Fermilab

Tevatron Progress: Operational, Instabilities, and Diagnostics Update

Fermilab Seminar
April 29, 2003

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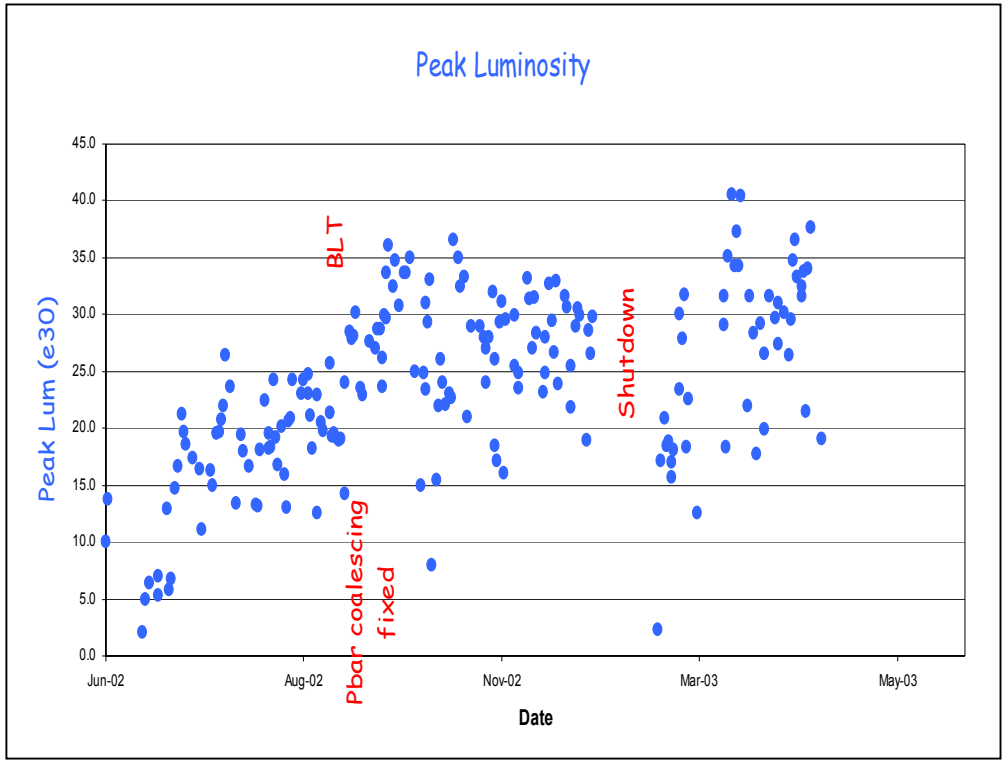
C. Y. Tan -- Instabilities
Jim Steimel -- Diagnostics

Luminosity Since June 2002



- 151 HEP stores
- 160 pb^{-1} to each detector
- Increase in luminosity from 15e30 to 40.5e30
- Run I record of 25.0e30 broken on 7/26/2002
- Run II record of 40.5e30 set on 3/20/2003

Goals and Current Performance

Parameter	Current Status	FY03 Goal	
Typical Luminosity	3.5e31	6.6e31	$cm^{-2}sec^{-1}$
Integrated Luminosity	6.0	12.0	pb^{-1}/week
Protons/bunch	200e9	240e9	
Antiprotons/bunch	22e9	31e9	

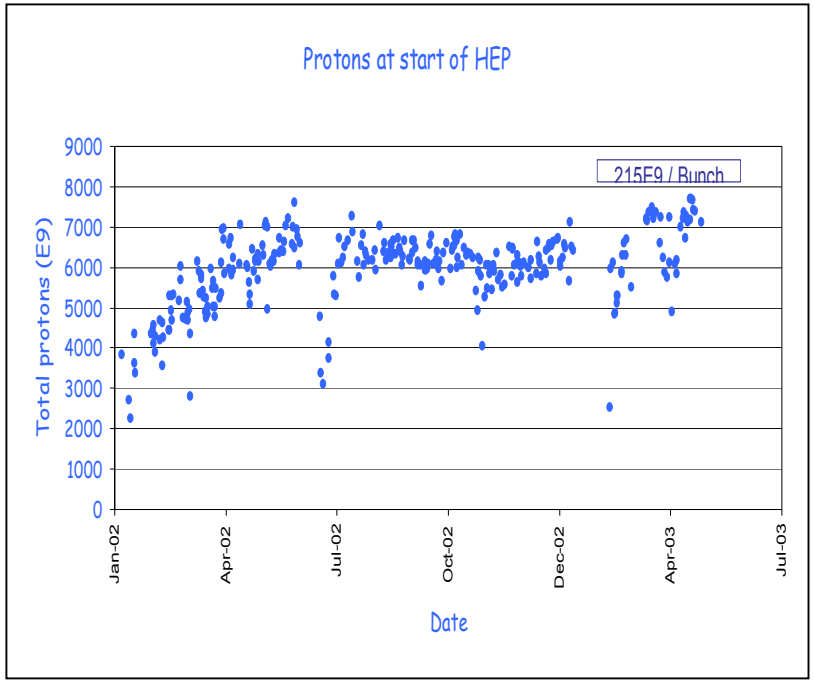
Higher intensity $\Rightarrow$ Fundamental physics limitations

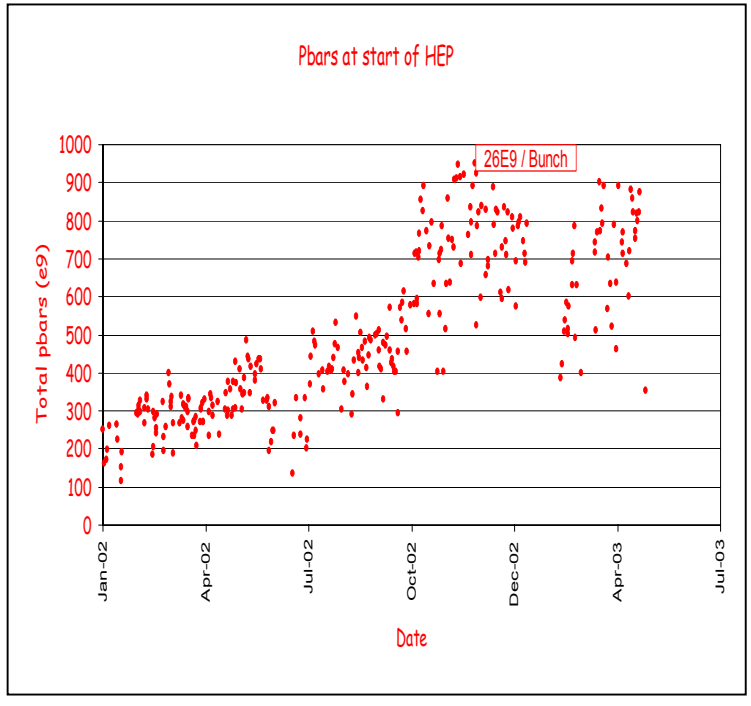
- Beam-Beam Effects
- Instabilities
- Beam Halo and Lifetimes

Understanding/Solving these issues requires …

- Stable Tevatron Lattice
- Diagnostics
- Study Time

Beam Intensities





Number of protons

Mostly steady

in the 200e9 range

Number of antiprotons

Increase factor of 2.5 Oct ⇒ March

from 9e9 ⇒ 22e9 per bunch

Tevatron Emittance

General comments on emittance blow-up from Flying Wire measurement**
(95%, normalized emittances):

- < 1π - 2π at proton injection
- ~ 5π - 6π at pbar injection
- < (negative) 2π - 3π protons at 150 (scraping)
- ~ (negative) 0π -3π pbars at 150 (scraping)
- 4π -7π blowup on ramp (prots and pbars)
- occasional instability, 5π – 50π, at 980 Gev

** There remains uncertainty of FW emittance measurements. (See later slides)

Reasons for $\mathcal{L}$-progress Since Jun'02

• "Shot lattice"	AA	x 1.40
• Pbar emittance at injection Tev/Lines		x 1.20
• Pbar coalescing improvement	MI	x 1.15
• Shoot from larger stacks		x 1.10
• Improved Tev Pbar efficiency		x 1.10
• More Protons at Low Beta		x 1.10
	total	x 3.3

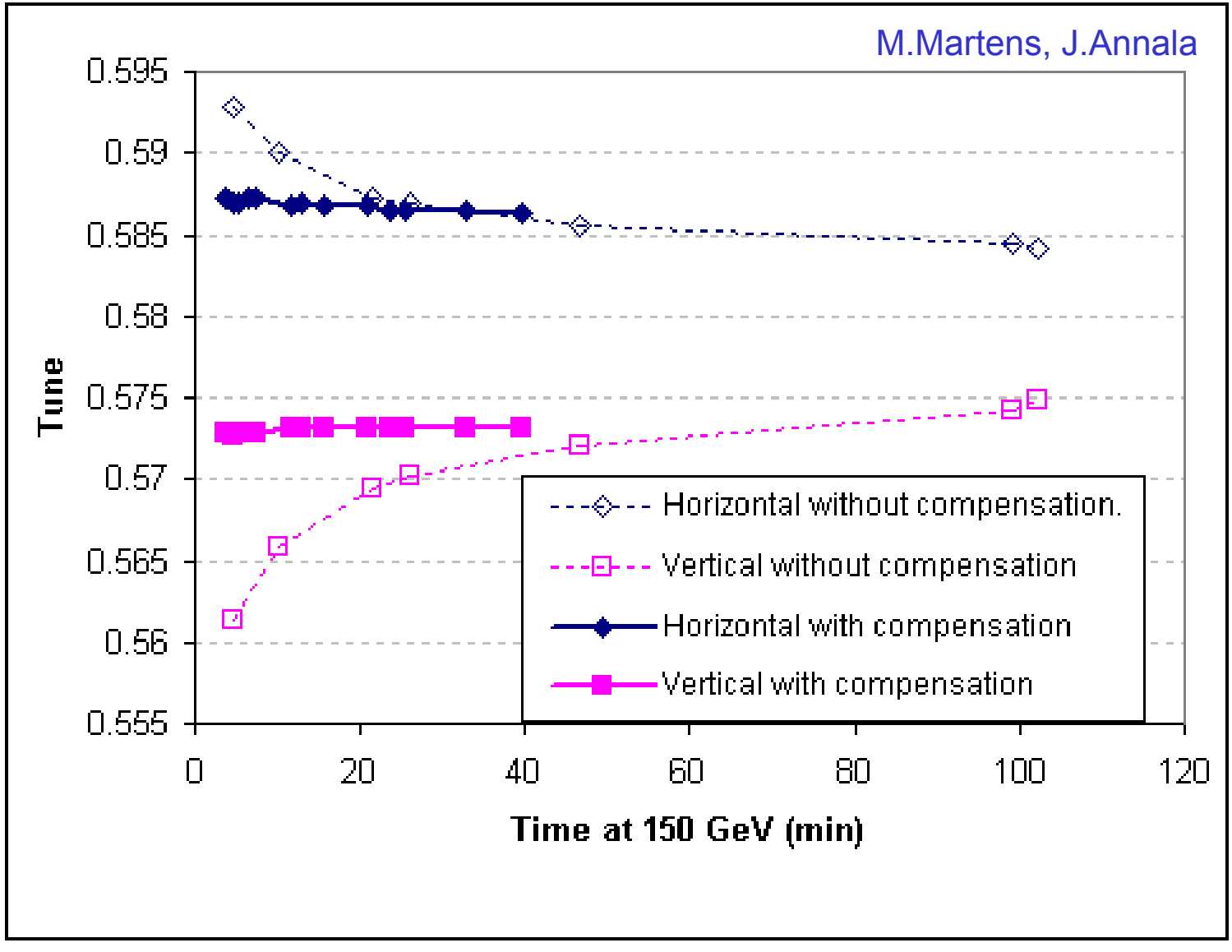
….plus additional improvements in the Tevatron:

- Tunes/coupling/chromaticities at 150/ramp/LB
- Orbit smoothing
- Longitudinal dampers to stop σ_s blowup
- Transverse dampers improves 150 Gev lifetime
- F11 vacuum

Tune/coupling/chromaticity/orbits

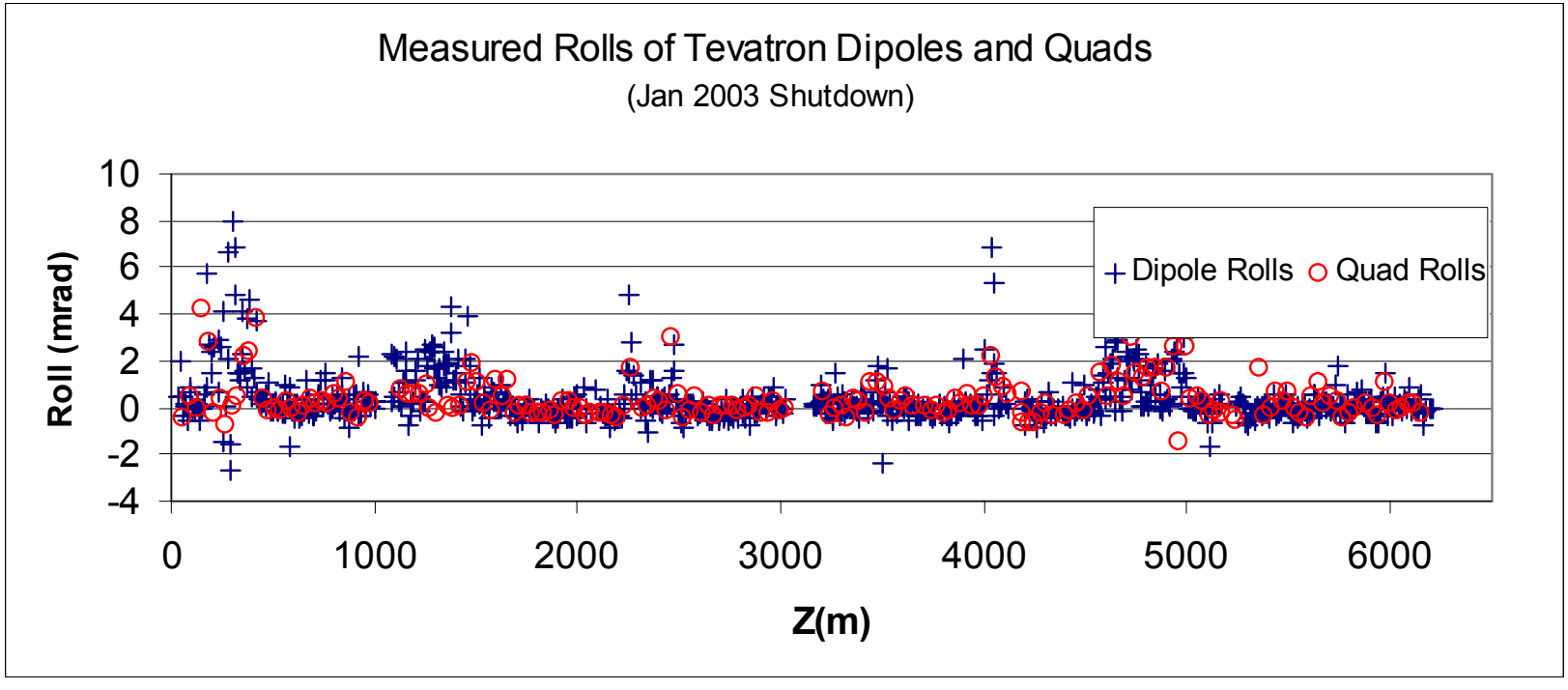
- Tune up is essential for consistent operations …
  - Much effort during "Studies Periods" is actually maintenance (orbit smoothing and tune/coupling/chromaticity adjustments)
- … and for understanding more complicated physics
  - Beam-beam effects, instabilities and dampers, beam lifetimes, beam halo rates, etc. are more difficult to understand when machine parameters drifting.
- Some troubles:
  - Tune/coupling drifts at 150 Gev. (Now compensated.)
  - Tune/coupling snapback on the ramp. (Now compensated.)
  - Chromaticity snapback? (Was measured. Is OK.)
  - Orbit drifts. (Started BPM and smoothing improvements)

Tune Drift @ 150 Gev



Tevatron Magnet Alignment

- Measured rolls of dipoles and quads during Jan 2003 shutdown.
- Used "portable tilt-meter" for quick measurements
- Data roughly consistent with vertical dipole corrector strengths
- Dipoles rolled 4 mrad gives ~0.5 mm "scalloped" vert orbit
- Coupling from one quad rolled 4 mrad gives min tune split ~0.0025



Beam-beam Interaction As Major Factor

- *Pbar transfer efficiency strongly depends on N_p, helix separation, orbits, tunes, coupling, chromaticity and beam emittances at injection*
- *Summary of progress with beam-beam since March 2002:*

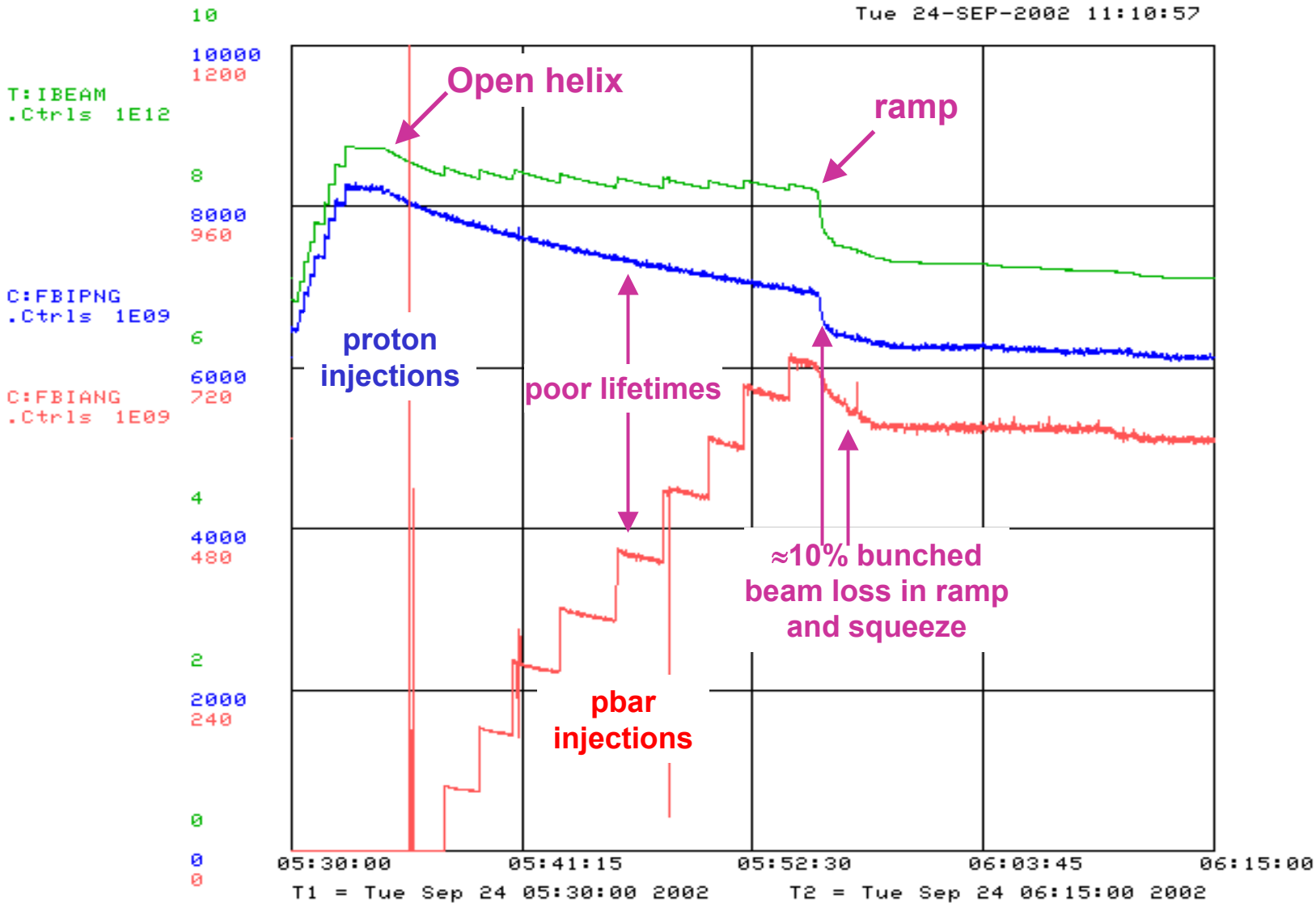
	Mar'02 *	Oct'02 **	Jan'03 ***
Protons/bunch	140e9	170e9	180e9
Pbar loss at 150 GeV	20%	9%	4%
Pbar loss on ramp	14%	8%	12%
Pbar loss in squeeze	22%	5%	3%
Tev efficiency Inj→low beta	54%	75%	75%
Efficiency AA→low beta	32%	60%	62%

* average in stores #1120-1128

** average in stores #1832-1845

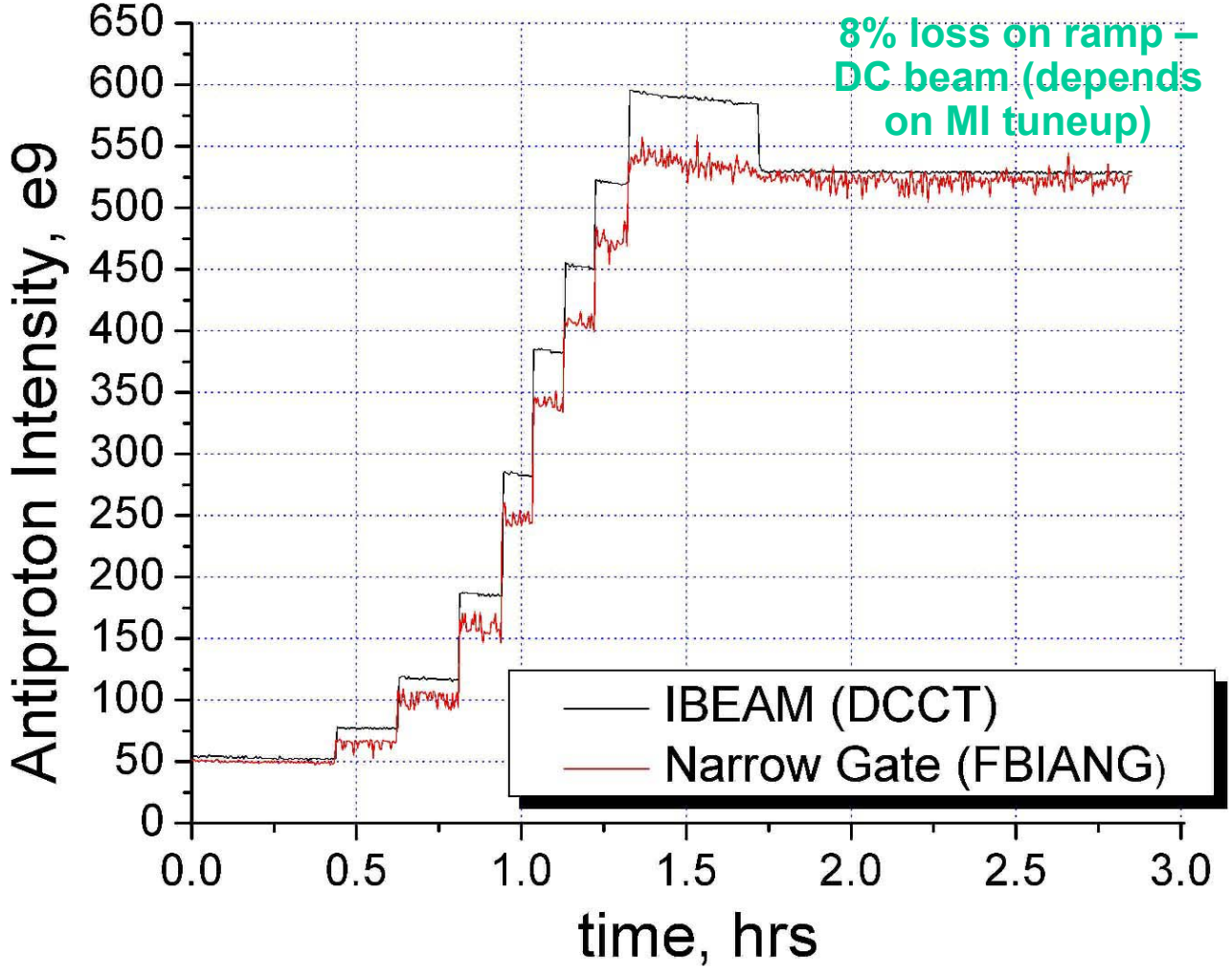
*** average in stores #2114-2153 (9 stores)

Tevatron Efficiencies



Beam-beam Effects: Pbar Only

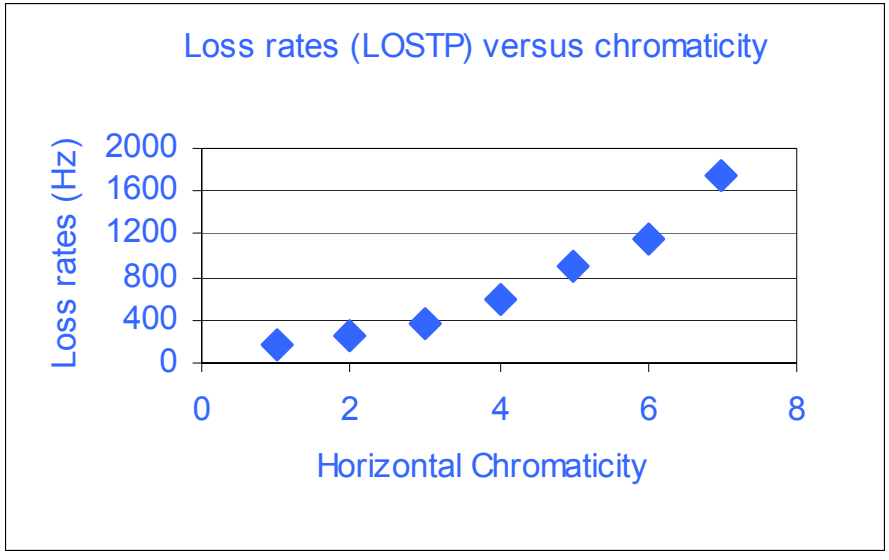
Antiproton Only Store: 1% loss on ramp, τ_{150}=20 hrs, τ_{980}=160 hrs

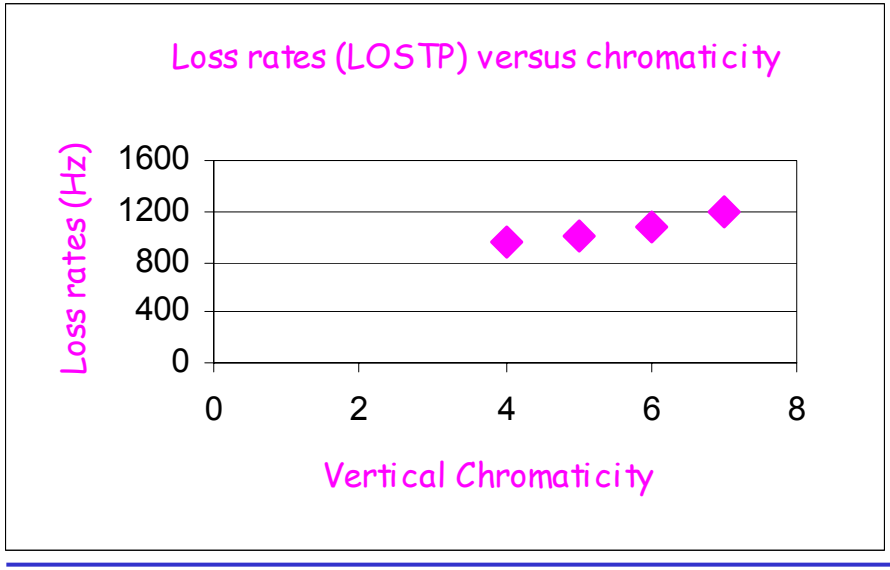


Lifetime Issues at 150 Gev

- Poor Pbar lifetime at 150 Gev
  - Depends on emittances, N_p, ξ, and bunch number
  - Lifetime ~ 0.5-1.0 hrs => ~3 hours
  - Original injection helix has been modified, separation increased and optimized to fit tight C0 aperture ("new-new helix")
  - Replace lambertsons @ C0 – gain 25 mm vertically
- Poor proton lifetime on helix
  - depends on chromaticity
  - Instability prevented lower chromaticity (now 8)
  - Dampers now allow us to lower chromaticity
  - Lifetime ~2 hours => ~ 3-4 hours (on a good day)

Lifetime and Chromaticity at 150 Gev

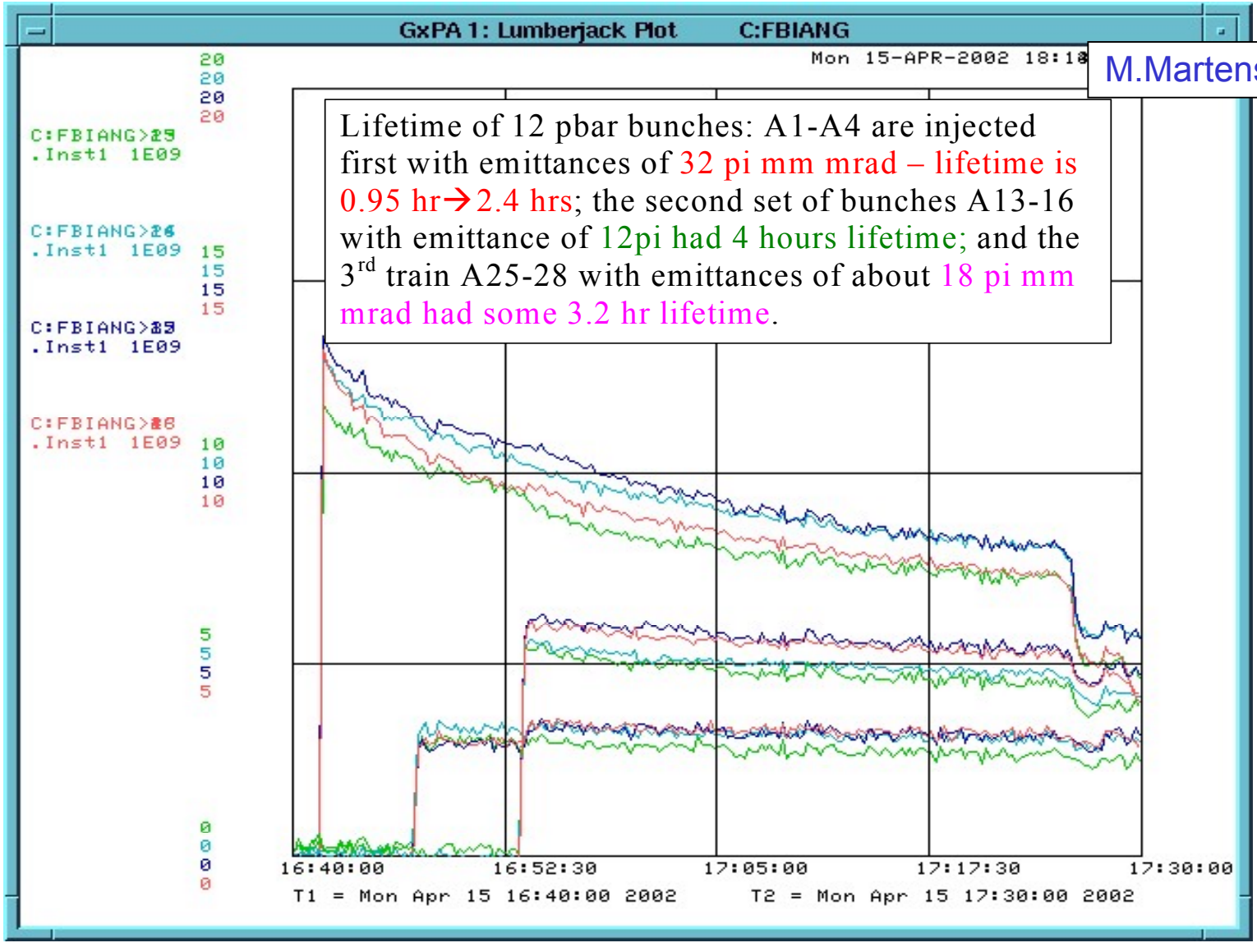




Measured loss rates as function of chromaticity (with protons on the pbar helix)

- Lower chromaticity is better for lifetime
- Instabilities appear $\xi < 3\text{-}4$
- Run with $\xi_H = 8$, $\xi_V = 8$ to avoid instabilities
- Dampers allow us to lower chromaticity and improve lifetime

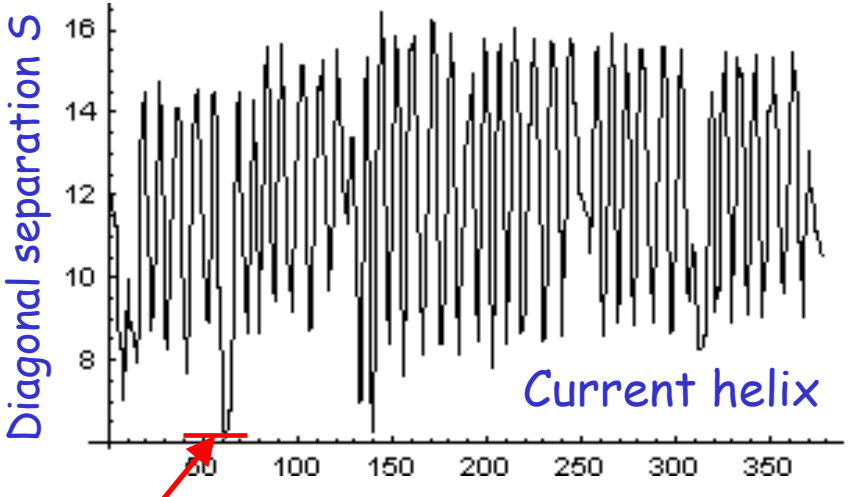
Beam-beam @ Injection Vs Emittance

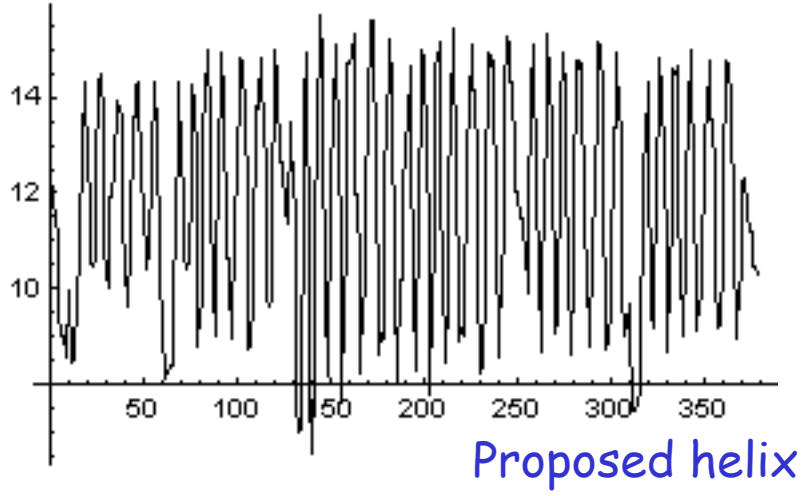


Attacking the Beam-beam Effects

- Smaller emittances from AA ("AA shot lattice")
- Reduced injection errors
  - Beam Line Tuner
- Better control of orbits / tunes / coupling
  - Tunes up the ramp
  - Tune and coupling drift at 150 Gev
  - Orbit smoothing
- Larger injection helix
  - C0 Lambertson replacement
  - New Separator settings

Helix Improvement





Aperture limitation at C0

$$S = \sqrt{(\Delta x/\sigma_x)^2 + (\Delta y/\sigma_y)^2}$$

Increasing proton/pbar helix separation

- Replace C0 Lambertson with MI magnets
- Increase vertical aperture at C0 from ~15mm -> 40 mm (but only ~30% larger helix due to other aperture limitations.)
- Modify helix to increase min separation, S_{min}, from 5.5 to 6.6

January 2003 Shutdown

- C0 Lambertson Replacement
  - Increases aperture at C0
  - Leads to increased proton/antiproton helical orbit separation.
- Schottky monitor
  - Measure chromaticity non-destructively
  - Measure tunes of individual bunches
- CDF Shielding
  - Add steel around low beta quads.
  - Should reduce backgrounds in muon chambers by factor of 5.
- New TEL electron gun.
  - Gaussian shaped emittance of electron beam
- Alignment Work

Priority

Tevatron Projects in FY'03

	project	Leader	Date
1	**Transverse dampers**	*Steimel*	Nov'02
1	**Pbar emittance at injection: BLT,A1 line, inj.damper**	*Scarpine* *Lebedev* *Steimel*	Nov'02 Dec'02 Feb'03
1	**C0 Lambertson replacement**	*Garbincius*	Feb'03
1	**Tev Lattice (A0)**	*Martens*	Feb'03
1	**Daily operations**	*TeV coord*	daily
1	**Operational orbit smoothing**	*Martens*	Dec'02
1	**Beam-beam studies and calculations**	*Sen*	Sep'03

Tevatron Projects in FY'03 (Cont'd)

Priority			
2	**Instability studies**	*Ivanov*	Dec'02
2	**150 GeV tunecoupling drift compns; b2 unwind**	*Martens*	Oct'02
2	**TEL**	*Shiltsev*	Feb'03
2	**Schottky detector at E17**	*Pasquinelli*	Feb'03
2	**Tevatron alignment**	*Stefansky*	Mar'03
2	**Longitudinal dampers**	*Steimel*	Apr'03
3	**Tevatron vacuum**	*Hanna*	Feb'03
3	**Losses/collimators**	*Moore*	Feb'03
3	**DC Beam/RF noise**	*Lebedev*	Apr'03
3	**SBD/FBI/FW (BPMs)**	*Pordes*	Dec'02
3	**SynchLite**	*Cheung*	Dec'02
3	**Chromaticity measurement**	*Still*	Dec'02
3	**Orbit motion spectrometer**	*Zhang*	Dec'02
3	**Pbar tunemeter, feedback**	*Tan*	Mar'03