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# Run II Status

Physics Advisory Committee Meeting

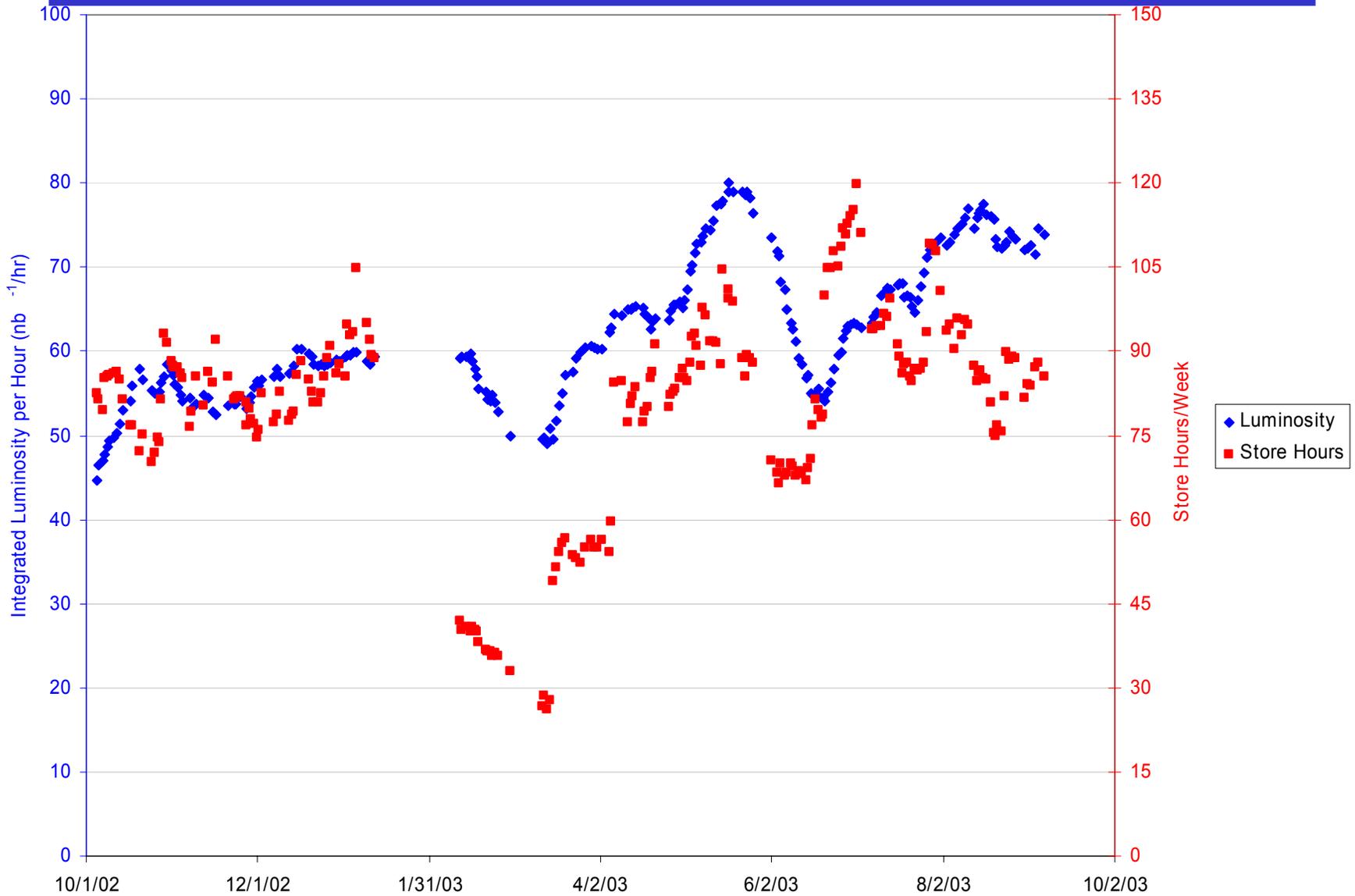
December 13, 2003

Dave McGinnis

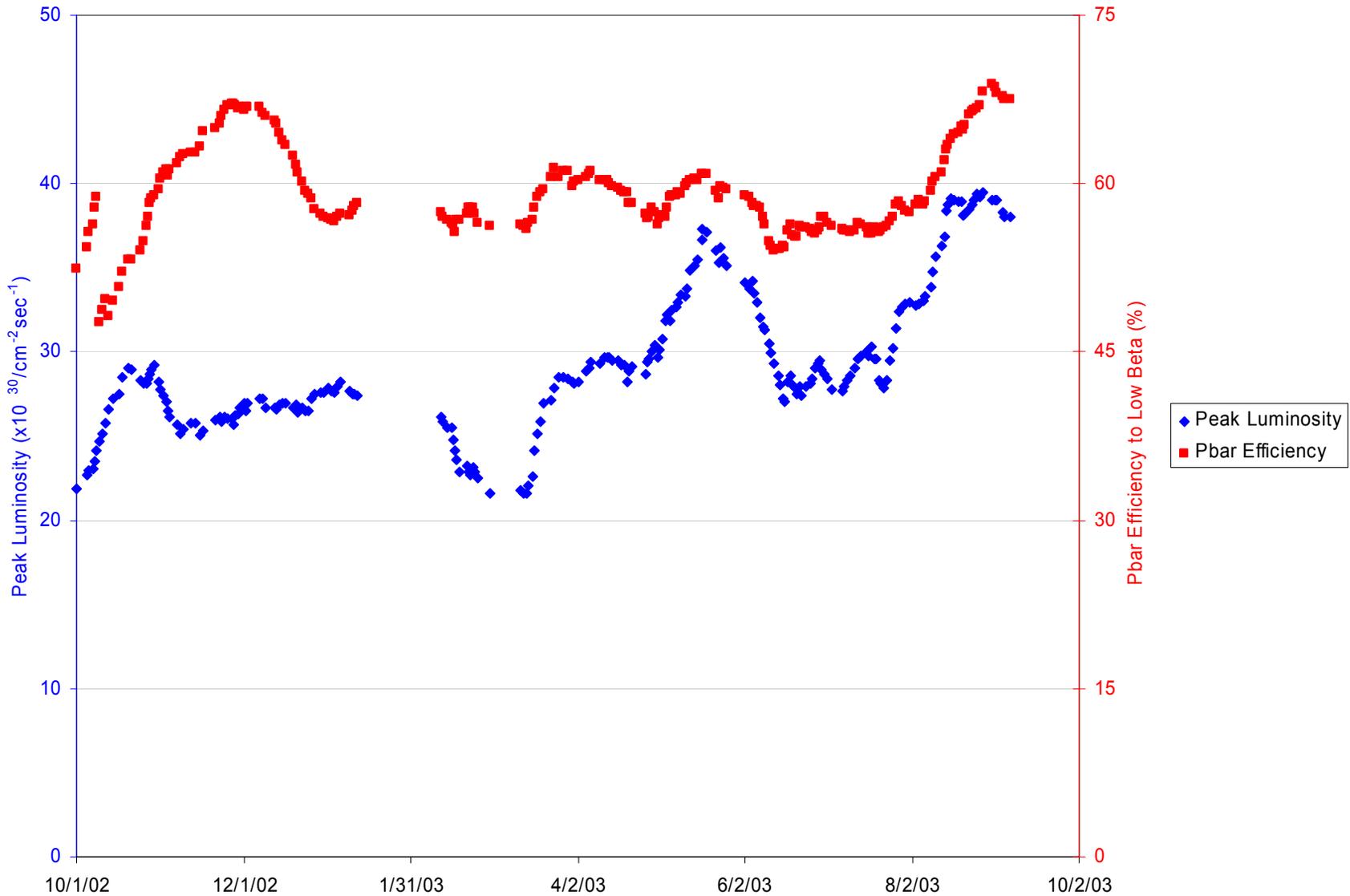
Accelerator Division

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# FY03 Performance



# FY03 Performance



# FY03 Performance

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Parameter	Last Store	Last 10 stores Average	Last 10 stores St. Dev.	Last 50 stores Average	Last 50 stores St. Dev.	
Initial Luminosity (Average)	40.2	37.5	4.6	36.1	6.5	$\times 10^{30} \text{cm}^{-2} \text{sec}^{-1}$
Integrated Luminosity per Store (Averaged)	1510.3	1053.0	396.9	1088.9	495.7	$\text{nb}^{-1}$
Luminosity per week (Averaged)	-	5.6	-	6.4	-	$\text{pb}^{-1}$
Store Length	19.9	14.1	5.4	14.9	6.7	Hours
Store Hours per week	-	75.5	-	87.8	-	Hours
Shot Setup Time	2.5	2.2	0.3	2.3	0.6	Hours
Protons per bunch	238.2	237.3	22.6	237.3	18.8	$\times 10^9$
Proton Efficiency to Low Beta	58.0	59.9	3.4	58.3	4.7	%
Antiprotons per bunch	22.6	22.5	3.0	22.2	2.6	$\times 10^9$
Start Stack	118.8	134.6	26.5	144.3	22.1	$\times 10^{10}$
End Stack	11.8	14.8	5.4	16.5	11.0	$\times 10^{10}$
Unstacked Pbars	107.0	119.8	24.0	128.2	19.6	$\times 10^{10}$
Pbar Transfer efficiency to Low Beta	76.0	68.5	6.3	63.3	7.7	%
HourGlass Factor	0.63	0.64	0.01	0.63	0.01	

# Run II (without the Recycler) and Run Ib

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- Projected - 5.3x ( $8.5 \times 10^{31} \text{cm}^{-2} \text{sec}^{-1}$  /  $1.6 \times 10^{31} \text{cm}^{-2} \text{sec}^{-1}$ )
  - Delivered - 2.3x ( $3.7 \times 10^{31} \text{cm}^{-2} \text{sec}^{-1}$  /  $1.6 \times 10^{31} \text{cm}^{-2} \text{sec}^{-1}$ )
  - More Pbars
    - projected - 3.3x
      - More protons on target - 2x ( $5 \times 10^{12} / 2.5 \times 10^{12}$ )
      - Faster Pbar cycle rate - 1.6x (2.4sec/1.5sec)
    - delivered - 1.9x
      - More protons on target - 1.9x ( $4.7 \times 10^{12} / 2.5 \times 10^{12}$ )
      - Faster Pbar cycle rate - 1x (2.4sec/2.4sec)
  - More Protons
    - projected - 1.17x ( $270 \times 10^9 / 230 \times 10^9$ )
    - delivered - 1.09x ( $250 \times 10^9 / 230 \times 10^9$ )
  - Shorter Bunch lengths
    - projected form factor - 1.25x (0.37m <- 0.6 m)
    - delivered form factor - 1.07x (0.52m <- 0.6 m)
  - Higher Energy
    - projected - 1.11x (1000 GeV/ 900 GeV )
    - delivered - 1.09x (980 GeV/ 900 GeV )
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# TEVATRON Projects

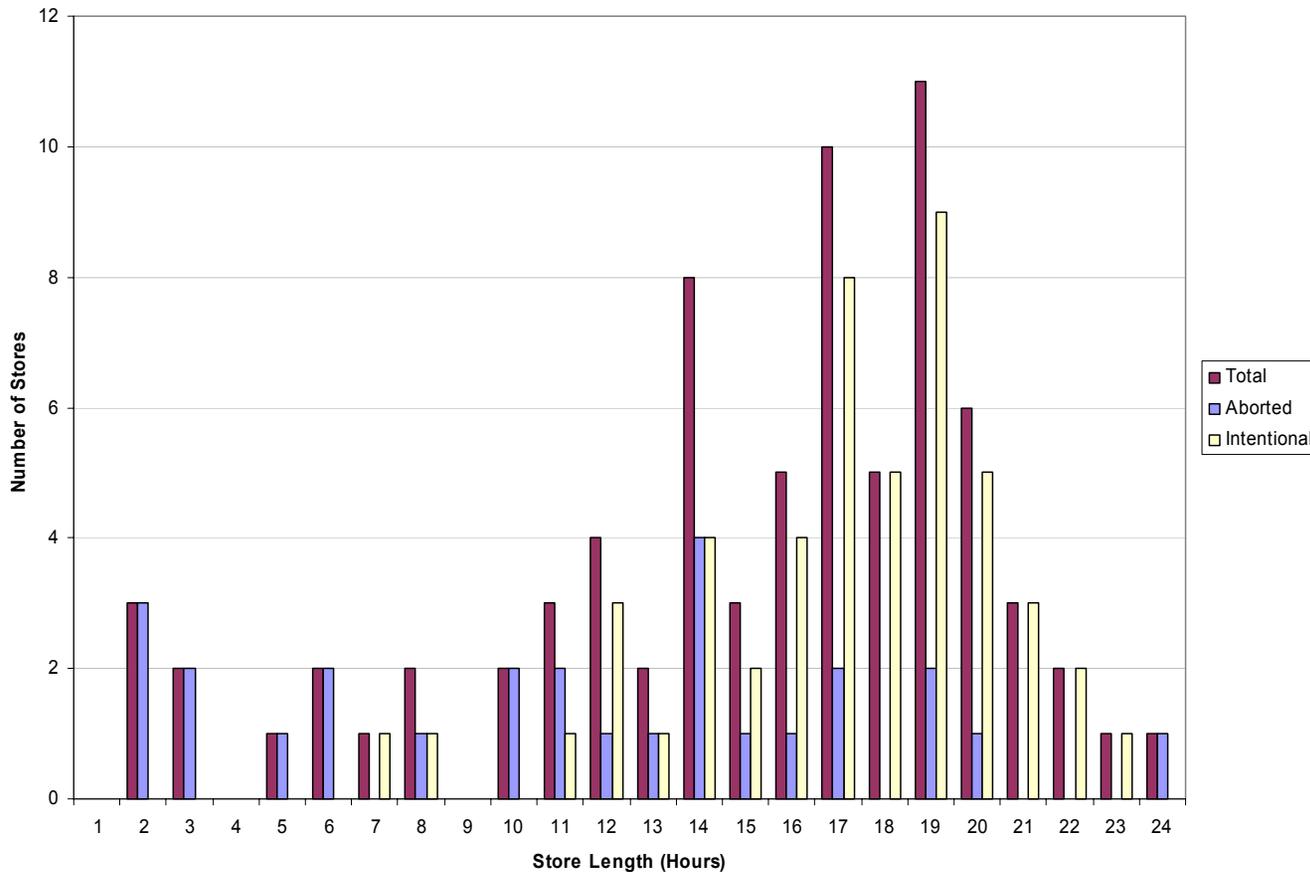
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- Transverse Emittance Dilution at injection
  - Injection lattice matching for pbars and protons
  - Smart bolt retro-fit (this shutdown)
  - New TEVATRON sextupole (borrowed from Pbar)
  - Injection dampers for pbars
- TEVATRON Chromaticity Control
  - Shielding of the F0 Lambertsons
  - Re-wiring of the TEV octupole circuits
- Better TEV Helices
  - Optimized helices at 150 GeV
  - TEV alignment

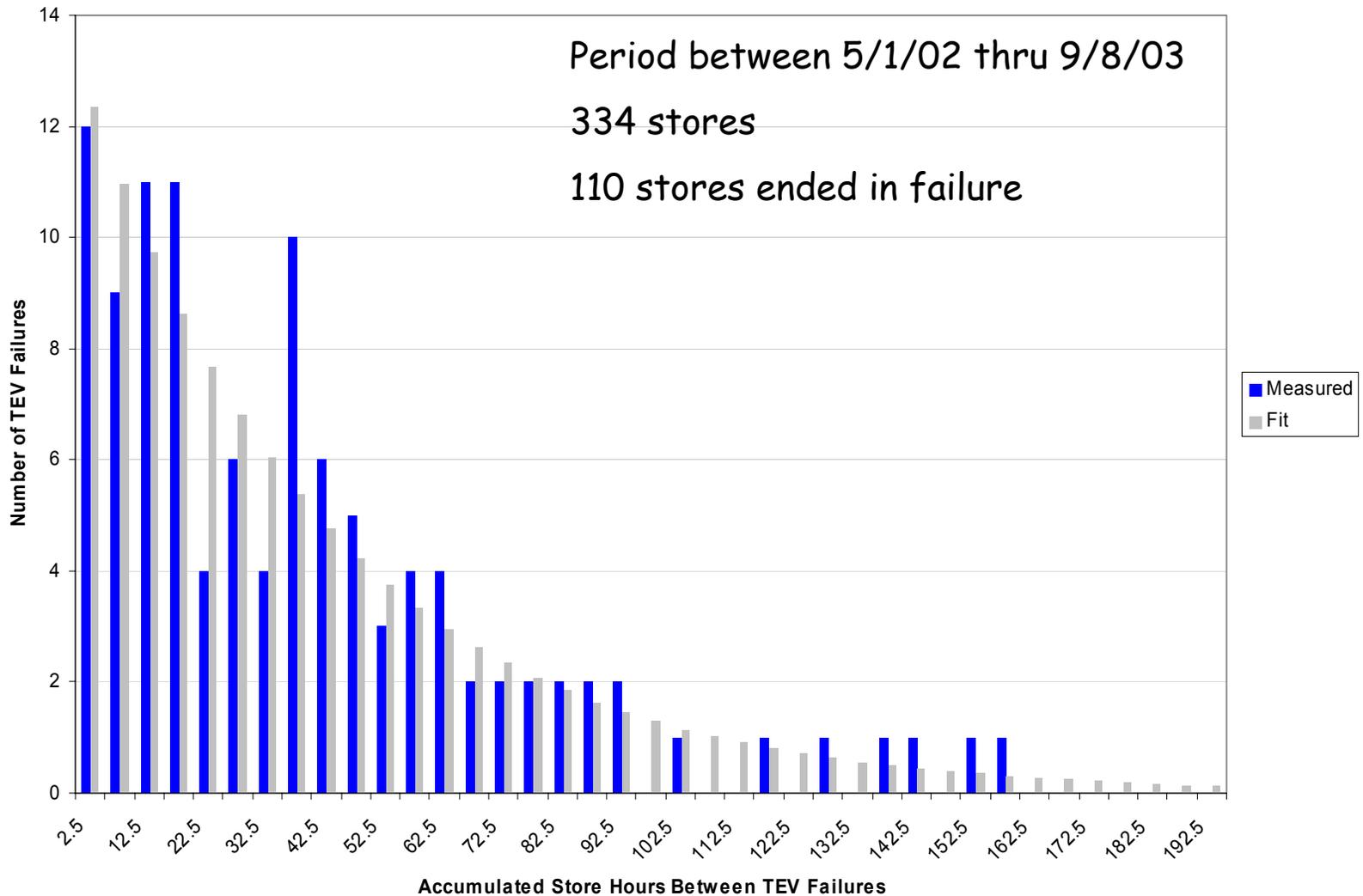
# TEVATRON Reliability

- Our highest luminosities were obtained by shooting from large stacks

- These large stacks were obtained by stacking for a long time because the previous store lasted a long time
- Our desire is to run long stores and stack big.
- However, our average store length is limited by equipment failure



# TEVATRON Store Reliability



# TEVATRON Store Reliability

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- A TEV failure is independent of the time in the store (exponential distribution)
  - The mean number of store hours between failures is 42 hours
  - 42 hours translates to a TEV reliability of 97.6% per hour
    - The probability that the TEV will remain at up for the next hour is 97.6%
- A TEV Reliability of 97.6% predicts that:
  - 1 out of every 4 stores will end in failure if our target store duration is 12 hours
  - 1 out of every 3 stores will end in failure if our target store duration is 17 hours
- Increasing the reliability by 1% will, on average, require the doubling of the lifetime of TEV components

# Pbar Production

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- Because our average store length is limited by equipment failure:
  - The only way to increase the luminosity significantly in FY04 is to increase the stacking rate.
  - The Pbar stacking rate is limited between "cooling" cycle time
- Pbar Cooling Cycle Projects
  - Debuncher Momentum Cooling Notch Filter Equalizers
  - New Stacktail BAW filters
  - Improved Stacktail crossover
  - Main Injector Beam loading compensation through the entire acceleration ramp
  - Main Injector Longitudinal Dampers

# Luminosity Parameters

Luminosity Parameters			
Phase	FY03	FY04	
Initial Luminosity	37.9	74.9	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Average Luminosity	20.7	44.4	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Integrated Luminosity per week	6.4	13.7	$\text{pb}^{-1}$
Integrated Luminosity per store	1.1	2.4	$\text{pb}^{-1}$
Number of stores per week	5.7	5.7	
Average Store Hours per Week	85	85	Hours
Store Length	15	15	Hours
Store Lifetime	11.0	13.0	Hours
HEP Up Time per Week	98	98	Hours
Good Week Ratio	1	1	
Shot Setup Time	2.2	2.2	Hours
	<b>FY03</b>	<b>RED</b>	

TEV Helices

# TEVATRON Parameters

TEVATRON Parameters			
Phase	FY03	FY04	
Number of Protons per bunch	250	260	$\times 10^9$
Number of Pbars per bunch	24.9	37.6	$\times 10^9$
Proton Emittance	32	29	$\pi$ -mm-mrad
Pbar Emittance	16	13	$\pi$ -mm-mrad
$\sigma_{\text{proton}}$	0.525	0.500	meters
$\sigma_{\text{pbar}}$	0.525	0.500	meters
BetaIP	40	35	cm
Transfer Eff. To Low Beta	0.73	0.8	
Using SBD Calibration			
Back Calculated Emittances	<b>FY03</b>	<b>RED</b>	

FO Lambertson

TEV Injection Matching

TEV Injection Coupling

TEV Helices

MI Long. Dampers

TEV Chromaticity control

# Antiproton Production Parameters

Antiproton Parameters			
Phase	FY03	FY04	
Zero Stack Stacking Rate	11.3	18.0	$\times 10^{10}$ /hour
Average Stacking Rate	8.2	11.3	$\times 10^{10}$ /hour
Stack Size transferred	122.6	169.1	$\times 10^{10}$
Stack to Low Beta	89.5	135.3	$\times 10^{10}$
Pbar Production	15.0	17.0	$\times 10^{-6}$
Protons on Target	5	5	$\times 10^{12}$
Pbar cycle time	2.4	1.7	Secs.
Pbar up time fraction	1	1	
Initial Stack Size	15	15	$\times 10^{10}$
Stack Size at 1/2 Stacking Rate	150	150	$\times 10^{10}$
	<b>FY03</b>	<b>RED</b>	

Debuncher Quad Stands

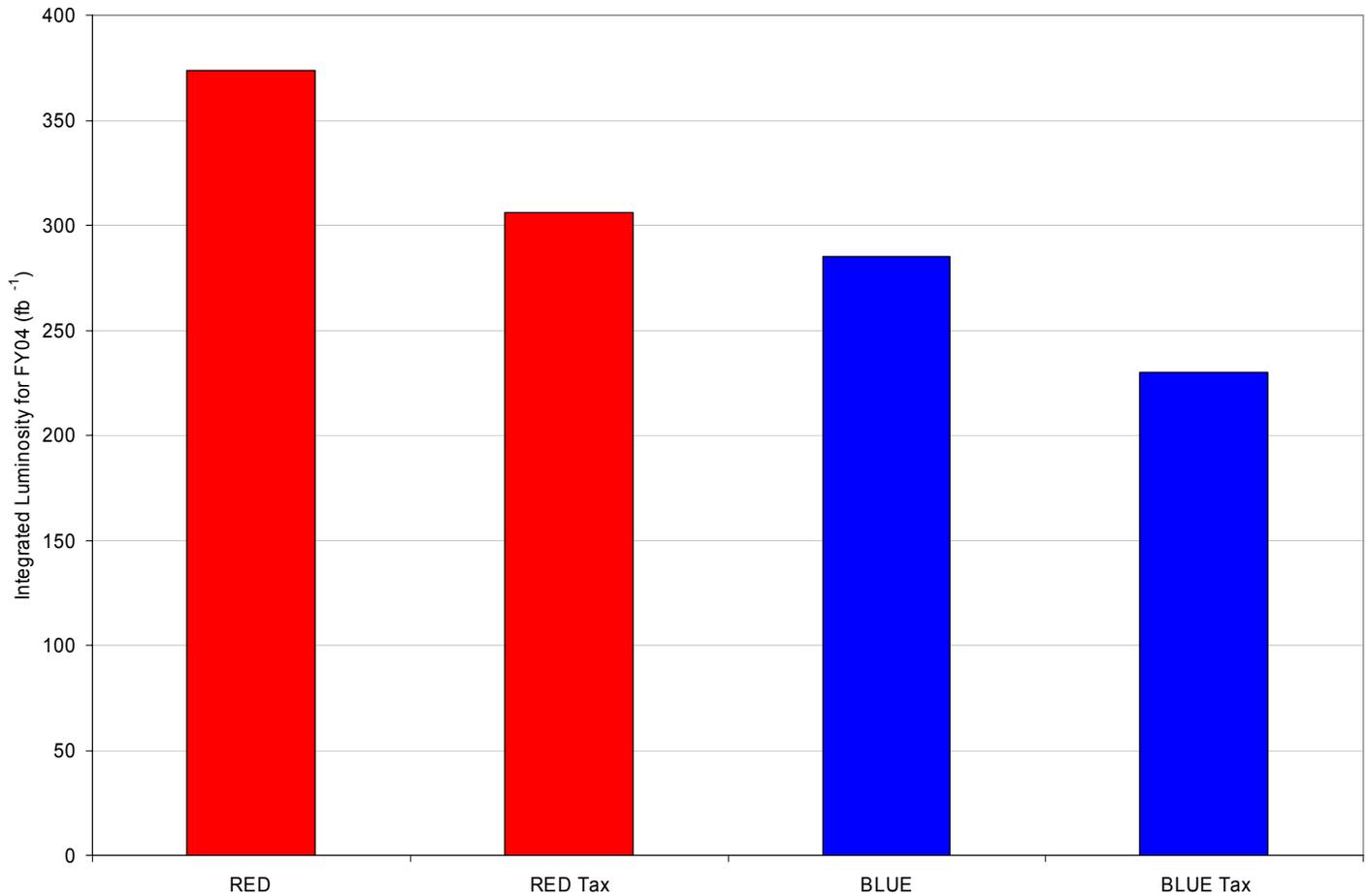
Debuncher filters

Stacktail filters

Stacktail phase crossover

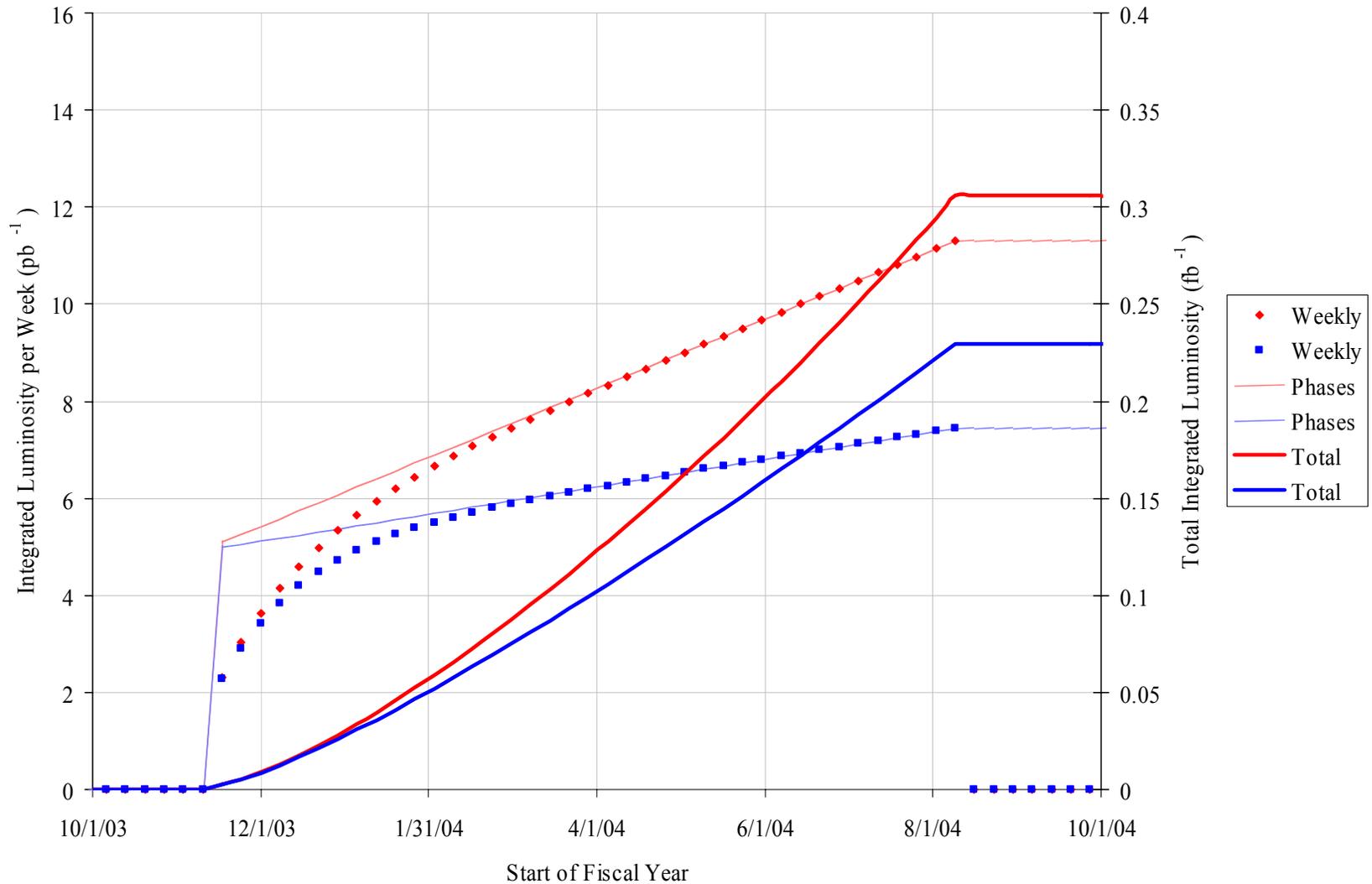
MI Long. Dampers

# FY04 Integrated Luminosity

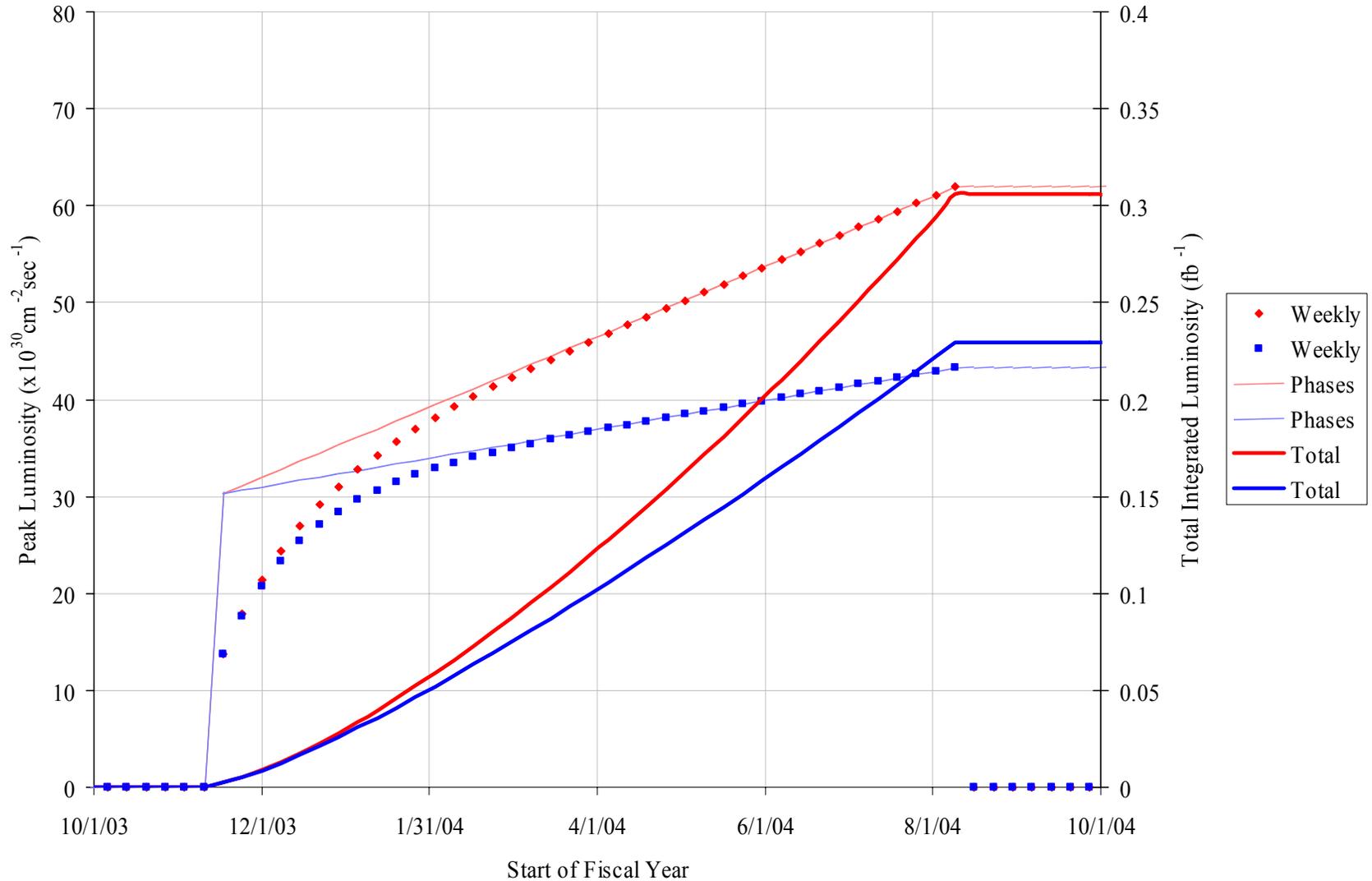


Fiscal Year	RED	RED Tax	BLUE	BLUE Tax	
FY04	373	306	285	230	pb <sup>-1</sup>

# Integrated Luminosity per Week - with Pbar tax



# Peak Luminosity - Pbar tax



# Luminosity Parameters

Phase	Luminosity Parameters					
	FY03	FY04	FY04	FY04	FY04	
Initial Luminosity	37.9	74.9	61.9	53.4	43.3	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Average Luminosity	20.7	44.4	36.8	30.5	24.7	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Integrated Luminosity per week	6.4	13.7	11.3	9.2	7.4	$\text{pb}^{-1}$
Integrated Luminosity per store	1.1	2.4	2.0	1.6	1.3	$\text{pb}^{-1}$
Number of stores per week	5.7	5.7	5.7	5.6	5.6	
Average Store Hours per Week	85	85	85	84	84	Hours
Store Length	15	15	15	15	15	Hours
Store Lifetime	11.0	13.0	13.0	12.0	12.0	Hours
HEP Up Time per Week	98	98	98	96	96	Hours
Good Week Ratio	1	1	1	1	1	
Shot Setup Time	2.2	2.2	2.2	2.2	2.2	Hours
	<b>FY03</b>	<b>RED</b>	<b>RED TAX</b>	<b>BLUE</b>	<b>BLUE Tax</b>	

# TEVATRON Parameters

Phase	TEVATRON Parameters					
	FY03	FY04	FY04	FY04	FY04	
Number of Protons per bunch	250	260	260	260	260	$\times 10^9$
Number of Pbars per bunch	24.9	37.6	31.1	30.3	24.5	$\times 10^9$
Proton Emittance	32	29	29	31	31	$\pi$ -mm-mrad
Pbar Emittance	16	13	13	15	15	$\pi$ -mm-mrad
$\sigma_{\text{proton}}$	0.525	0.500	0.500	0.500	0.500	meters
$\sigma_{\text{pbar}}$	0.525	0.500	0.500	0.500	0.500	meters
BetaIP	40	35	35	37	37	cm
Transfer Eff. To Low Beta	0.73	0.8	0.8	0.77	0.77	
Using SBD Calibration Back Calculated Emittances	<b>FY03</b>	<b>RED</b>	<b>RED TAX</b>	<b>BLUE</b>	<b>BLUE Tax</b>	

# Antiproton Parameters

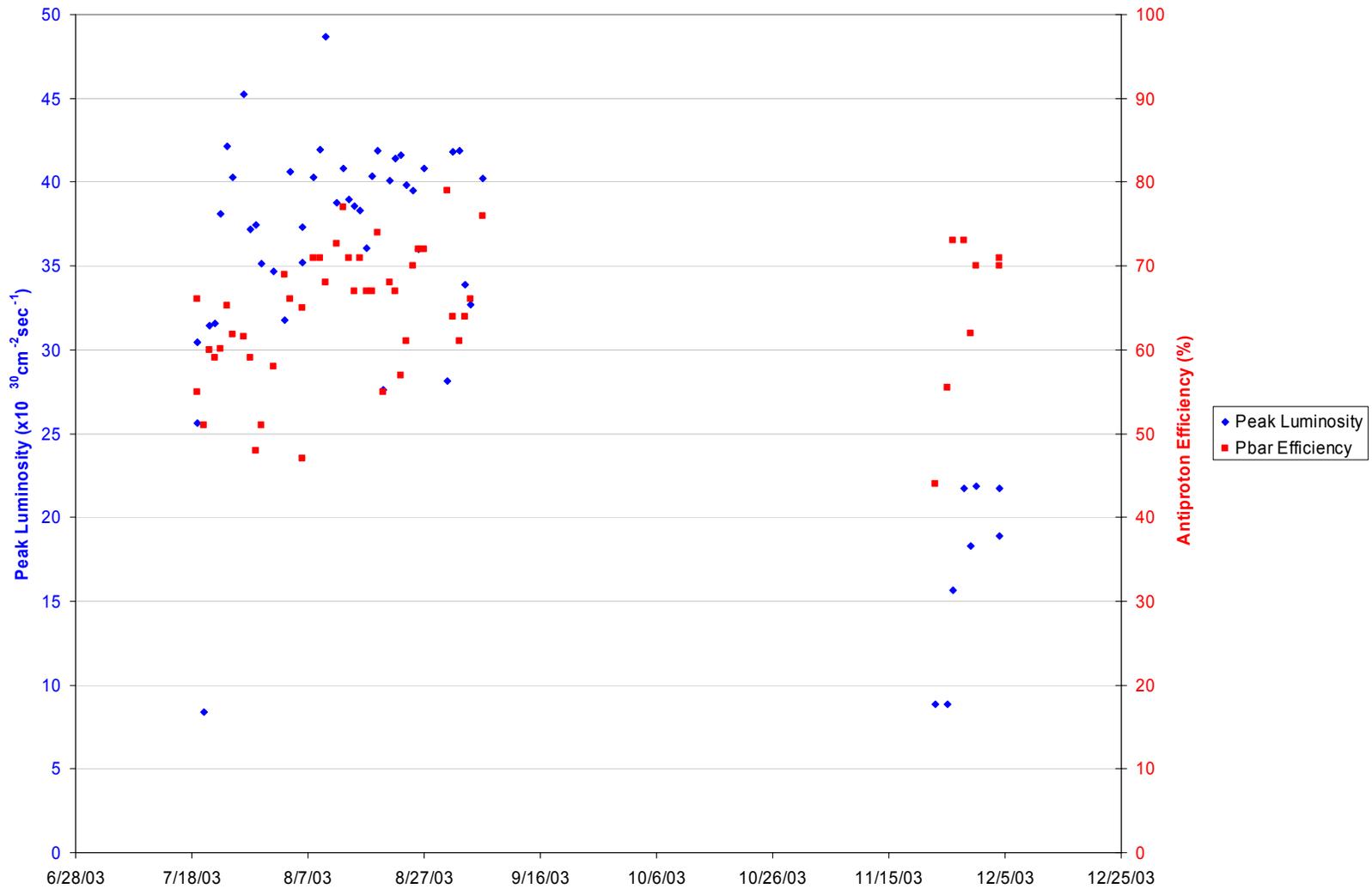
	<b>Antiproton Parameters</b>					
Phase	FY03	FY04	FY04	FY04	FY04	
Zero Stack Stacking Rate	11.3	18.0	18.0	13.7	13.7	$\times 10^{10}$ /hour
Average Stacking Rate	8.2	11.3	9.3	9.4	7.6	$\times 10^{10}$ /hour
Stack Size transferred	122.6	169.1	139.9	141.4	114.6	$\times 10^{10}$
Stack to Low Beta	89.5	135.3	111.9	108.9	88.2	$\times 10^{10}$
Pbar Production	15.0	17.0	17.0	16.0	16.0	$\times 10^{-6}$
Protons on Target	5	5	5	5	5	$\times 10^{12}$
Pbar cycle time	2.4	1.7	1.7	2.1	2.1	Secs.
Pbar up time fraction	1	1	0.75	1	0.75	
Initial Stack Size	15	15	15	15	15	$\times 10^{10}$
Stack Size at 1/2 Stacking Rate	150	150	150	150	150	$\times 10^{10}$
	<b>FY03</b>	<b>RED</b>	<b>RED TAX</b>	<b>BLUE</b>	<b>BLUE Tax</b>	

# Startup Strategy

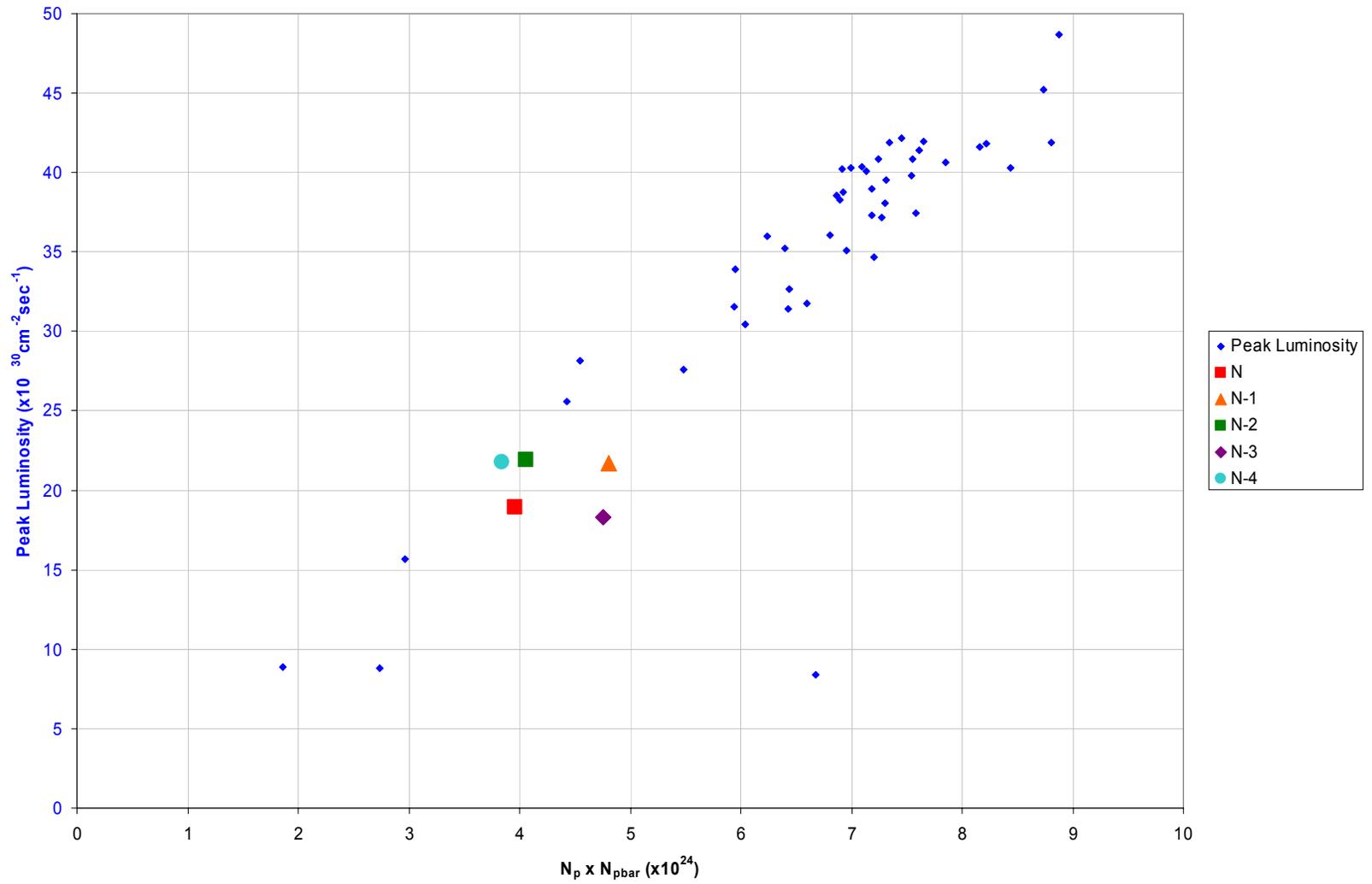
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- Establish luminosity as quickly as possible
  - Startup tasks will focus on accelerator fundamentals
    - Orbits
    - Tunes
    - Chromaticity
    - Transfer mechanics
  - Advanced commissioning of the accelerator upgrades installed during this shutdown will await the return of routine study periods after luminosity is established.

# Luminosity Since the End of the Shutdown



# Peak Luminosity vs Charge at Low Beta





# Comments on Startup

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- **Recycler Vacuum work has been a great success**
  - Emittance growth rate reduced by a factor of 5
  - Emittance growth rate is a factor of 2 better than is "needed" for the Run II Upgrades
  - Emittance growth rate is better than specified in the Recycler Design Report
  - Stored Lifetime of  $60 \times 10^{10}$  pbars  $>$  700 hours
  - Longitudinal emittance will be the main focus of future studies
- **Effects of TEVATRON shutdown work**
  - Amount of strength needed in the coupling correction circuits is greatly reduced
  - Amount of strength needed in orbit correctors is greatly reduced
  - Chromaticity at 150 GeV has been reduced
  - Proton lifetime on the 150 GeV Helix has increased from 2 hrs. to  $>$ 10 hrs
  - Antiproton transfer efficiency to low beta is  $>$  70%
- **Injector Chain running low**
  - Reason for low luminosities on initial stores
  - Recent studies in Booster have brought intensity back to pre-shutdown value
  - Recent work in Pbar has brought the stacking rate close to pre-shutdown values

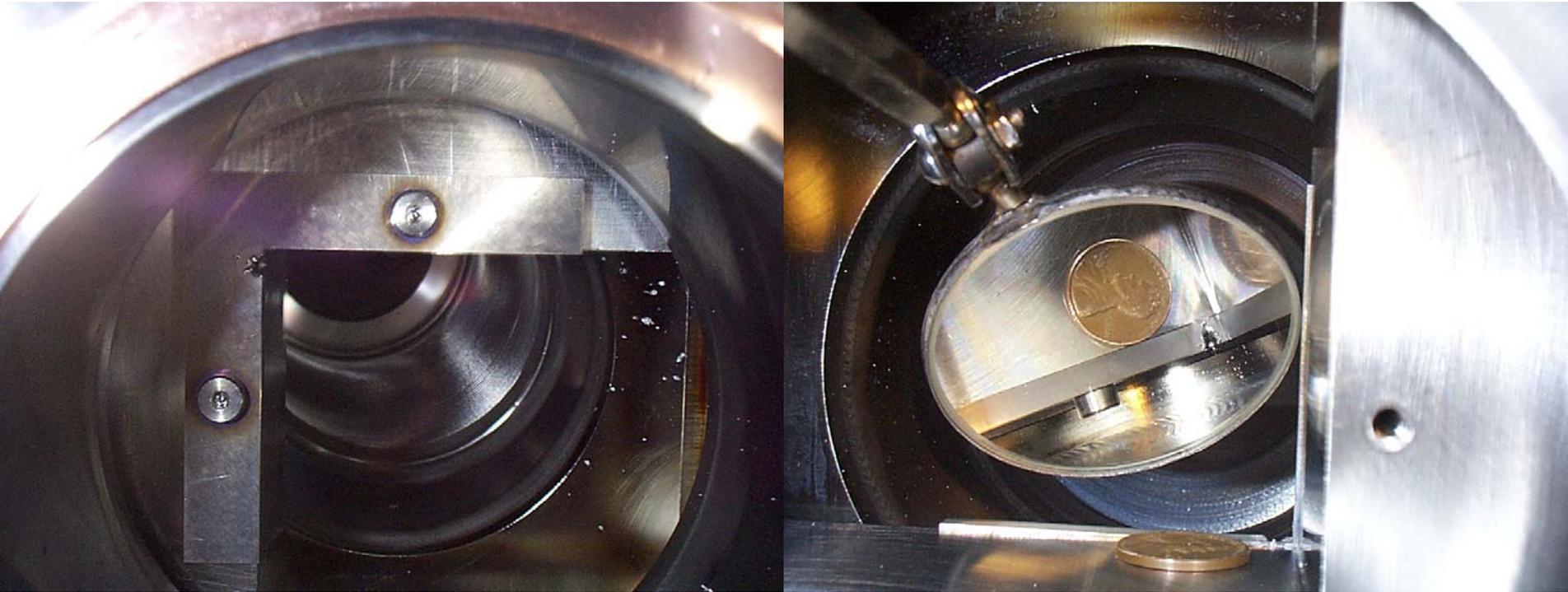
# Comments on TEVATRON 16 House Quench

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- Cause
  - Error in motor control of CDF pots ran the pots into the beam
  - Resulting in a series of cascading losses and quenches
- Effects
  - Destruction of 3 TEV collimators
    - But collimators protected the experiments
    - Collimator debris caused TEV vacuum problems
  - Failure of TEV Spool piece component (conning tower)
- Correction
  - Written investigation report to be released mid-next week (Dec 17)
  - A procedure to verify that the abort system is working properly (Jan. 1 2004 )
    - Examine the possibility of a hardware system that can detect if the abort system is functioning
  - Review of the policy for masking aborts (Feb.1, 2004 )
  - Upgrade the Tev BLM System so that the BLM system is the primary trigger for the abort system (late summer 2004?)
- Side effects
  - Will move IP at CDF down by 4mm to increase efficiency silicon detector

# D48 Collimator Damage

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# FY04 Study Strategy

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- FY04 Parasitic Study Strategy
  - Recycler "Pbar Tax"
    - 25% of the Pbar stacking time line will go to Recycler commissioning
    - Uses of the tax: MI Access time, Proton events, Pbar transfers
  - Present 80% Stack size / 20% Time-line strategy
- FY04 Dedicated Study Strategy
  - A study period would begin only if the previous 14 days contained 140 hours of store time.
  - Study periods would occur twice a week.
  - Study periods will be short (8-12 hours)
  - There would be at least two stores between each study period.
  - Studies would be blocked according to themes.
  - At the end of the study block (or theme) a short write-up (TEV Note or Pbar Note) describing the results of the studies would be expected.
- Maintenance studies would occur at the discretion of the Run Coordinator.

# Run II Upgrade Plan

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## DOE Reviews since Aspen meeting

Submitted "The Run II Luminosity Upgrade: Project Plan and Resource-Loaded Schedule" on June 15 (from Aspen!)

- Project organization
- Resource-loaded Schedule
- + Performance modeling → Luminosity Projection

- **Lehman review July 21-23**
  - ← review v1.0 of the plan (as submitted in June)
- **Mini-review Oct 8**
  - ← track progress versus v1.0, progress on recommendations...
- **Lehman review Feb 24-26**
  - ← review v2.0 (major update)
  - Outcome of reviews
  - V1.0 → v2.0
  - Highlights (just remarks) of Technical Progress

# v1.0 Review

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v1.0: complete bottom-up resource-loaded schedule, except

- Does not include a plan for Recycler commissioning  
(... recall, vacuum problems had seriously delayed commissioning)
- Also, some specific subproject plans not fully developed (Tev BPMs, Tevatron helix/separators, Wire BBC)

Major milestones and luminosity projection assume a plausible timescale and effort for the Recycler

## Outcome of the Review

- Various recommendations, management milestones ... (covered in October mini-Review)
- Action Items: make v2.0 and follow up reviews in Oct and Feb

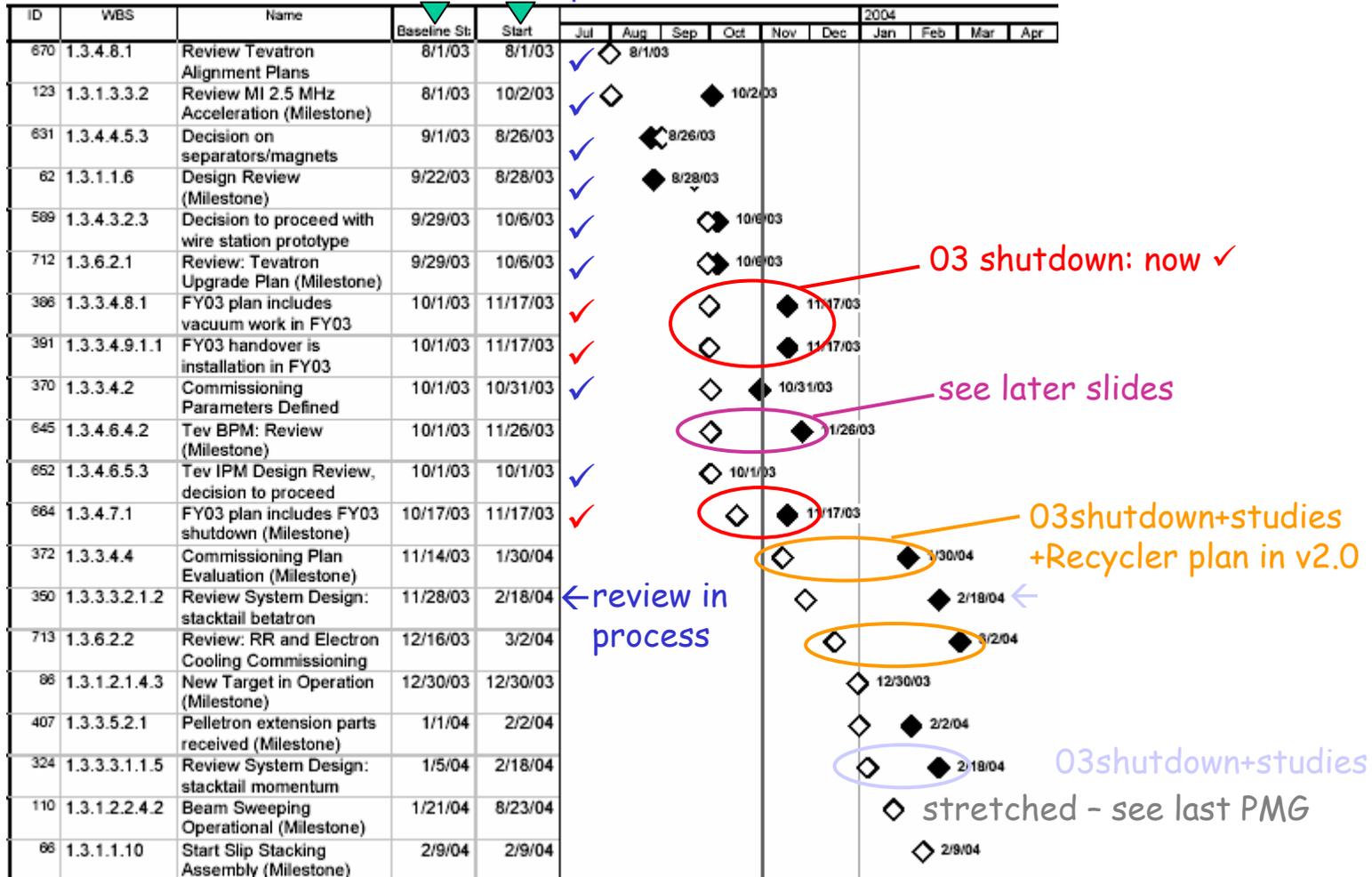
"Run II is a ...campaign..."

-D. Lehman

# Milestones

- milestones <Feb review ordered by v1.0 baseline date (V1.0 estimates ~May)

v1.0 Oct update



# Technical Reviews

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- Standardized review procedure
- Formal charge - documentation - report  
<http://www-bd.fnal.gov/run2upgrade/reviews/index.html>
- Many of the review committees include experts from other institutions

Several of the reviews → better define scope for subprojects:

- Tevatron helix/separators
- Beam-beam compensation plans

Others punctuate progress

- Approval for major purchases for slip-stacking
- Plan for 2.5 MHz acceleration
- Performance parameters for Recycler commissioning

# Milestones Status

	Class	WBS	Milestone Description	MS Date	Status
1	C	1.3.4.8.1	Review the alignment plans developed by the Tevatron Alignment Task Force	8/1/03	Done 8/1/03
2	C	1.3.1.3.3.2	Technical review: progress and plans for 2.5MHz acceleration in the Main Injector	8/1/03	Done 10/2/03
3	B	1.3.4.4.5.3	Scope review: decision on creating additional space in the lattice and to build longer separators at the interaction regions.	9/1/03	Done 8/26/03
4	C	1.3.1.1.6	Technical review: slip stacking beam studies and the design of the beam-loading compensation system, prior to funding the major purchases.	9/22/03	Done 8/28/03
5	B	1.3.4.3.2.3	Scope review: decision to proceed with wire stations prototyping, based on modeling of beam-beam compensation	9/29/03	Done 10/6/03
6	B	1.3.6.2.1	Scope review: evaluation of upgrade plans and options for the Tevatron beam-beam mitigation and instrumentation - Following the initial work of the Tevatron Task Force.	9/29/03	Evaluate after completion of items #3 and #5
7	C	1.3.3.4.8.1	Progress evaluation: confirmation that the Recycler vacuum work is completed in the FY03 shutdown	10/1/03	Pending
8	C	1.3.3.4.9.1.1	Progress evaluation: confirmation that the Main Injector dampers are installed in the FY03 shutdown and that only commissioning is left to complete	10/1/03	Done 10/1/03
9	C	1.3.3.4.2	Technical review: performance parameters defined for Recycler commissioning	10/1/03	Review in progress
10	C	1.3.4.6.4.2	Technical review: Tevatron BPM system specifications and design, prior to major purchases	10/1/03	Spec review Done 9/17/03 Tech review Sched.
11	C	1.3.4.6.5.3	Technical evaluation and scope review: Tevatron IPM, decision to proceed, prior to major purchases	10/1/03	In progress Rev. Done 10/3/03

# Technical Progress

## Very good technical progress: highlights include

- Slip-stacking: studies @ total intensity  $6 \times 10^{12}$  (60% of spec. intensity, 75% of design proj) order placed for RF PA's
- New Li lens: prototype filled
- AP2+DB Acceptance: doc'n and alignment, moveable quads, studies identified several limiting ap's...
- Recycler: excellent progress vacuum during shutdown - and excellent progress in commissioning since shutdown
- Electron Cooling: studies with full electron beamline going well at wideband - difficulty in measuring solenoid fields, but on schedule
- Tevatron: alignment work in shutdown, projects defined for separators, IPM, BPMs...

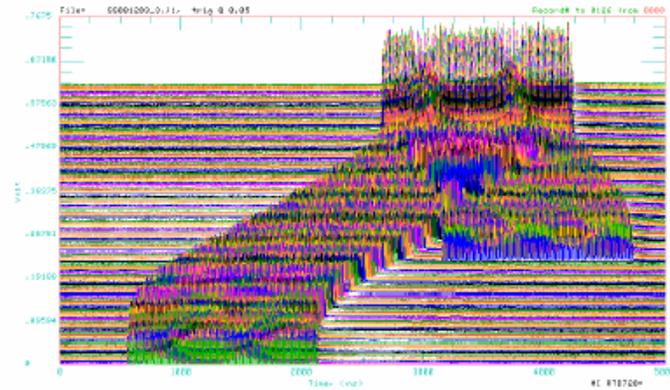


Figure 3. Mt range plot. The signal came from WCM with a resolution of 0.5ns/sample. The data were obtained every 1.42ms for 0.18s.

## v2.0 (for review in Feb)

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- Update work plan based on reviews
- All estimates reviewed/updated
- Include more detail on specific subprojects where plans more developed (AP2+DB, Tev BPMs...)
- **Include fully developed Recycler commissioning plan**
- Update shutdown schedule
- New luminosity projection
  
- Goal: completed draft of the schedule by Jan 1
- Work in progress - so far - major milestones expected to be maintained to within ~3 months
  
- Updated plan due to DOE Jan 30, Review Feb 20-23

# Summary

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- In FY03, we focused on
  - Increasing the proton intensity ( $250 \times 10^9$ /bunch)
  - Increasing the transmission efficiency of pbars to low beta (73%)
- Our goal in FY04 is to increase the potential for integrating luminosity by a factor of 2 over FY03. This increase will be done mainly by increasing:
  - Zero stack stacking rate
  - Transmission efficiency of pbars to low beta
- The vast majority of hardware needed to accomplish the FY04 goals was installed by the end of this shutdown.
- The Collider is commissioned
  - We are in an operating phase with periodic upgrades to be installed during shutdowns.
  - With an integrated accelerator study philosophy and an operations model of the complex, we will balance
    - Integrating luminosity
    - Accelerator studies
    - Commissioning the Recycler