The Run II Plan

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Outline

- Introduction
- Elements of the Run II Plan
- Current Status
  - Accomplishments
  - Technical Highlights
  - Project Status
- Performance Projections
- Summary

The Run II Plan

- Goal: maximize the integrated luminosity delivered
- Peak Luminosity

$$L = \frac{3\gamma f_0}{\beta^*}(BN_p)\left(\frac{N_p}{\varepsilon_p}\right)\frac{F\left(\beta^*, \theta_{x,y}, \varepsilon_{p,\bar{p}}, \sigma^L_{p,\bar{p}}\right)}{\left(1+\varepsilon_{\bar{p}}/\varepsilon_p\right)}$$

Emittances ε_p, ε_{pbar}, form factor F, β^* provide some gains

But major improvements from bunch intensities

- especially total number of pbars BN_{pbar},
- proton brightness (N_p/ε_p) is constrained by beam-beam tune shift

- Luminosity lifetime (tunes, beam-beam interactions)
- Reliable operation – an essential component, major gains in the last year

Address all via *operational improvements* and *upgrade projects*

The Run II Upgrade Plan
Principal Elements

WBS 1. Luminosity Upgrades

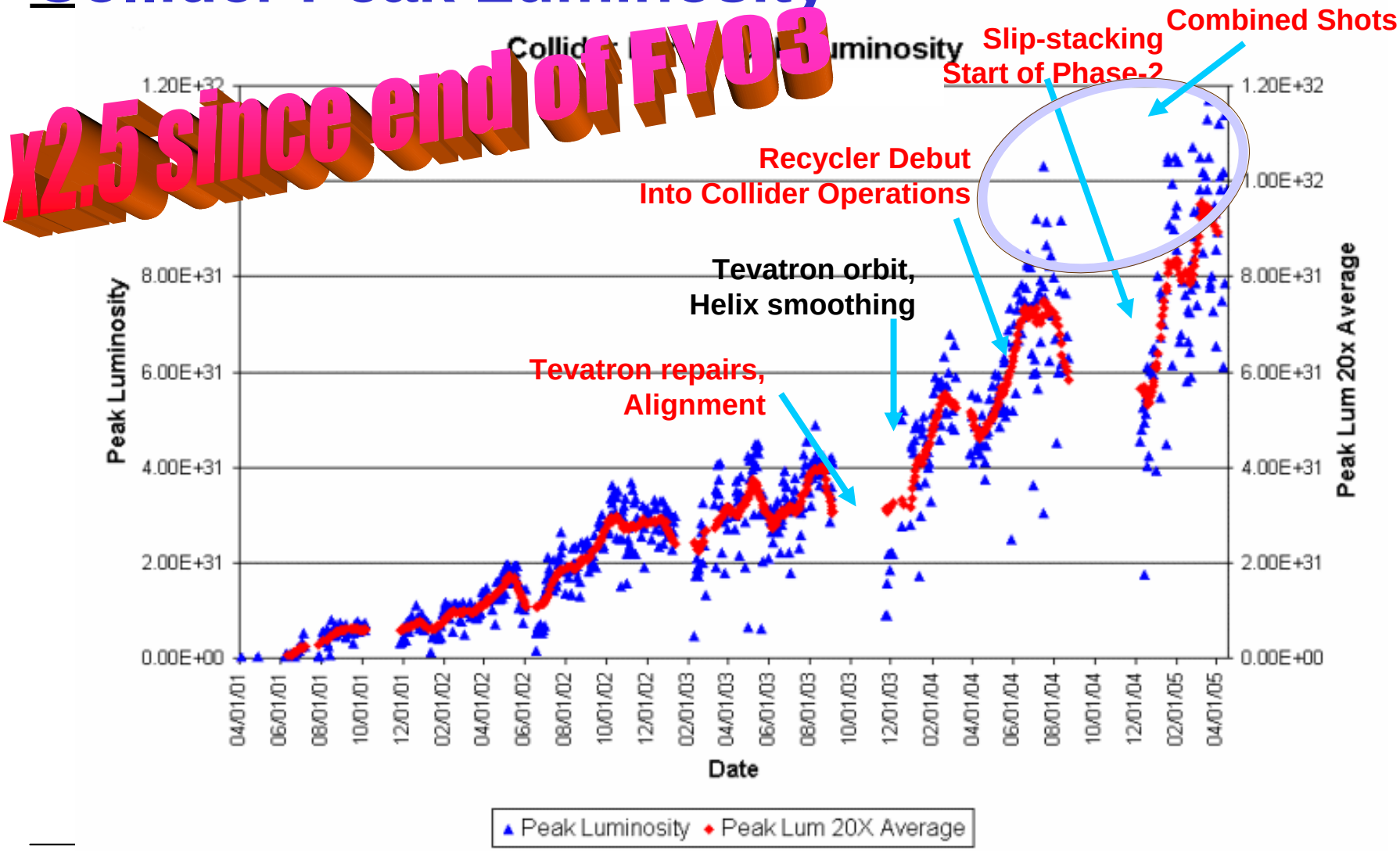
- Increase antiproton production by increasing number of protons on the production target
  - ➔ 1.1 Protons on pbar target (8E12 ppp)
- Increase antiproton collection efficiency
  - Increase the gradient of the antiproton collection lens
  - Increase the aperture of the antiproton collection transfer line (AP2) and the Debuncher ring.
  - ➔ 1.2 Antiproton Acceptance
- Increase the antiproton stacking and storing capabilities
  - Increase the flux capability of the Accumulator stacktail stochastic cooling system.
  - Use the Recycler as a second antiproton storage ring
    - Transfer stacks of pbars from Accumulator to Recycler, periodically
    - Use both stochastic and electron cooling in the Recycler to maintain large stacks of antiprotons with desired beam properties.
  - ➔ 1.3 Antiproton Stacking and Cooling
- Upgrade Tevatron to efficiently handle higher intensity bunches
  - ➔ 1.4 Tevatron High Luminosity

WBS 2. Reliability Upgrades

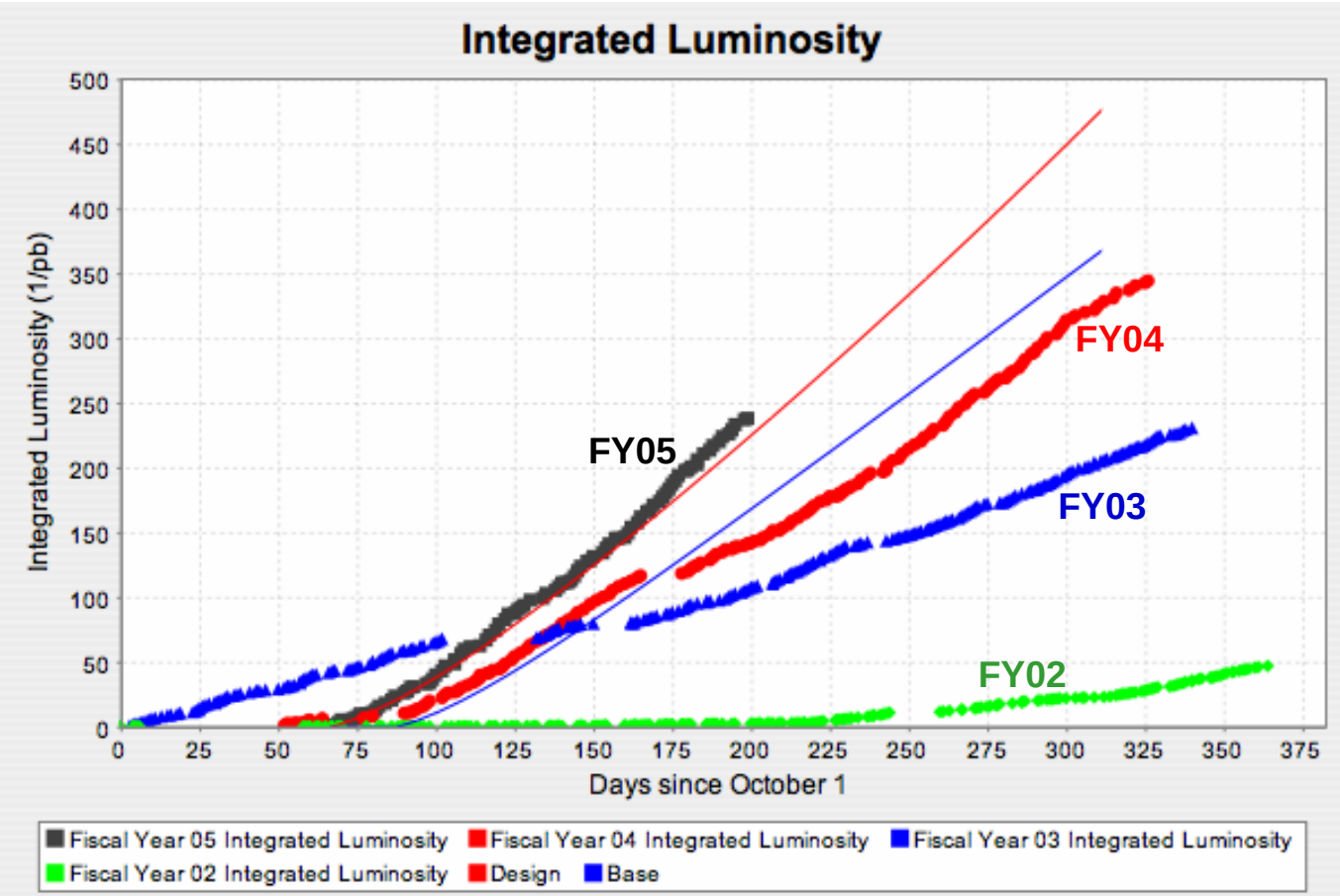
Major Accomplishments

- Reliability Upgrades throughout the complex
  - Tevatron repairs/alignment, VFC card replacements, Linac tubes, Recycler Vacuum
- Operational Improvements
  - Tev helix, orbit smoothing, transfers between machines
- Luminosity Upgrades
  - Recycler commissioned & used as 2nd pbar storage ring
  - E-cool R&D completed; Installed in the Recycler
  - RF upgrades in MI completed and Slip-stacking commissioned
  - Target upgrade and modest aperture improvements in pbar source
  - Helix improvements in the Tevatron with new separators
  - Instrumentation improvements made
  - Started Phase-2 of Run II operations on schedule
- Upgrades hand-in-hand with operations

Run II Upgrades & Collider Peak Luminosity



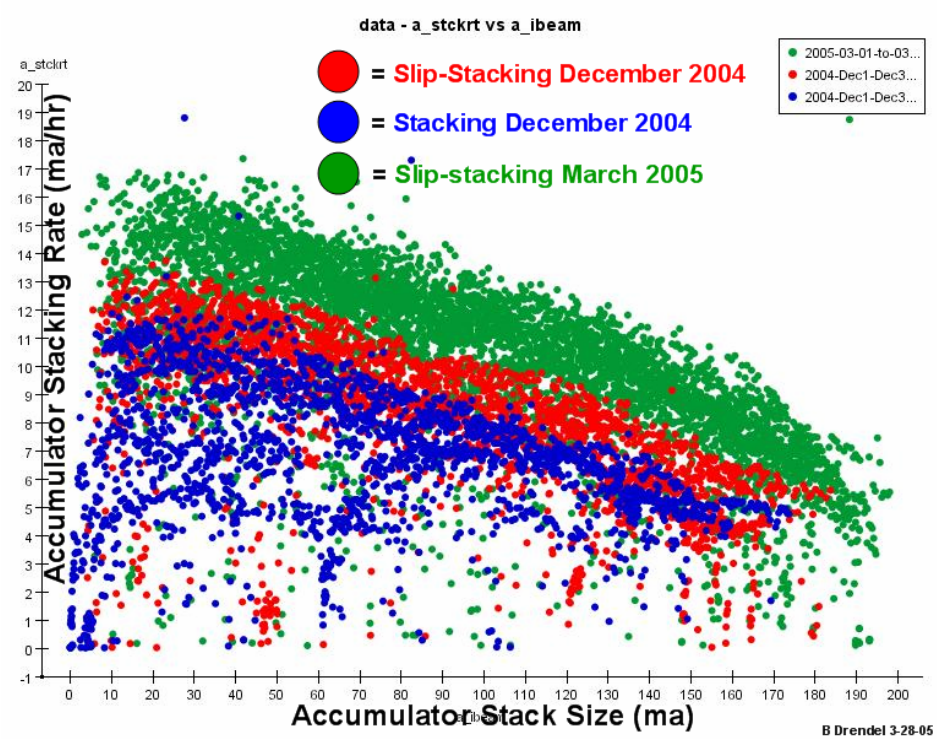
Run II
Integrated luminosity

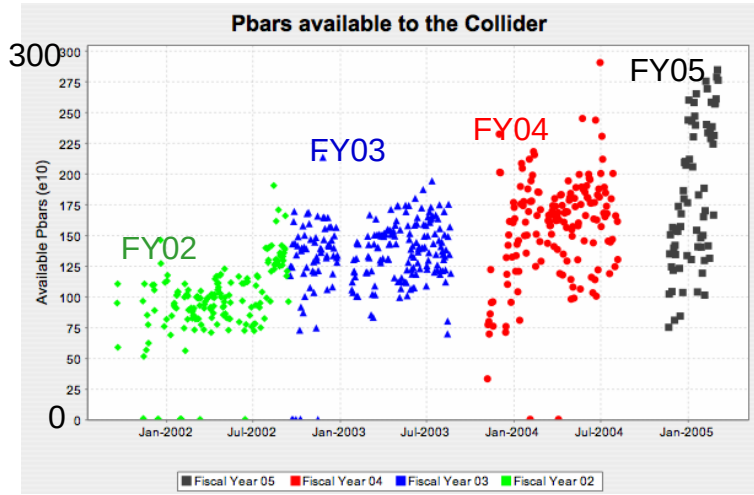


Run II ∫L.dt ~ 900 pb^{-1}

Weekly ∫L.dt Record~21 pb^{-1}

Antiprotons





Since FY04

- Pbar peak stack rate: 13 mA/hr → >16 mA/hr

Technical Highlights

- Digital Dampers in MI commissioned and used in most modes of operation
- New heat-resilient pbar production targets installed in July 2004
- Pbar collection (Lithium) Lens
  - New design complete; bench test of prototype-1 successful; expect to install before the ’05 shutdown
- pbar Source Aperture Improvements
  - Eliminated some physical aperture restrictions by relocations and modifications of identified elements in AP2 and DB
  - Improved Instrumentation/diagnostics in progress
  - Study strategy changed to primarily use stacking cycles instead of reverse protons ← semi-parasitic instead of dedicated
  - Modest improvements in pbar admittance seen

Technical Highlights
The Recycler & e-cooling of Antiprotons

- Recycler commissioned on schedule (June 1, 2004)
- pbar beam from Recycler selectively "momentum mined" for Tevatron shots
- E-cool R&D completed at wide-band lab
- Installation of e-cool equipment in MI-31 and the Recycler tunnel complete
- Commissioning of electron cooling in progress
  - Electron beam circulated in cooling section

Technical Highlights

WBS 1.3 Antiproton Stacking & Cooling

- Stacktail system performing well with stack rates over 16 mA/hr
- Pick-up and Kicker tank designs for stacktail bandwidth upgrade finalized
- Planning tests for bandwidth upgrade, high intensity proton stacking studies and tests of reconfigured stacktail system during Fall 2005.
- Stacktail system upgrade to take place in 2 phases
  - Stacktail reconfiguration (easily reversible)
  - Bandwidth upgrade (not easily reversible)

Technical Highlights

WBS 1.4 Tevatron High Luminosity

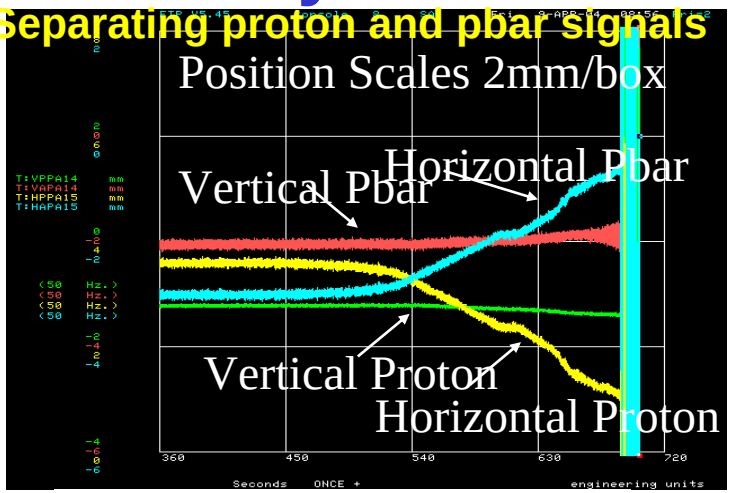
- Tevatron alignment & repairs
  - Re-shimming of dipoles, stand replacements, field measurements, alignment, monitoring system
- Helical orbits and separators
  - 2 additional separators and polarity switches installed in ’04 shutdown and commissioned.
  - 15 - 20% larger separation between p and pbar orbits
  - R&D on HV operation, electrodes in progress
- Active beam-beam compensation
  - Tevatron Electron Lens (TEL) R&D in progress

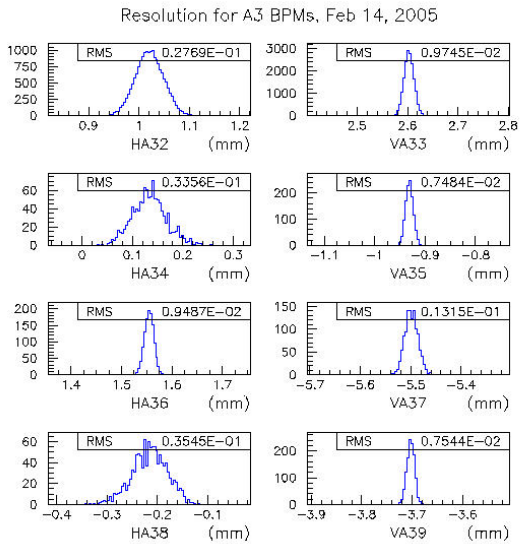
Technical Highlights

WBS 1.4 Tevatron High Luminosity

- Tevatron BPM Project
  - Joint CD/AD effort
  - A major success
  - Project making **very good progress** though completion date has slipped by a few months
  - An order of magnitude improvement in proton position measurements and new for pbars
  - Position resolutions in the range of ~10 -25 μ
  - Will be extremely useful in understanding beams
    - Can see synchrotron and betatron lines, quadrupole oscillations, H-V coupling, etc.
- 85% installed
- ~ 50% connected/ commissioned

Separating proton and pbar signals





Schedule and Strategy Update

- Electron cooling equipment installation complete (Feb. 05)
- Next: Commission electron cooling of pbars in Recycler
  - estimate demo of cooling by September 05
  - (Tentative '05 shutdown 10/3/05)
    start in HEP by end 05 ?
- Need operating experience with electron cooling before installing the bandwidth upgrade in the Stacktail
  - now scheduled for 06 shutdown

→ Mixed source operation (pbars from both Accumulator and Recycler) until e-cooling phased into operation – capitalize on improved reliability

→ Commission rapid transfers: Accumulator → Recycler (end of 05)

→ Phased approach to the Stacktail Upgrade

→ (1) Reconfigure the existing system once e-cool is operational
- ~30E10/hr (x2 margin), core ~ 40-60E10, transfer > hourly to Recycler
- quick to implement and reverse

→ (2) Bandwidth upgrade after e-cool is in stable operation
- ~40E10/hr (x2 margin), core ~ 20-40E10, transfer ~ half-hourly
- major shutdown to install and reverse

Project Status

- Regular reporting at monthly PMG

Status as of March 31, '05

WBS	Name	Actual % Complete (A)	Planned % Complete (P)	A/P %
0	Run II	65%	69%	95%
1	Luminosity Upgrades	67%	72%	93%
1.1	Protons on Pbar Target	74%	75%	98%
1.2	Pbar Acceptance	50%	58%	87%
1.3	Pbar Stacking & Cooling	71%	78%	91%
1.4	Tevatron High Luminosity	69%	73%	95%
1.5	Shutdowns	50%	50%	100%
1.6	Project Management	59%	63%	94%
2	Maintenance & Reliability	54%	51%	104%

M&S Budget

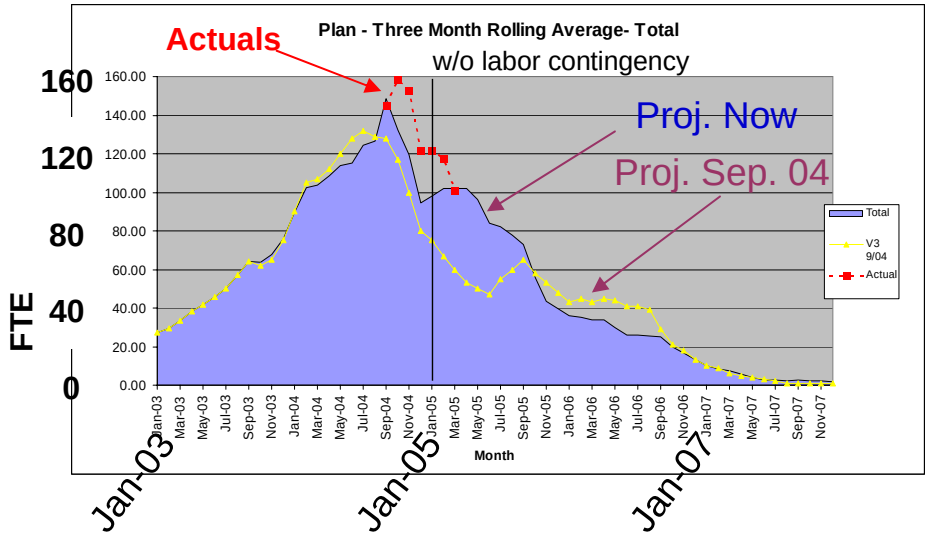
- Budget guidance including contingency = $20,946K FY04-06

M&S in Then Yr $K	FY04	FY05	FY06	Total
Budget Guidance	12,444	7,547	955	20,946

- Base estimate = **$17,587K** (Jan. est.)+$658K (CRs in process)=$18,245K
- Obligations +RIP ~ $12,580 K
- Currently **~45%** contingency on estimate to complete

Labor Profile

- Base labor profile in FTE estimated from RLS
  - FTE=work/0.85
  - w/o labor contingency
- Actuals collected from effort reporting in Divisions
  - Follows the estimate trend
- Features in the new estimate
  - The Jan – Aug 05 hump due to slewing + added new scope
  - Drop for >Sep. 05
    - De-scope in Tev Separators project



Snap-shot for the month of March 05
Actual vs Estimate

Adjusted FTE March 2005		Actual	Plan
		Totals	3 Mo. rolling ave.
Run II Upgrades		**100.9**	**103.5**
1	**Luminosity Upgrades**	**91.6**	**87.6**
1.1	**Protons on Target**	**6.6**	2.3
1.2	**pbar Acceptance**	**6.9**	11.5
1.3	**pbar Stacking and Cooling**	**32.3**	29.7
1.4	**Tevatron High Luminosity**	**42.7**	39.6
1.6	**Management**	**3.1**	4.5
2	**Reliability Upgrades**	**9.3**	**15.9**

Luminosity Projections & Risk Analysis

Luminosity Projections

Our plan is to deliver the Design Projection

But, develop an understanding of fallback scenarios

Mixed-source operation and the phased stacktail upgrade allow more natural introduction of key upgrades (e-cooling and Stacktail upgrades) and provide a more robust fall-back position

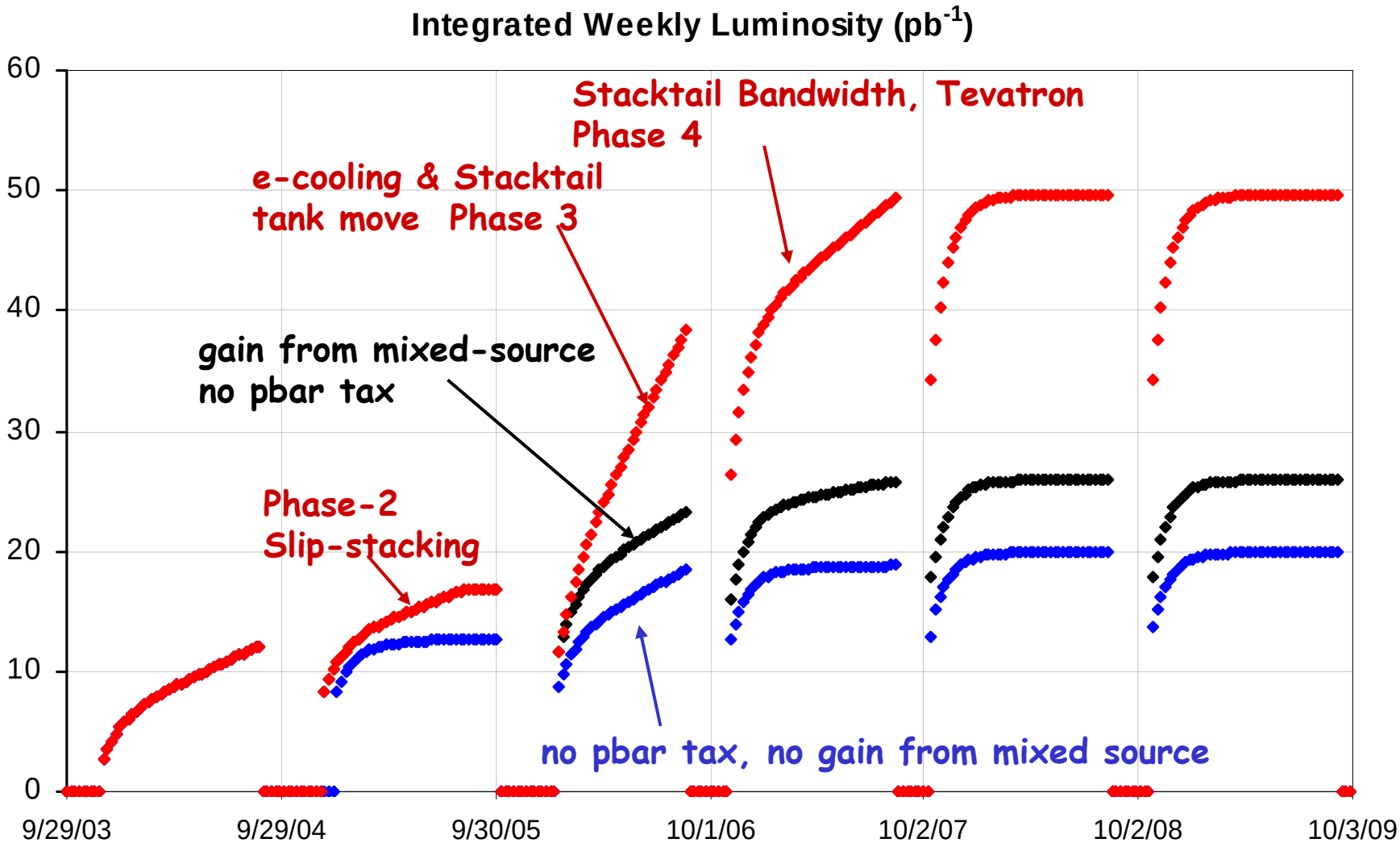
Three Curves

- Design Projection: electron cooling and Stacktail upgrade
- Black Projection: no electron cooling, mixed-source operation beyond 05 (20% gain), Deb→Acc acceptance issues solved
- Blue Projection: no electron cooling, Deb-Acc acceptance only minor improvements and no gain from mixed-source

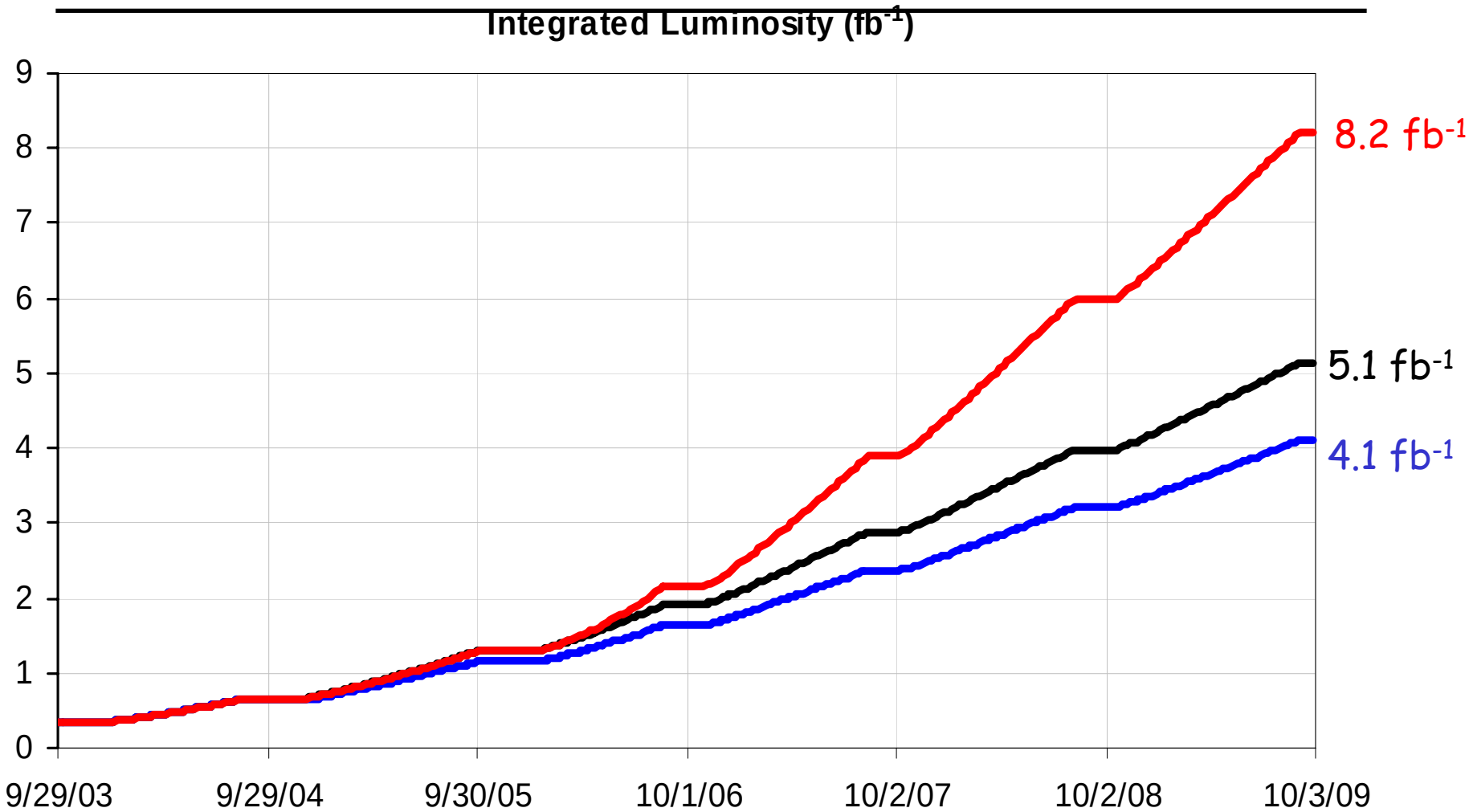
All assume slip stacking and 100 HEP hrs per week average long-term

Latest update: Incorporate the current tentative shutdown schedule for FY05-09

Weekly Luminosity



Integrated Luminosity



Parameters: Design Curve

Phase	2	2	3	4_5	6	
Parameter	FY05 Last 10 stores **	Slip Stacking	Recycler Ecool + Stacktail tank FY07	Stacktail +Helix	Reliability	Units
Initial Luminosity	98	96	219	284	284	$x10^{30} cm^{-2} sec^{-1}$
Integrated Luminosity per week	19	17	38	50	50	pb^{-1}
Average Store Hours per Week	128	100	100	100	100	Hours
Store Length	21.6	20	20	15	15	Hours
Number of Protons per bunch	240	260	260	270	270	$x10^{9}$
Number of Pbars per bunch	37	42	99	131	131	$x10^{9}$
Zero Stack Stacking Rate	14	24	30	46	46	$x10^{10}$/hour
Average Stacking Rate	8	10	22	39	39	$x10^{10}$/hour
Stack Size transferred	200	201	447	589	589	$x10^{10}$
Pbar Production	16	17	21	32	32	$x10^{-6}$
Protons on Target	6.1	8	8	8	8	$x10^{12}$
Pbar cycle time	2	2	2	2	2	Secs.
Pbar up time fraction	0.74	0.75	1	1	1	
A->R Transfer interval			2.5	0.5	0.5	Hours
A->R Transfer efficiency			90	98	98	%
A->R Transfer Time			0.2	0.05	0.05	Hours

**as of 3/25/05

Summary

- Luminosity performance last year has been spectacular
- We are making very good technical progress
- Electron cooling of pbars and stack rate are the biggest technical challenges
- Funding and resource situation is good
- The design luminosity projection is still ~8 fb^{-1} thru 2009
- New phasing of upgrades and mixed-source operation make the fall-back scenarios more robust, >4 fb^{-1}