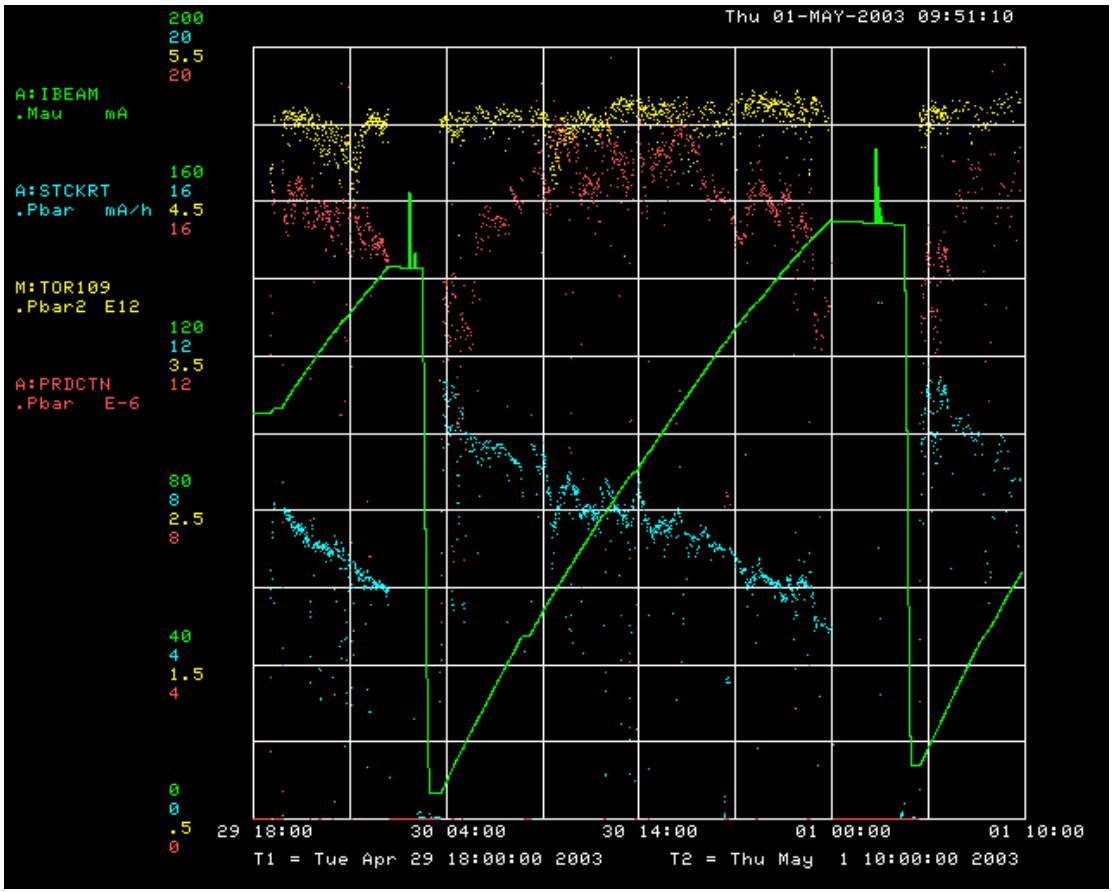


March 6, 7 turns, 1 dog

March 3, 7 turns, both dogs

(from E. Prebys)

Booster Performance



Recent stacking performance. Also providing >4E16 protons/hour to miniBooNE

Recycler Commissioning

- Prior to January shutdown beam lifetime was >100 hours, with equilibrium emittance of ~7 π-mm-mrad and ~75 eV-sec with 70E10 antiprotons.

- During the shutdown the number of ion pumps was doubled in ~3/4 of the ring, ~20% of the ring was baked, and additional instrumentation was added.

-Since the shutdown the beam lifetime has been ~3 times worse, and the emittance growth rate ~3 times faster. Contaminated vacuum is thought to be the culprit.

-Some instrumentation and beampipe will be removed and those sections will be rebaked in order to recover (at least) the previous vacuum.

-Stochastic cooling systems have been commissioned; transverse emittance monitor has been commissioned; beam line tuner has been commissioned

-New BPM system is being built and is scheduled for completion of installation by July.

-Ramped correctors have been commissioned – horizontal orbit distortions due to MI 120 GeV ramp have been reduced to <.3mm rms.

Summary

- **Factor of 2.4 increase in peak luminosity over last 12 months**
- **Factor of 3 increase in weekly integrated luminosity over last 12 months**
- **Increased stacking rate and Accumulator stack size**
- **Progress on instrumentation**
- **Improvements in theoretical understanding of issues**

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