Run II Plan

Phase 1

Current Operations Status and Near Term Plans

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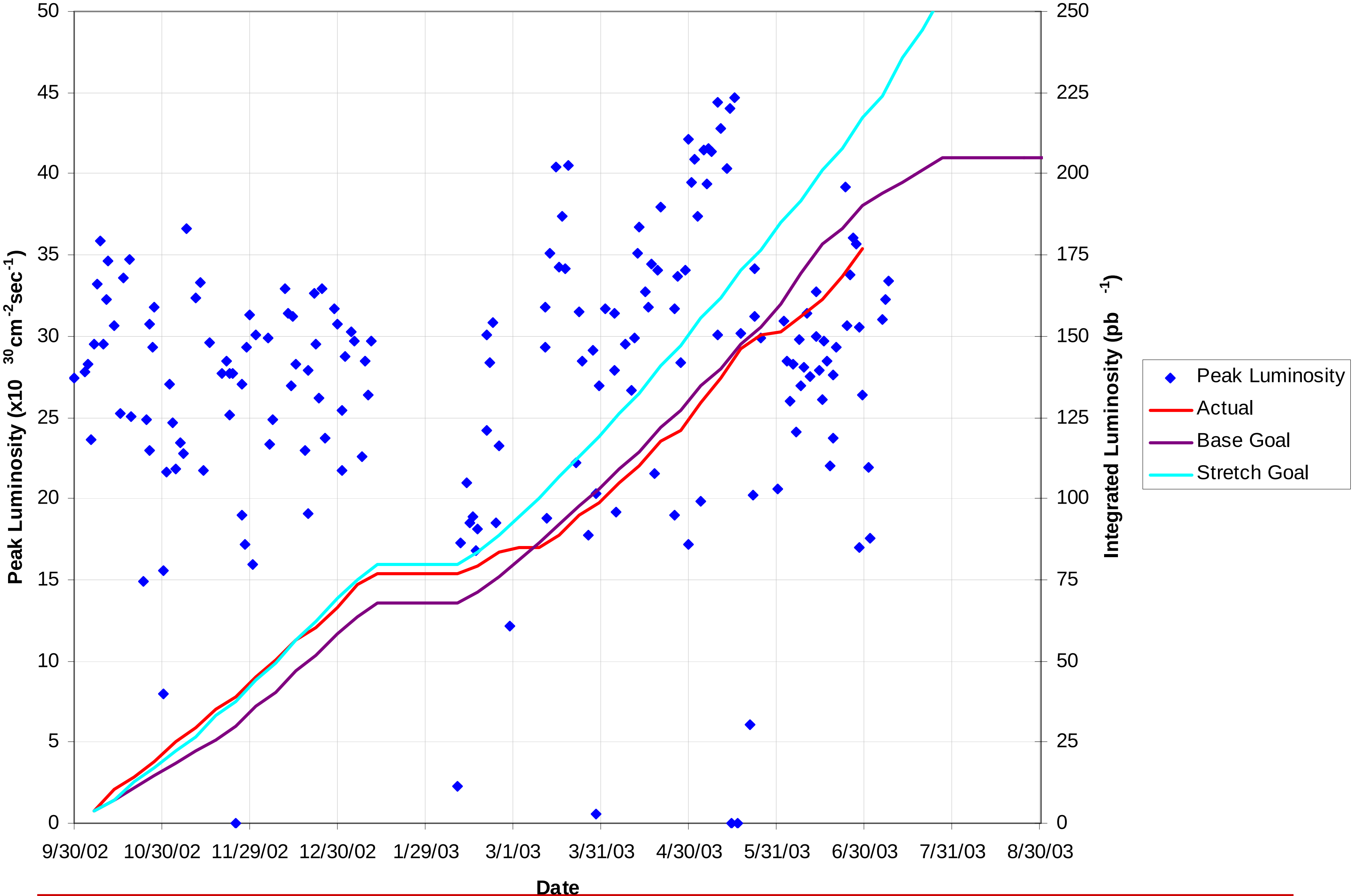
DOE Review

July 21, 2003

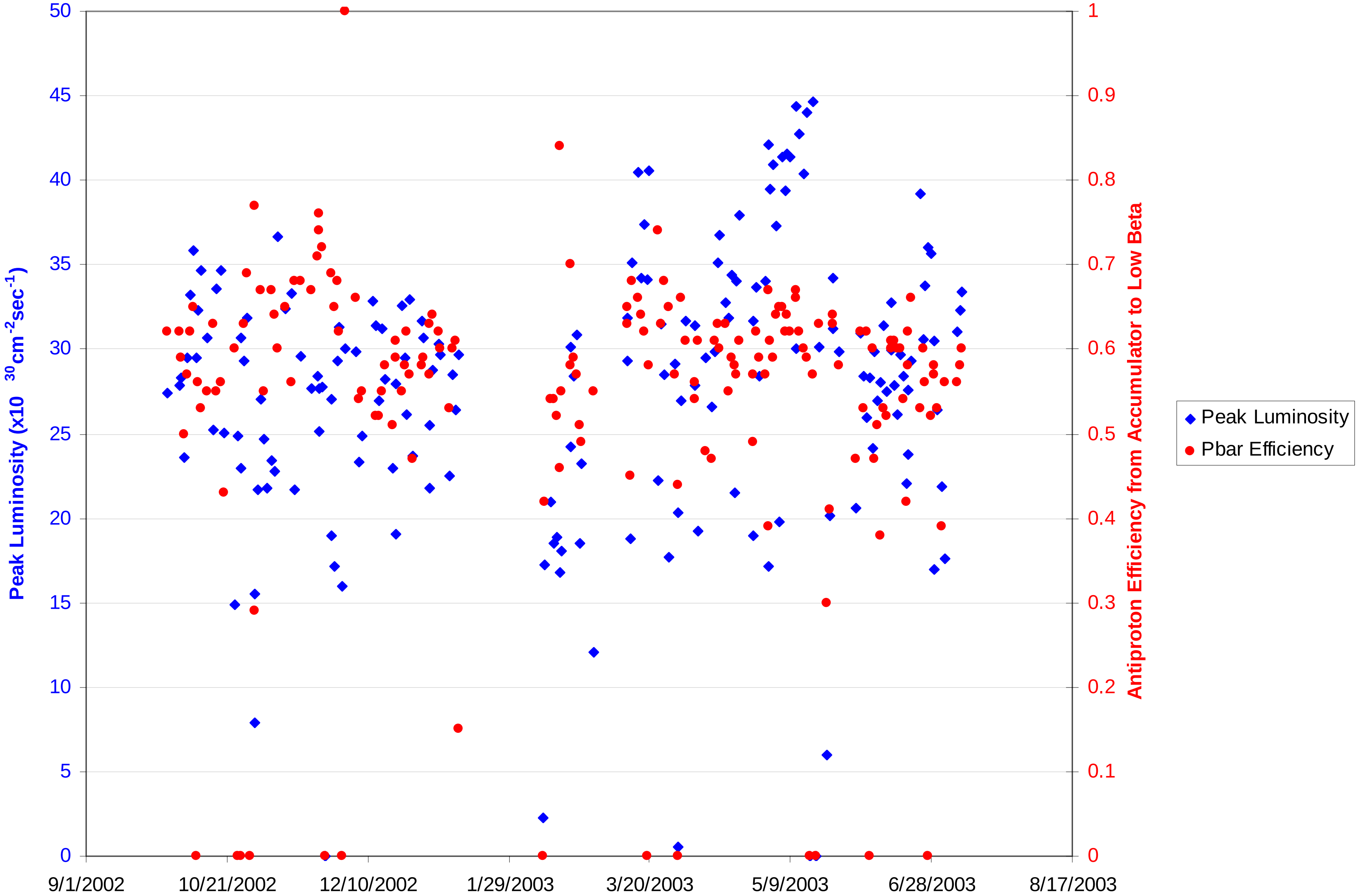
Outline

- A comparison between current performance and Run II Handbook projected performance will be shown.
- This comparison will be used to illustrate the areas that have fallen short of expectations.
- An overview of a plan that is already in progress and directly addresses shortcomings in collider performance will be presented.

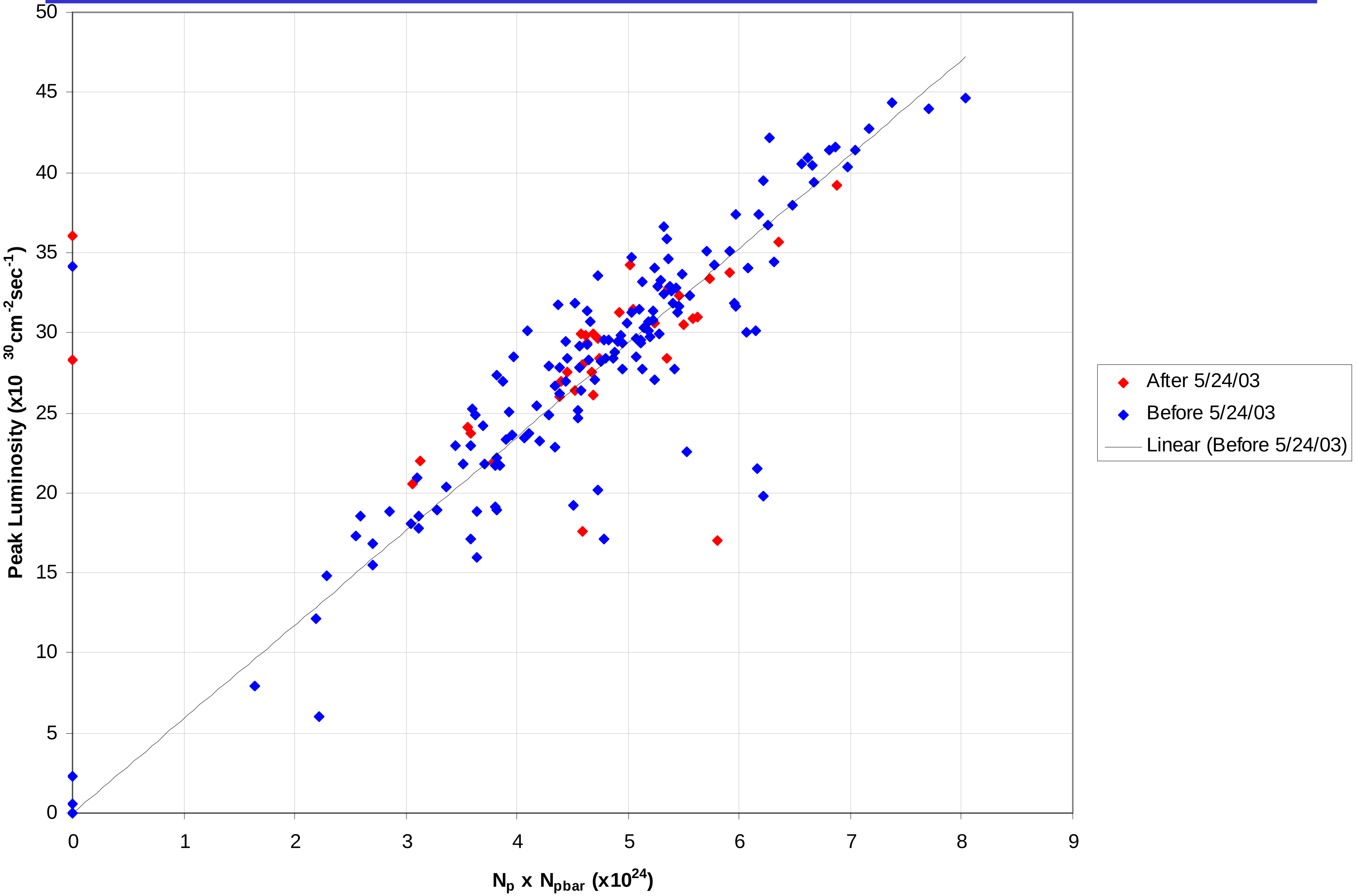
FY03 Luminosity Performance



Peak Luminosity and Efficiency



Luminosity and Particles in the Collider



Run II (without the Recycler) and Run Ib

- Projected - 5.3x ($8.5 \times 10^{31} cm^{-2} sec^{-1}$ / $1.6 \times 10^{31} cm^{-2} sec^{-1}$)
- Delivered* – 1.94x ($3.1 \times 10^{31} cm^{-2} sec^{-1}$ / $1.6 \times 10^{31} cm^{-2} sec^{-1}$)
- 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* - 0.83x ($192 \times 10^{9}/230 \times 10^{9}$)
- Shorter Bunch lengths
  - projected form factor - 1.25x (0.37m <- 0.6 m)
  - delivered form factor* – 1x (0.6m <- 0.6 m)
- Higher Energy
  - projected – 1.11x (1000 GeV/ 900 GeV)
  - delivered* – 1.09x (980 GeV/ 900 GeV)

*Based on average of 75 Stores between 2/10/03 – 6/5/03

FY03 Collider Parameters

Parameter	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
Initial Luminosity (CDF)	31.2	9.6	42.0	47.4	68.0	$x10^{30}cm^{-2}sec^{-1}$
Average Instantaneous Luminosity (CDF)	19.4	6.8	22.3	27.0	37.9	$x10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per Store (CDF)	985.7	450.5	1713.0	1650.0	2251.3	nb^{-1}
Luminosity per week (CDF)	4.7	2.6	4.6	7.0	10.9	pb^{-1}
Number of Stores per Week	4.7	-	-	-	4.8	
Store Length	14.4	5.5	21.3	17.0	14.5	Hours
Intentional Store Length	16.6	3.4	21.3	17.0	14.5	Hours
Aborted Store Length	10.6	6.4	-	-	-	Hours
Store Hours per week	68.6	31.9	46.3	91.6	70.3	Hours
Time spent stacking per store	14.6	3.4	19.5	20.9	14.5	Hours
Shot Setup Time	2.8	2.6	1.8	2.0	2.0	Hours
Store Lifetime	13.6	3.8	14.9	13.6	10.8	Hours
Protons per bunch	192.1	29.0	203.8	242.0	240.0	$x10^{9}$
Antiprotons per bunch	20.0	4.3	24.7	25.5	36.3	$x10^{9}$
Start Stack	135.3	25.1	166.0	173.0	174.3	$x10^{10}$
End Stack	11.2	13.6	12.0	11.0	0.0	$x10^{10}$
Zero Stack Stack Rate	11.7	1.6	11.7	11.7	18.0	$x10^{10}$/Hour
Zero Stacking Rate Stack Size	303.7	1.7	303.7	303.7	300.0	$x10^{10}$
Pbar Transfer efficiency to Low Beta	57.9	7.5	57.7	56.7	75.0	%
HourGlass Factor	0.64	0.03	-	0.65	0.65	

*Based on 75 Stores between 2/10/03 – 6/5/03

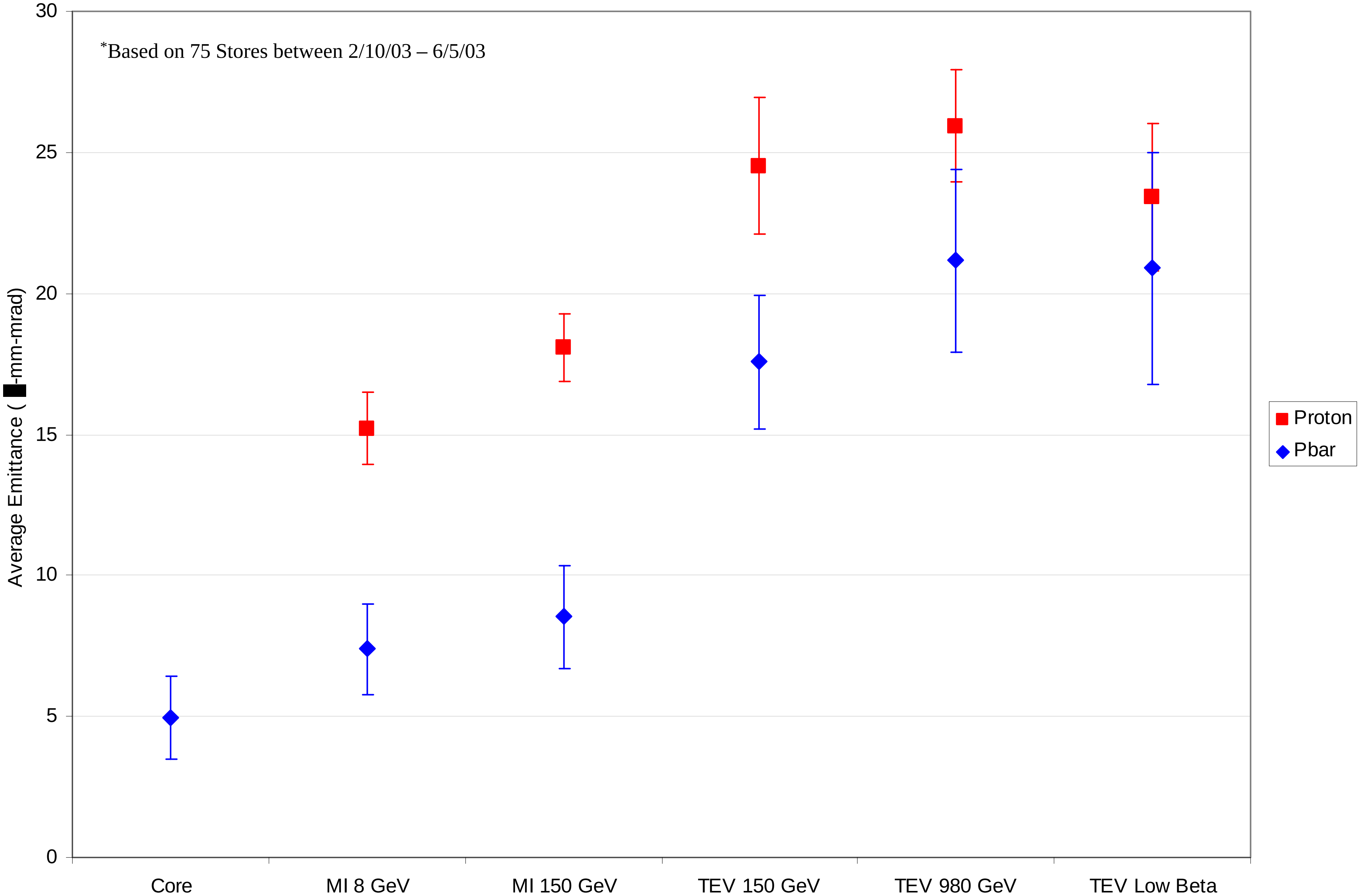
FY03 Collider Emittances

Emittance (measured)	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
Accumulator (Pbar)	5.0	1.5	6.6	7.0	7.0	π-mm-mrad
MI 8 GeV (Pbar)	7.4	1.6	8.9	9.4	9.0	π-mm-mrad
MI 150 GeV (Pbar)	8.5	1.8	10.1	10.5	11.0	π-mm-mrad
TEV 150 GeV (Pbar)	17.6	2.4	21.9	19.9	18.0	π-mm-mrad
TEV 980 GeV (Pbar)	21.2	3.2	-	24.0	19.0	π-mm-mrad
TEV Low Beta GeV (Pbar)	20.9	4.1	22.7	25.1	20.0	π-mm-mrad

Emittance (measured)	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
MI 8 GeV (Proton)	15.2	1.3	14.8	15.5	15.0	π-mm-mrad
MI 150 GeV (Proton)	18.1	1.2	17.5	18.3	18.0	π-mm-mrad
TEV 150 GeV (Proton)	24.5	2.4	22.3	25.9	19.0	π-mm-mrad
TEV 980 GeV (Proton)	25.9	2.0	-	26.6	20.0	π-mm-mrad
TEV Low Beta GeV (Proton)	23.4	2.6	21.9	24.1	20.0	π-mm-mrad

*Based on 75 Stores between 2/10/03 – 6/5/03

FY03 Collider Emittances



FY03 Collider Efficiencies

Efficiency	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
MI Injection (Pbar)	94.5	4.2	96.0	96.0	96.0	%
MI Acceleration (Pbar)	98.8	3.5	100.0	100.0	100.0	%
Coalescing (Pbar)	87.6	5.9	86.0	91.0	90.0	%
Tev Injection (Pbar)	90.2	5.7	93.0	90.0	95.0	%
TEVAcceleration (Pbar)	89.9	3.6	85.0	83.0	95.0	%
Initiate Collisions (Pbar)	92.7	8.3	92.0	91.0	97.0	%

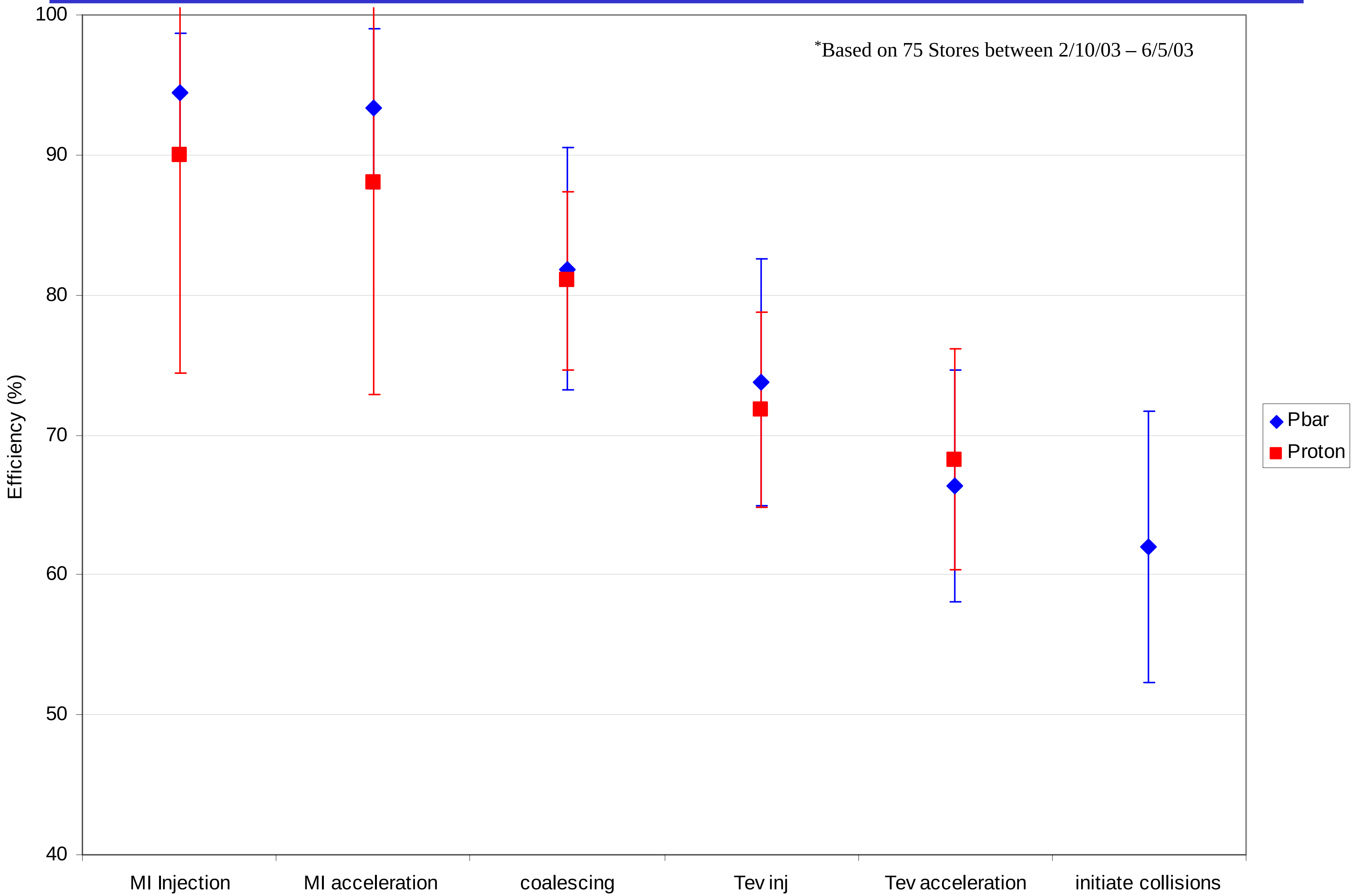
Cumulative Efficiency	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
MI Injection (Pbar)	94.5	4.2	96.0	96.0	96.0	%
MI Acceleration (Pbar)	93.3	5.7	96.0	96.0	96.0	%
Coalescing (Pbar)	81.9	8.7	82.6	87.4	86.4	%
Tev Injection (Pbar)	73.8	8.8	76.8	78.6	82.1	%
TEVAcceleration (Pbar)	66.4	8.3	65.3	65.3	78.0	%
Initiate Collisions (Pbar)	62.0	9.7	60.0	59.4	75.6	%

Efficiency	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
MI Injection (Proton)	90.0	15.6	100.0	85.0	95.0	%
MI Acceleration (Proton)	97.8	2.2	98.0	100.0	100.0	%
Coalescing (Proton)	86.5	4.3	85.0	90.0	90.0	%
Tev Injection (Proton)	89.1	4.6	88.0	91.0	95.0	%
TEVAcceleration (Proton)	95.7	5.8	96.0	95.0	95.0	%

Cumulative Efficiency	Average*	St. Dev.*	Best Integrated	Best Peak	Phase 1 End	
MI Injection (Proton)	90.0	15.6	100.0	85.0	95.0	%
MI Acceleration (Proton)	88.0	15.1	98.0	85.0	95.0	%
Coalescing (Proton)	81.0	6.4	83.3	76.5	85.5	%
Tev Injection (Proton)	71.8	7.0	73.3	69.6	81.2	%
TEVAcceleration (Proton)	68.3	7.9	70.4	66.1	77.2	%

*Based on 75 Stores between 2/10/03 – 6/5/03

FY03 Collider Efficiencies



Transmission Efficiency

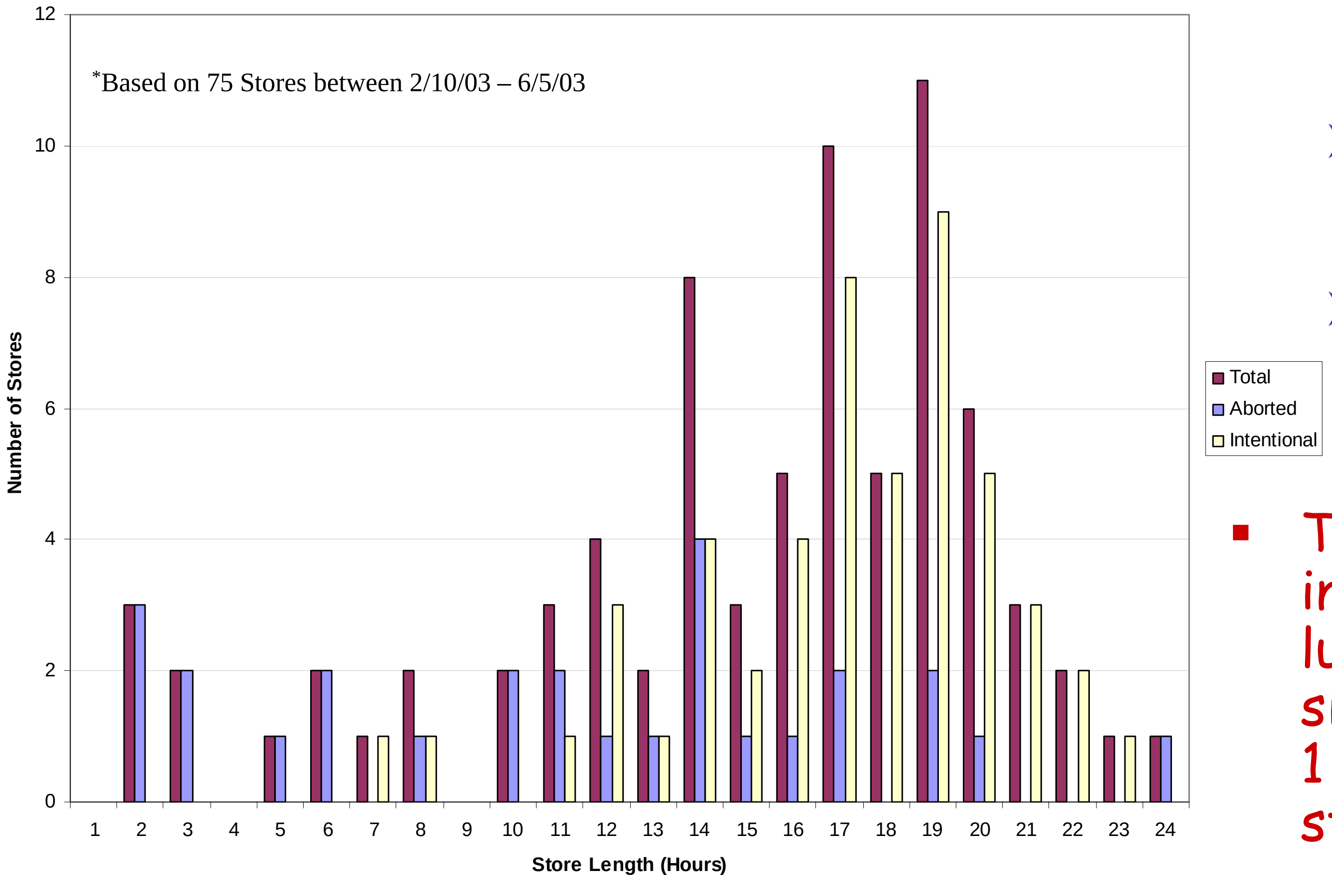
- At first glance, 60% antiproton transmission efficiency from the Accumulator Core to Low Beta seems to be the root of the problem.
- However, the 60% transmission efficiency is composed of many stages of transfers each with relatively good efficiency $60\% = (90\%)^5$
- To improve the transfer efficiency to 75%, the average efficiency of each stage of the pbar transfer must increase from 90% to 95%
- Increasing the pbar transfer efficiency from 60% to 75% will increase the luminosity by a factor of 1.25

Transmission Efficiency

- To increase the transmission efficiency we must:
  - Reduce emittance dilution at injection
    - Injection lattice matching for pbars and protons
      - First pass complete
      - Second pass awaiting study time
    - Injection dampers for pbars
      - To be installed in early FY04
  - Reduce long range beam-beam effects
    - Better TEV Helices
      - Optimized helices at 150 GeV
        - » designed – waiting for study time
      - Bigger and optimized helices up the ramp
        - » designed – waiting for study time
    - Smaller beam sizes
      - Injection lattice matching for pbars & protons

Stack Size and Store Length

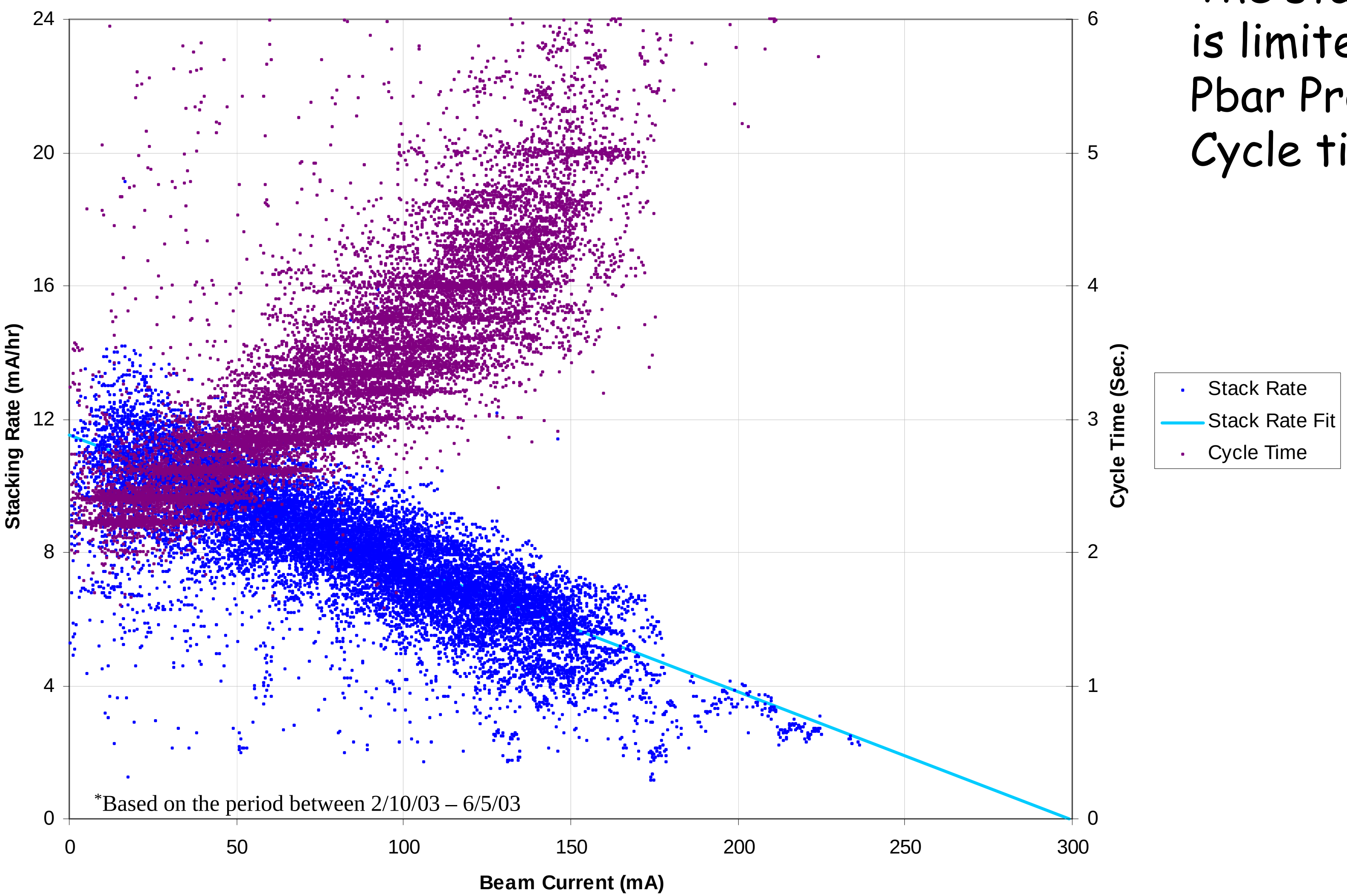
- Our highest luminosities were obtained by shooting from large stacks



- 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 <u>average</u> store length is limited by equipment failure

- The only way to increase the luminosity significantly in Phase 1 is to increase the stacking rate

Pbar Stacking Rate

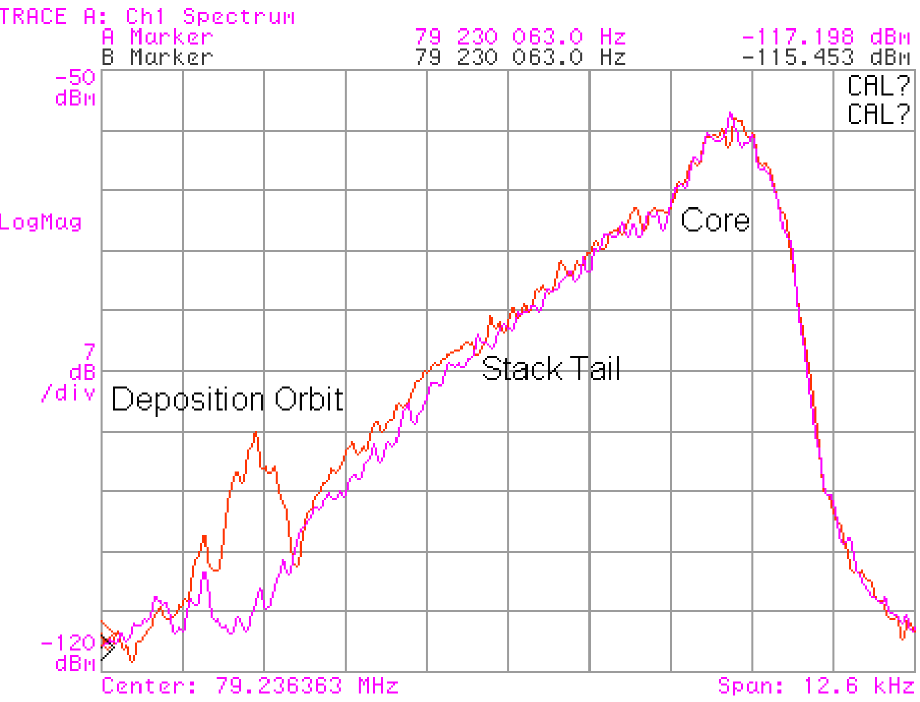


- The stacking rate is limited by the Pbar Production Cycle time

Why is the Cycle Time so Slow?

- Beam must be cleared off the Stacktail deposition orbit before next beam pulse.
  - The more gain the Stacktail has, the faster the pulse will move.

Accumulator Longitudinal Spectrum

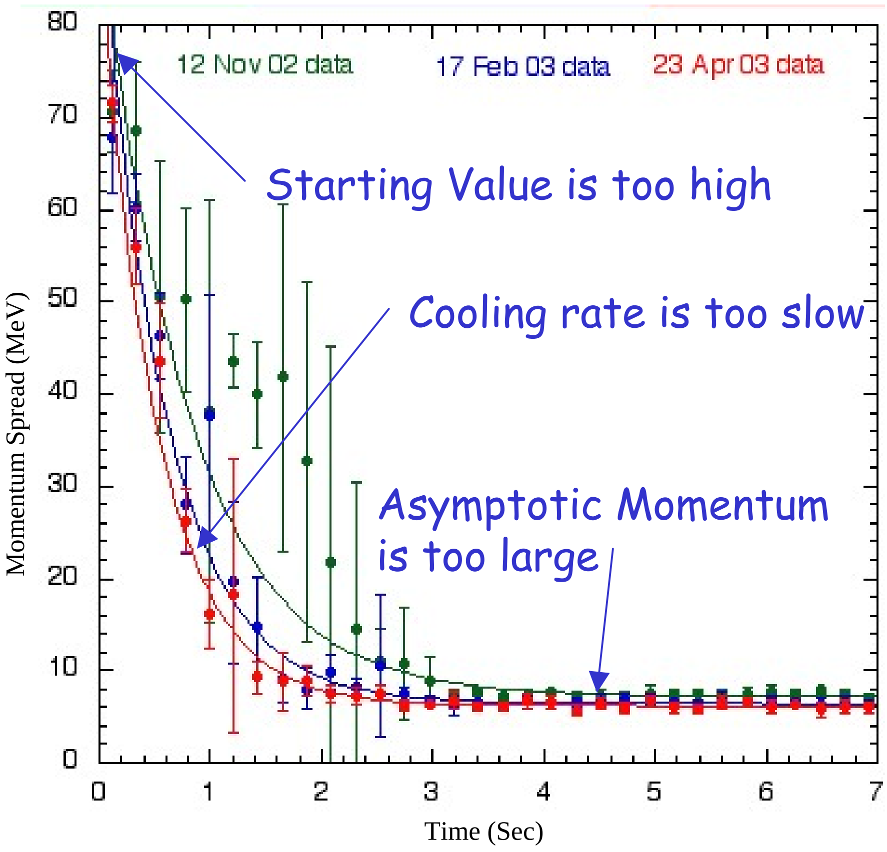


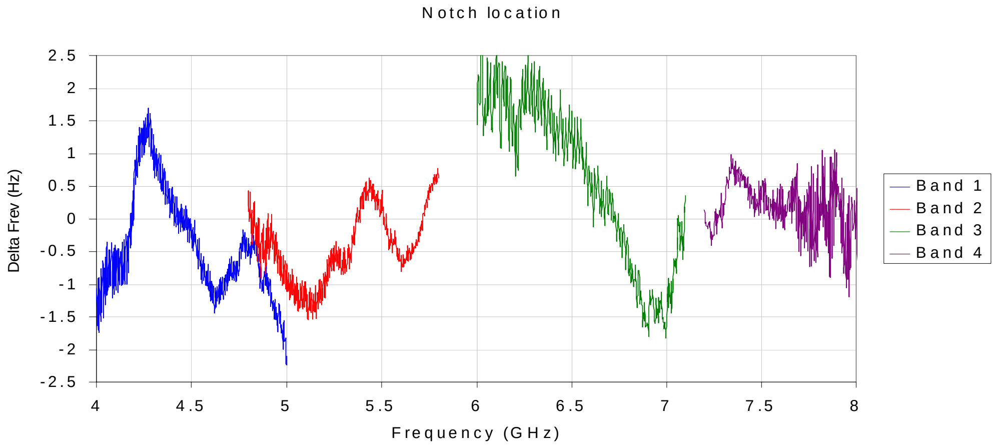
- The Stacktail gain is limited by
  - System instabilities between the core beam and the injected beam
  - Transverse heating of the Stacktail on the core
- As the stack gets larger
  - The instability feedback path grows stronger
  - The core transverse cooling gain is reduced
- The gain of the Stacktail must be turned down to compensate
- The cycle time must increase for the lower Stacktail gain

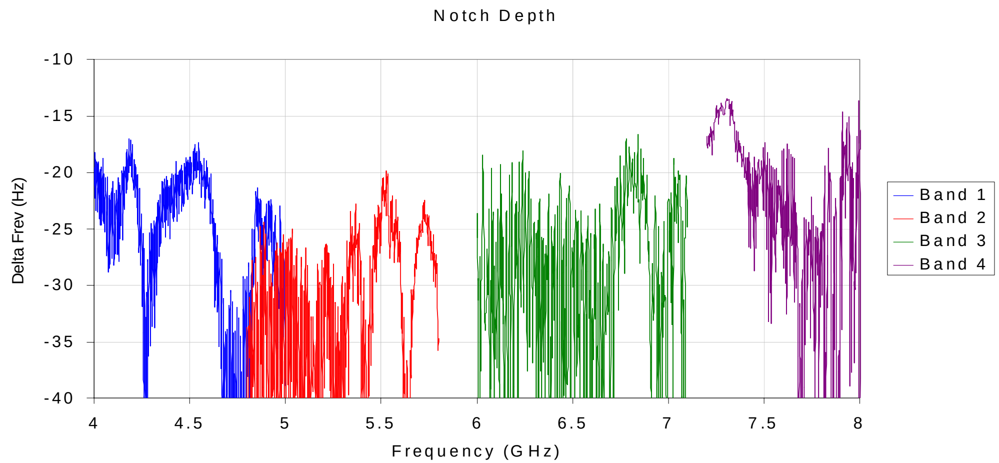
- For a given Stacktail gain, the larger the momentum spread of the injected pulse, the longer it takes to clear the pulse from the Stacktail Deposition orbit.
  - The momentum spread coming from the Debuncher is too large.
    - Bunch length on target
    - Debuncher Cooling rate
    - Debuncher asymptotic momentum

Debuncher Momentum Cooling

- Reducing the Debuncher Momentum Cooling Notch filter dispersion by 33% will permit the zero stack cycle time to be lowered from 2.4 sec to 1.7 sec
  - First iteration complete
  - Second iteration to be installed this shutdown

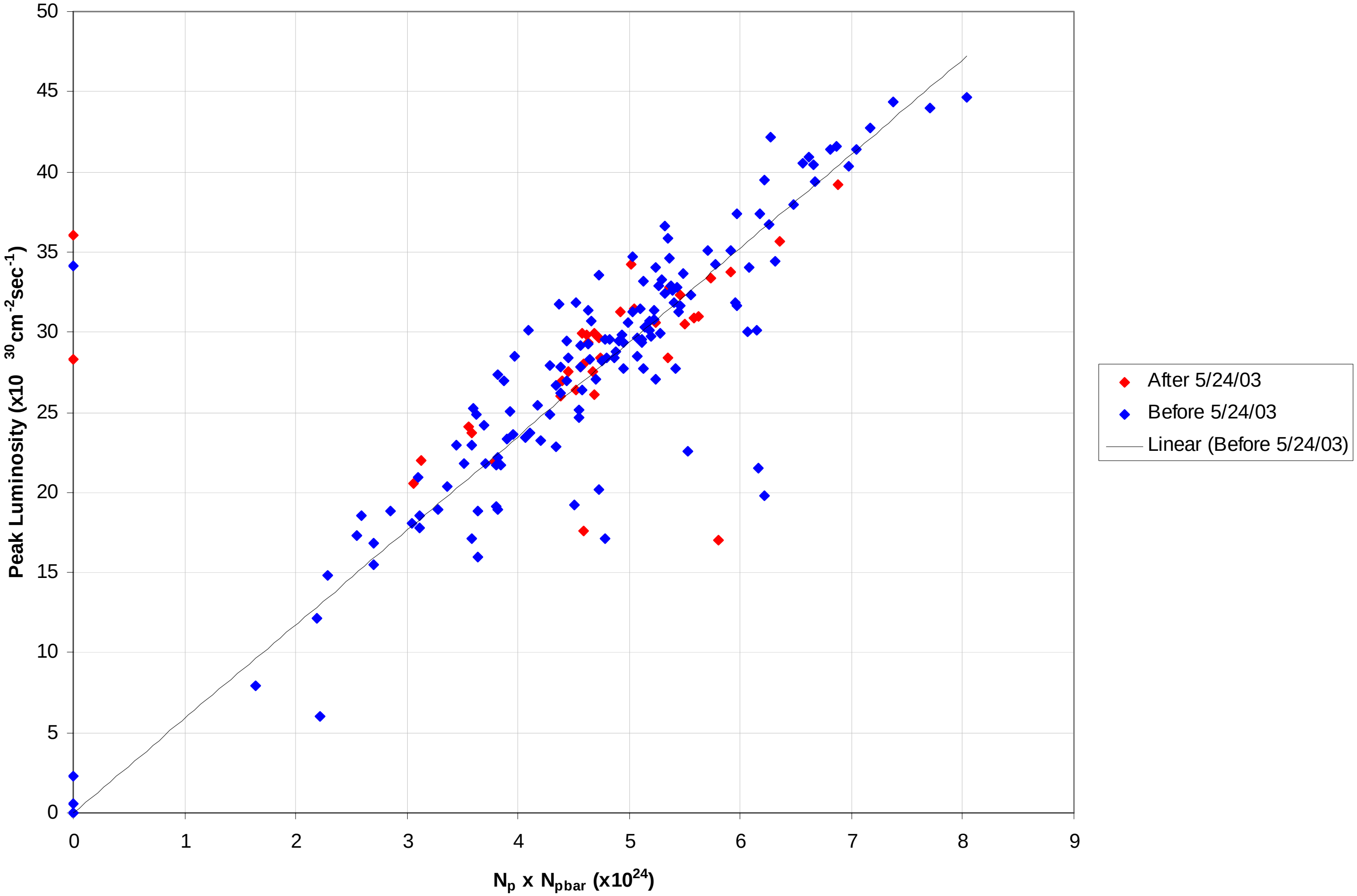






More Protons at Low Beta

- In addition to more pbars, our highest luminosity stores were obtained with large number of protons/bunch

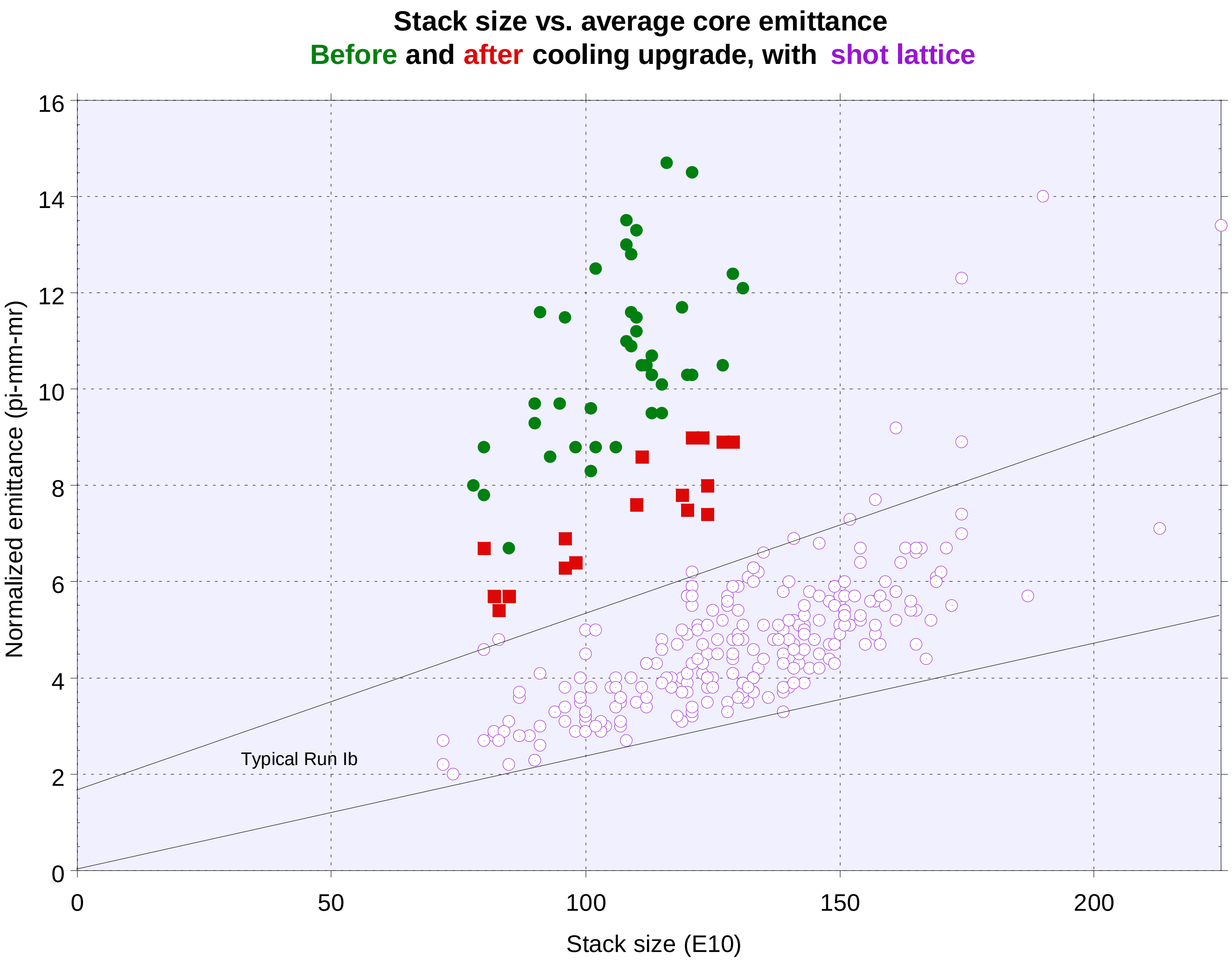


More Protons at Low Beta

- The number of protons in the TEV was increased significantly after the combination of:
  - Transverse dampers installed and commissioned at injection in the TEV
  - The removal of C0 Lambertson
    - Was removed for the purpose of increasing the helix separation
    - Also reduced the transverse impedance of the machine significantly which allowed a substantial reduction in the chromaticity of the machine.
- The F0 Lambertsons now account for a significant amount of the transverse impedance in the TEV
  - A shield will be installed in the F0 Lambertsons this shutdown to reduce the impedance further.
- More protons in the TEV require more protons from the injectors in the same longitudinal phase space
  - Main Injector beam loading compensation – done
  - Main Injector longitudinal dampers – awaiting to be installed

Large Pbar Stacks and Emittances

- Larger Pbar stacks give larger pbar emittances which will
  - exacerbate long range beam-beam effects.
  - Reduce the luminosity per particle



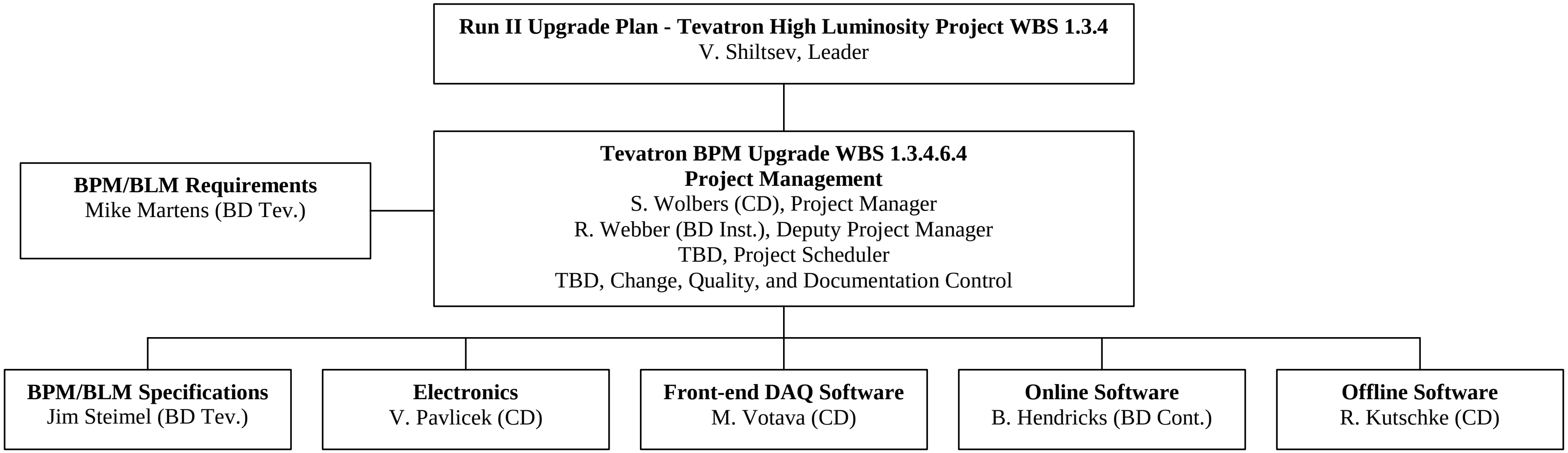
Long Range Beam-Beam

- More protons in the TEV will also exacerbate long range beam-beam effects
- To reduce long range beam-beam effects, the TEV needs :
  - Reduce emittance dilution at injection
    - Injection lattice matching for pbars and protons
      - First pass complete
      - Second pass awaiting study time
    - Injection dampers for pbars
      - To be installed in early FY04
  - Reduce long range beam-beam effects
    - Better TEV Helices
      - Optimized helices at 150 GeV
        - designed – waiting for study time
      - Bigger and optimized helices up the ramp
        - designed – waiting for study time
    - Smaller beam sizes
      - Injection lattice matching for pbars & protons

TEVATRON Reproducibility

- The TEVATRON is a finicky machine to operate.
- We have identified a number of issues that might make the TEVATRON much easier to operate
  - TEV diagnostics
  - TEV coupling
  - TEV alignment
- There is a plan to align the TEVATRON
  - Install a new alignment network (this shutdown)
  - Reduce the coupling by shimming the smart-bolts in ~100 TEV dipoles (this shutdown)
  - Remove the largest magnet rolls
    - Warm or cold (this shutdown) ?
  - Re-align the TEV magnets where needed

TEVATRON Reproducibility



Tevatron BPM Upgrade
Organization Chart

- A new TEV BPM system will be built to aid in orbit control

Summary

- The goal for Phase 1, which ends in November 04, is to increase the peak luminosity by at least a factor of 2.2 over the present average value.
- This will be done by:
  - Faster Stacking – 1.54x
    - More protons on target – 1.06x
    - Better production – 1.13x
      - Orbit control in the Debuncher
    - Faster Pbar cycle time – 1.28x
      - Shorter bunches on target
        - MI beam loading compensation
        - MI longitudinal dampers
      - Better Debuncher notch filters
      - Fixing the stacktail phase crossover
  - More protons to Low Beta – 1.25x
    - F0 Lambertson shielding
    - Injection lattice matching
    - Injection dampers
    - Optimized Helices
    - MI beam loading compensation
    - MI Longitudinal dampers

Summary (continued)

- Higher efficiency and lower emittances to low beta – 1.25x
  - Injection lattice matching
  - Injection dampers
  - Optimized helices

- In addition, we will make the TEV easier to operate by:
  - Aligning the TEV
    - Alignment network
    - Smart Bolt shimming
    - Roll removal
    - alignment
  - Upgrading Instrumentation
    - Building a new BPM system