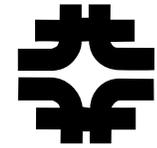


Proton Plan

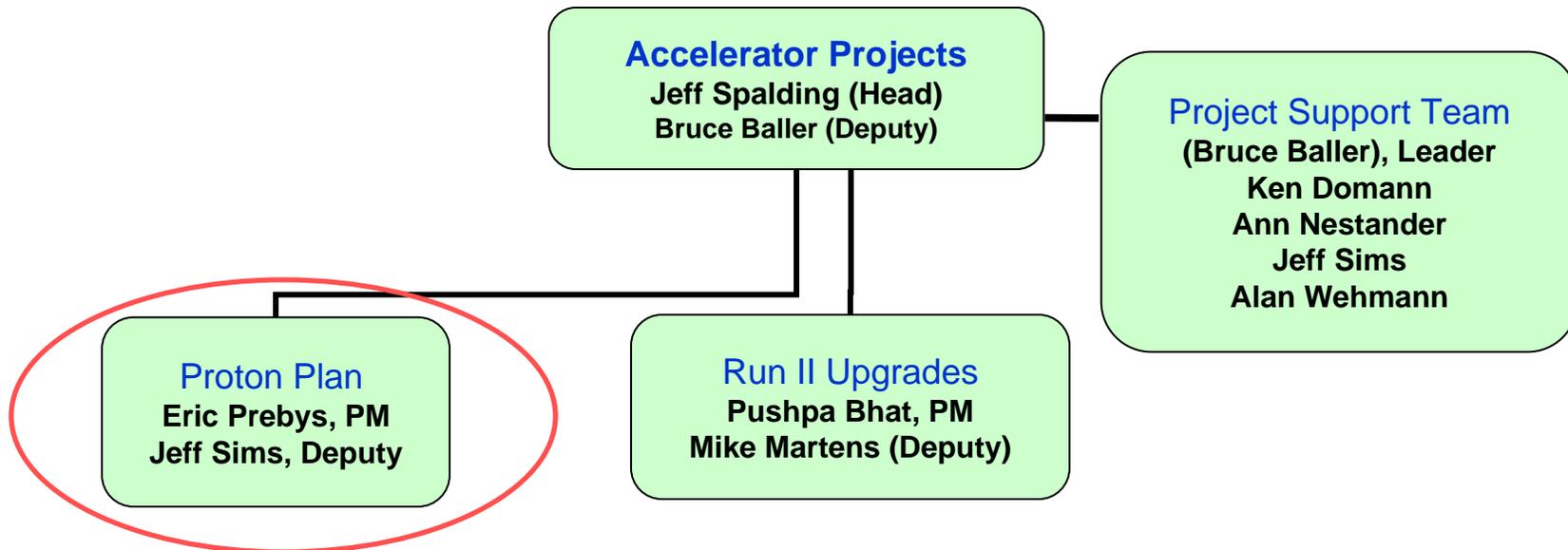
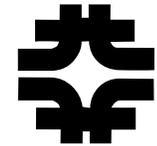
Eric Prebys, FNAL Accelerator Division

Proton Plan Charge



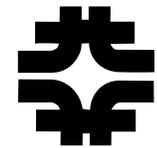
- Develop a plan for a set of upgrades and operational improvements to maximize proton delivery to:
 - NuMI beamline (120 GeV from MI)
 - Booster Neutrino Beam (BNB) (8 GeV from Booster)
- (Original) Goal: complete the upgrades over the next 3 years, and operate through 2015 or beyond
 - This plan precedes the Proton Driver replacement of the existing Proton Source (Linac+Booster).
 - We are currently refining our plans in the wake of the BTeV cancellation.
- Develop the budget and timeline for these improvements
- Estimate projected proton delivery (PoT) to both beam lines

Management Organization



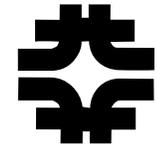
- Benefit from experiences with the Run II plan
- Project support team:
 - Resource-Loaded Schedule (MS Project) – Domann
 - Accounting - Cobra interface to Lab's system - Nestander
 - Project management support – Sims
 - Web and documentation support - Wehmann

Context: Staged Approach to Neutrino Program



- Stage 0 (now):
 - Goal: deliver $2.5E13$ protons per 2 second MI cycle to NuMI ($\sim 2E20$ p/yr)
 - Deliver $1-2E20$ protons per year to Booster Neutrino Beam (currently MiniBooNE)
- Stage 1 (~ 2008):
 - A combination of Main Injector RF improvements and operational loading initiatives will increase the NuMI intensity to $4-5E13$ protons per 2.2 second cycle ($\sim 3E20$ p/yr)
 - This will increase by $\sim 20\%$ as protons currently used for pbar production become available
 - It is hoped we can continue to operate BNB at the $2E20$ p/yr level during this period.
- Stage 2 (post-collider):
 - Consider (for example) using the Recycler as a preloader to the Main Injector and reducing the Main Injector cycle time
 - The exact scope and potential of these improvements are under study
- Stage 3 (proton driver)
 - Main Injector must accommodate $1.5E14$ protons every 1.5 seconds
 - NuMI beamline and target must also be compatible with these intensities.

Limits to Proton Intensity



- Total proton rate from Proton Source (Linac+Booster):
 - Booster batch size
 - Typical $\sim 5E12$ protons/batch
 - Booster repetition rate
 - 15 Hz instantaneous
 - Currently 7.5Hz average (limited by injection bump and RF cooling)
 - Beam loss
 - **Damage and/or activation of Booster components**
 - Above ground radiation
- Total protons accelerated in Main Injector:
 - Maximum main injector load
 - Six “slots” for booster batches ($3E13$)
 - Up to ~ 11 with slip stacking ($5.5E13$)
 - RF stability limitations (currently $\sim 4E13$)
 - Cycle time:
 - 1.4s + loading time (1/15s per booster batch)

Operational
Limit

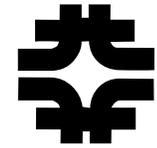
Plan Strategy



See document: BEAMS-DOC-1441 (11/09/04) at
<http://beamsdocs.fnal.gov/cgi-bin/public/DocDB/DocumentDatabase>

- **Increase the proton delivery from the Booster (to both NuMI and BNB)**
 - Increase acceptance by improving orbit control and beam quality
 - Increase maximum average Booster repetition rate
- **Increase the beam intensity in the Main Injector for NuMI**
 - Main Injector multi-batch operation
 - Slip stacking in Main Injector (probably requires RF upgrade)
- **Improve operational reliability**
 - Alleviate 7835 Problem
 - Linac quad supplies

Current Budget Guidance



- After the cancellation of BTeV, we have the following budget guidance (M&S+SWF):

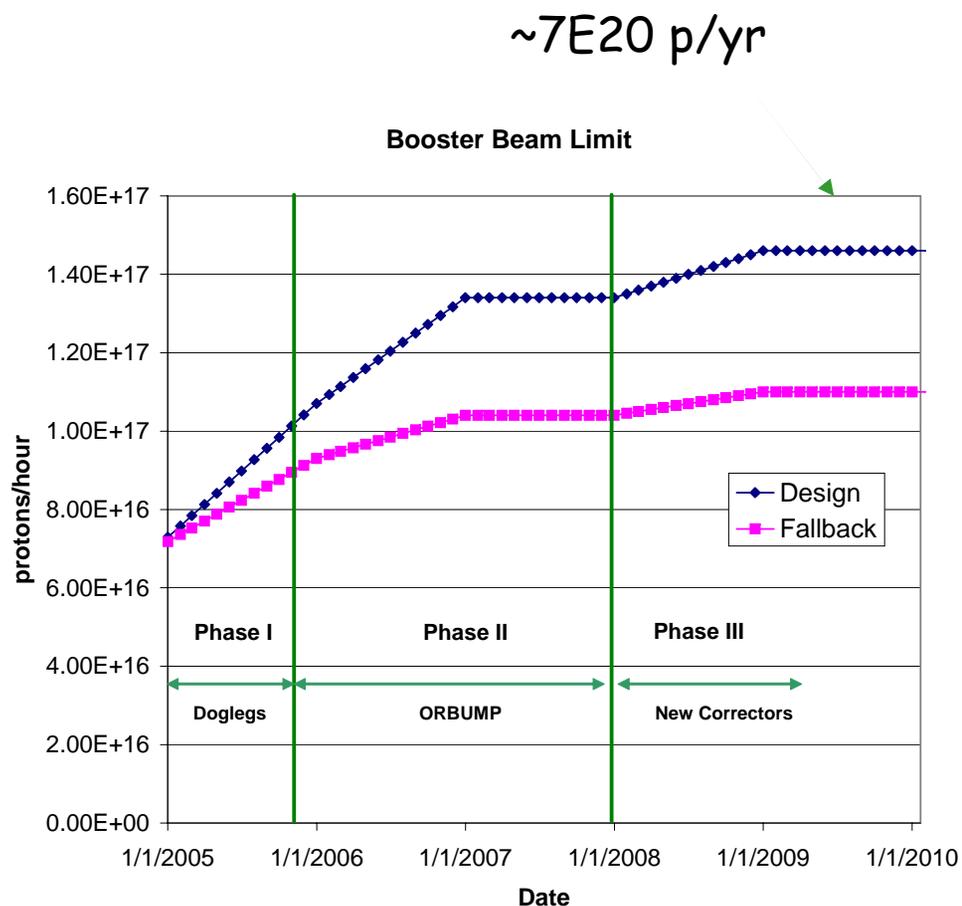
	FY05	FY06	FY07	FY08	Total
Present Guidance	7327	7845	6915	6116	28203

- This results in a scenario very close to the “delayed” scenario in the original document.

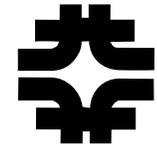
Booster Throughput



- Major Improvements:
 - New ORBUMP system (2005 shutdown)
 - Relocate L13 dump to MI-8 line (2005 shutdown)
 - New corrector system (2007)
 - 19th and 20th cavities added
- Performance
 - Rep rate (after 2005)
 - 7.5 Hz -> 8-9 Hz
 - Total protons (by end 2008)
 - 8E16 pph -> 1.45E17 pph
 - Batch size (by end 2008):
 - 5E12 -> 5.5E12

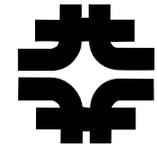


Main Injector Loading

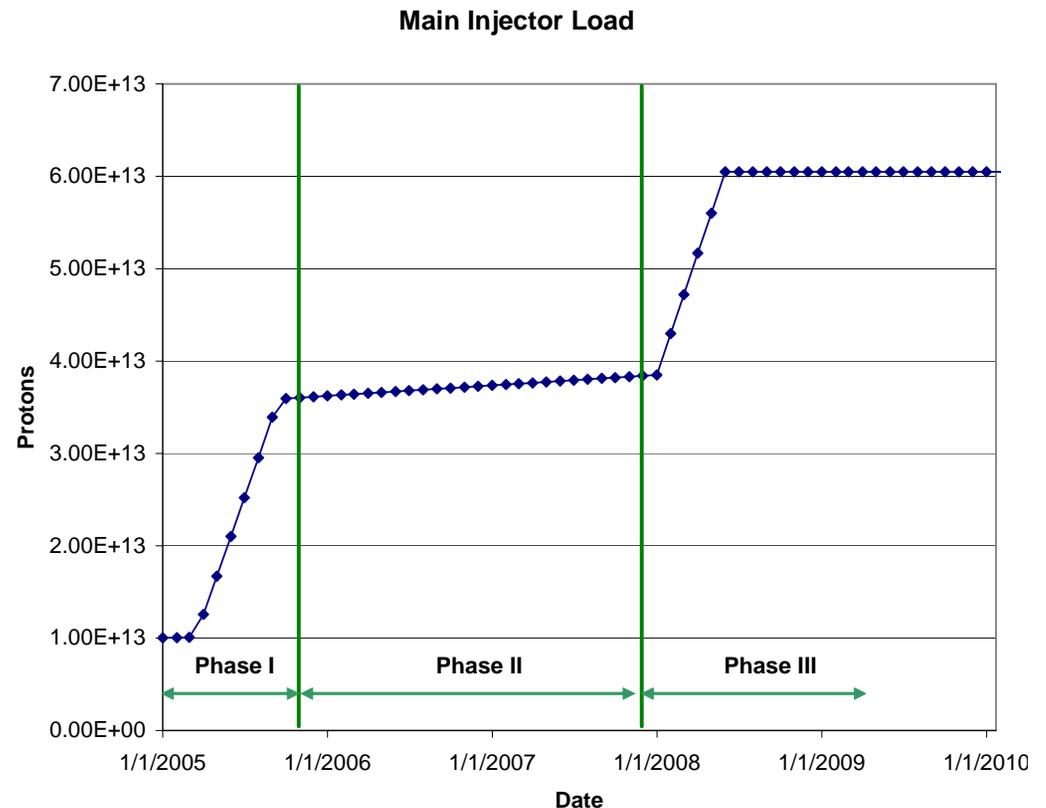


- Initial NuMI operation (“2+5”):
 - Two batches are slip stacked for antiproton production
 - Five more batches loaded for NuMI
 - All are accelerated together
- Ultimate NuMI operation (“2+9”):
 - Five batches will be loaded into the Main Injector, leaving one empty slot
 - Six more batches will be loaded and slipped with the first to make two for antiproton production and 9 for NuMI
 - This may exceed the capacity of the current RF system

Main Injector Loading (cont'd)



- Major Improvements:
 - Large Aperture Quads (2005 shutdown)
 - Loss monitoring and collimations system (TBD)
 - Multi-batch operation
 - Dual PA upgrade (??)
- Performance
 - 2 (pbar) + 5 Numi 5E12 batches @ 2 sec in 2005
 - 2 (pbar) + 9 NuMI 5.5E12
 - Batches @ 2.2 sec in 2008

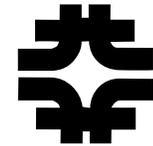


Recent Scope Changes



- Criteria to be in plan (one of following):
 - Critical path to plan goals.
 - Expensive (>\$200K)
 - Requires significant coordination across departments
- Descoped:
 - Instrumentation upgrades
 - However, it is hoped we can pursue instrumentation upgrades within department budgets, now that the proton plan has absorbed some of the burden.
 - Booster solid state RF
- Added (proposed):
 - Booster dump relocation
 - New booster notcher
 - Main Injector injection kicker mods
 - Pbar extraction kicker mods
 - Stage II working group

Proton Plan Schedule - Level 3 Summary



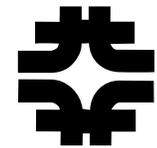
WBS	Name	Start	Finish	2004	2005		2006		2007		2008		2009	
					H2	H1	H2	H1	H2	H1	H2	H1	H2	
1	Proton Plan	Thu 9/30/04	Tue 9/30/08											
1.1	Linac Upgrades	Wed 12/15/04	Tue 1/2/07											
1.1.1	Linac PA Vulnerability	Wed 12/15/04	Mon 3/20/06											
1.1.2	Linac Quad Power Supplies	Mon 1/3/05	Tue 1/2/07											
1.1.3	Linac Instrumentation Upgrade (descoped)	Mon 5/2/05	Fri 9/30/05											
1.2	Booster Upgrades	Thu 9/30/04	Tue 10/16/07											
1.2.1	Determine Rep Rate Limit	Mon 5/2/05	Fri 7/29/05											
1.2.2	OrBump System	Thu 9/30/04	Fri 12/9/05											
1.2.3	Corrector System	Tue 1/4/05	Tue 10/16/07											
1.2.4	30 Hz Harmonic	Mon 1/3/05	Tue 10/3/06											
1.2.5	Gamma-t System	Mon 5/2/05	Fri 9/30/05											
1.2.6	Alignment Improvements	Mon 5/2/05	Fri 9/29/06											
1.2.7	Drift Tube Cooling	Tue 1/4/05	Mon 11/14/05											
1.2.8	Booster RF Cavity #20	Mon 10/3/05	Wed 9/27/06											
1.2.9	Booster Solid State RF Pas (descoped)	Fri 4/1/05	Fri 4/1/05											
1.2.10	Booster Instrumentation Upgrade (descoped)	Mon 5/2/05	Fri 9/28/07											
1.2.11	Booster Dump Relocation	Fri 4/1/05	Mon 11/21/05											
1.2.12	Booster Chopper	Mon 5/2/05	Fri 4/28/06											
1.3	Main Injector Upgrades	Thu 9/30/04	Tue 7/1/08											
1.3.1	Large Aperture Quads	Thu 9/30/04	Thu 12/1/05											
1.3.2	Main Injector Collimation System	Tue 2/1/05	Mon 12/4/06											
1.3.3	NuMI Multibatch Operation	Mon 2/7/05	Tue 1/2/07											
1.3.4	Main Injector RF Upgrade	Tue 3/1/05	Tue 7/1/08											
1.3.5	MI Instrumentation Upgrades (descoped)	Wed 6/1/05	Mon 11/7/05											
1.4	Management	Mon 5/2/05	Tue 9/30/08											
1.5	Proton Study Group	Fri 4/1/05	Fri 3/31/06											

All Milestones



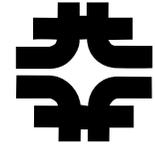
WBS	Name	Finish	2004		2005		2006		2007		2008		2009
			H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	
1.1.1.1.2	Linac Task Force Phase 1 Report Issued	Mon 2/14/05			2/14								
1.3.4.1.6	Review MI RF Upgrade Prototype Test (Internal)	Thu 5/26/05					5/26						
1.3.2.1.2.2	Review Concept for MI-8 Collimation System	Tue 5/31/05					5/31						
1.5.2	Submit Preliminary Proton Study Group Report	Wed 6/1/05					6/1						
1.1.1.1.4	Linac Task Force Phase 2 Report Issued	Thu 6/30/05					6/30						
1.1.2.1.5	Linac Quad Power Supplies Design & Dwgs Complete	Fri 7/1/05					7/1						
1.2.2.1.2.6	OrBump Magnets Ready for Install on Girder	Fri 7/1/05					7/1						
1.2.2.1.3.4	OrBump Stripline Assy Complete	Mon 8/1/05					8/1						
1.2.2.1.4.5	OrBump Girder Assy Complete	Tue 8/9/05					8/9						
1.2.2.2.10	OrBump Power Supply Ready for Installation	Fri 9/30/05					9/30						
1.2.4.1.1	30 Hz Harmonic Project Decision	Mon 10/31/05					10/31						
1.4.5	Start 2005 Shutdown	Tue 11/1/05					11/1						
1.5.3	Submit Final Proton Study Group Report	Tue 11/1/05					11/1						
1.3.2.1.2.7	MI-8 Collimators Installation Complete	Mon 11/7/05					11/7						
1.3.3.1.3.1.4	Barrier Bucket Cavity Installation Complete	Mon 11/14/05					11/14						
1.2.11.3.10	Booster Dump Relocation Installation Complete	Tue 11/15/05					11/15						
1.3.1.1.7.5	Large Aperture Quad P.S. Installation Complete	Mon 11/21/05					11/21						
1.3.2.1.3.2	Review Concept for MI Collimation System	Mon 11/28/05					11/28						
1.2.3.3.3	Corrector PS Design Complete	Tue 11/29/05					11/29						
1.3.1.1.6.3	Large Aperture Quads Align/Install Complete	Thu 12/1/05					12/1						
1.2.2.1.6.6	OrBump System Installation Complete	Fri 12/9/05					12/9						
1.4.6	Finish 2005 Shutdown	Tue 1/3/06					1/3						
1.3.4.1.5	Review MI RF Upgrade Plan	Thu 2/2/06					2/2						
1.2.3.1.5	Corrector Prototype Magnet Complete	Mon 2/20/06					2/20						
1.1.2.2.2.5	Linac Quad Tank #1 Commissioning Complete	Tue 3/14/06					3/14						
1.1.1.1.6	Linac Task Force Complete	Mon 3/20/06					3/20						
1.2.8.1.3.4	RF Cavity #20 Misc Control Modules Ready for Installation	Fri 5/5/06					5/5						
1.4.7	Start 2006 Shutdown	Mon 8/7/06					8/7						
1.2.8.1.4.5	RF Cavity #20 Solid State Driver Amplifier Ready for Installation	Mon 8/21/06					8/21						
1.2.8.1.1.4	RF Cavity #20 Ferrite Bias Supply Ready for Installation	Wed 9/13/06					9/13						
1.2.8.1.2.5	RF Cavity #20 Misc Control Modules Ready for Installation	Wed 9/13/06					9/13						
1.3.2.1.3.7	MI Collimation System Install/Align Complete	Wed 9/20/06					9/20						
1.2.8.1.7	RF Cavity#20 Installation Complete	Wed 9/27/06					9/27						
1.2.4.2.4	30Hz Installation Complete	Tue 10/3/06					10/3						
1.4.8	Finish 2006 Shutdown	Tue 10/3/06					10/3						
1.3.4.2.7	DOE Approve MIE Line Item Package	Mon 10/30/06					10/30						
1.3.2.1.4	Main Injector Loss Mitigation Complete	Mon 12/4/06					12/4						
1.1.2.2.3.4	Linac Quad Installation Complete	Tue 1/2/07					1/2						
1.2.3.4.5	Corrector PS Fabrication Complete	Tue 1/30/07					1/30						
1.2.3.2.8	Corrector Magnets Ready for Installation	Thu 6/21/07					6/21						
1.4.9	Start 2007 Shutdown	Mon 8/6/07					8/6						

Main Injector RF (1.03.04)



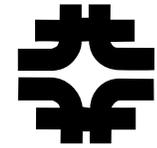
- The Main Injector Upgrade path remains the single largest uncertainty in the Proton Plan
 - Might be possible to reach intensities of the current Plan without upgrades of any kind.
 - Represents ~half the budget!!!
- Towards a decision
 - Proceed with two/PA prototype
 - Proceed with systematic studies in the Main Injector
 - Organize a workshop this summer
 - Will consider the following
 - Potential of feed forward system
 - Potential and concerns with two PA solution
 - New RF system proposals.
 - Will coordinate needs of current plan, Stage II Plan, and Proton Driver
 - Generate a performance/price table
 - Goal: reach a decision for Stage I by end of FY05

200 MHz Power Tube (7835) Situation



- The 7835's have been a historical weak spot in the complex
 - Original technology
 - Made by one company (Burle) which has had major quality control issues
 - Often been forced to borrow spares from ANL, LANL, and BNL to keep program going.
- The Proton Plan includes a working group to evaluate the 7835 situation
 - Short term
 - Maximize delivery of tubes to provide a two year supply of spares by end of 2006
 - Determined best way was a single, large order
 - Longer term
 - Generate a plan should the supply of 7835's cease
 - Build them ourselves?
 - New tube?
 - Multibeam 200 MHz klystron?
 - New low energy linac?
 - These solutions will be beyond the scope of this plan, but we want to have them in place by 7/1/05

Recent Developments with Burle

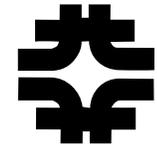


- **Burle has been sold!!!!**
 - Buyer still confidential, but “foreign”, so must be approved by the government
 - Rumored to “sort of” have “something to do” with “tubes” already
 - might mean test tubes, tube socks, tube tops, etc.
 - Must continue to support coaxitron for the Navy until ~2020
 - In light of that, it is claimed that we are still profitable.
 - We will keep our fingers crossed.
- Present spares: 4 (+1 high hour tube)
- Current delivery schedule (21 total):
 - APR-05: 1
 - MAY-05: 3
 - JUN-05: 3
 - JUL-05: 2
 - AUG-05: 0
 - SEP-05: 2
 - OCT-05: 2
 - NOV-05: 2
 - DEC-05: 2
 - JAN-06: 2
 - FEB-06: 2

Standard order (4 new + 5 rebuilds)

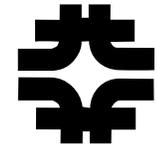
Proton Plan order (all new)

Major Projects for 2005 Shutdown



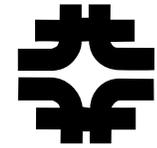
- Linac
 - New pulsed power supplies for one tank
- Booster
 - New injection bump (ORBUMP) system
 - Relocate Long 13 dump to MI-8 line
- Main Injector
 - Install seven large aperture quads

Proton Projections



- Phases of Operation
 - Phase I (now)
 - Booster lattice distortions ameliorated
 - Booster limited to 7.5Hz total repetition rate
 - Main Injector limited to $4E13$ protons (2+5 operation)
 - Phase II (after 2005 shutdown)
 - Injection bump (ORBUMP) replaced
 - Drift tube cooling in Booster RF cooling finished
 - Booster capable of 8-9Hz operation
 - MI still limited to 2+5 operation
 - Phase III (after 2007 shutdown)
 - MI RF upgrade complete
 - 2+9 operation to NuMI

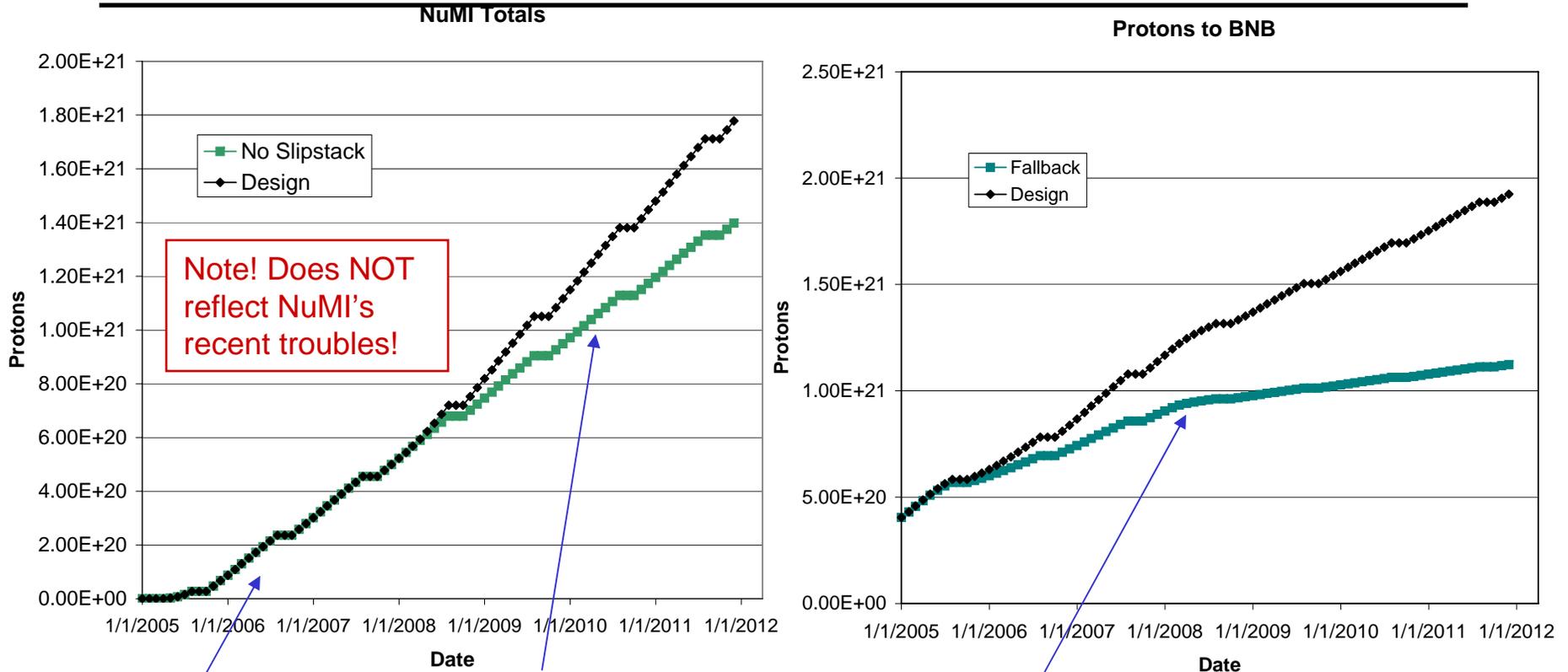
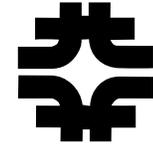
“Design” PoT from the document



	Booster Batch Size	Main Injector Load	Cycle Time	MI Intensity	Booster Rate*	Total Proton Rate	Annual Rate at end of Phase	
		(AP + NuMI)	(sec)	(protons)	(Hz)	(p/hr)	NuMI	BNB
Actual Operation								
July, 04	5.0E+12	1+0	2.0	0.5E+13	5.1	0.8E+17	0	3.3E+20
Proton Plan								
Phase I	5.10E+12	2+1→2+5	2.0	3.6E+13	6.3	1.0E+17	2.0E+20	1.5E+20
Phase II	5.3E+12	2+5	2.0	3.7E+13	7.5	1.2E+17	2.2E+20	2.8E+20
Phase III	5.50E+12	2+9	2.2	6.0E+13	8.3	1.5E+17	3.4E+20	2.2E+20
Beyond Scope of Present Plan								
11 Hz	5.50E+12	2+9	2.2	6.1E+13	11.0	2.0E+17	3.4E+20	5.0E+20

Each phase evaluated ~one year after associated improvements complete

Long Term Projections

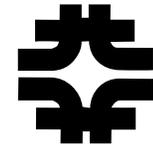


How are we doing so far?

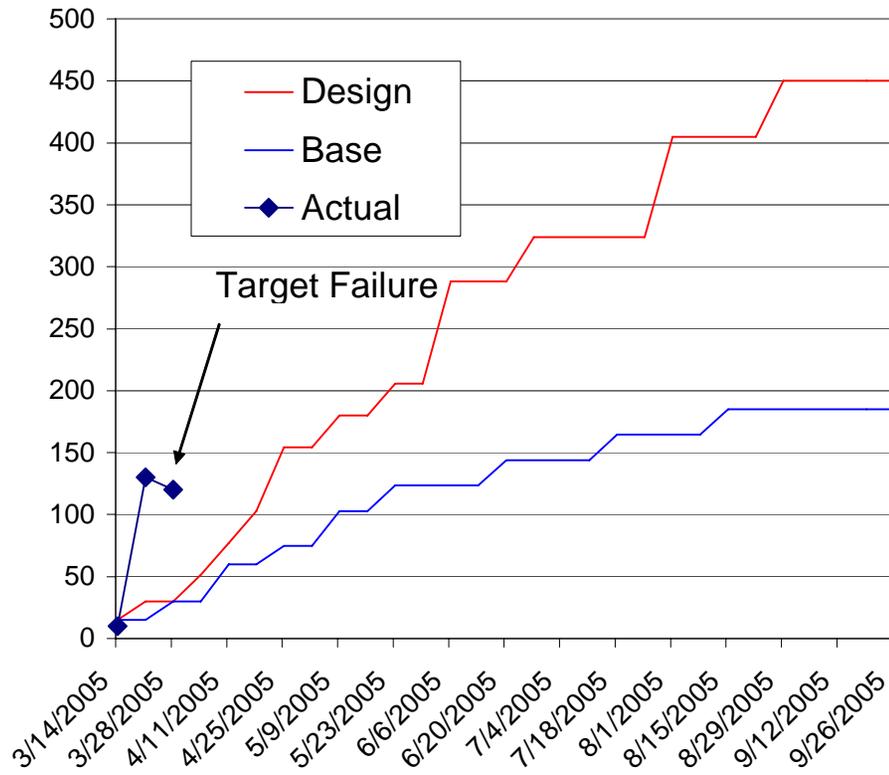


- In light of the NuMI target failure, it's not meaningful to analyze separate NuMI and BNB progress separately.
- After summarizing initial NuMI performance, we will concentrate on total proton delivery:
 - Hourly rates: compare actual total rate to pbar+BNB+NuMI projections.
 - Integrated total: compare MiniBooNE actual to BNB+NuMI projections.
- Except for shutdown dates, these have not changed for 2005 since the November document.

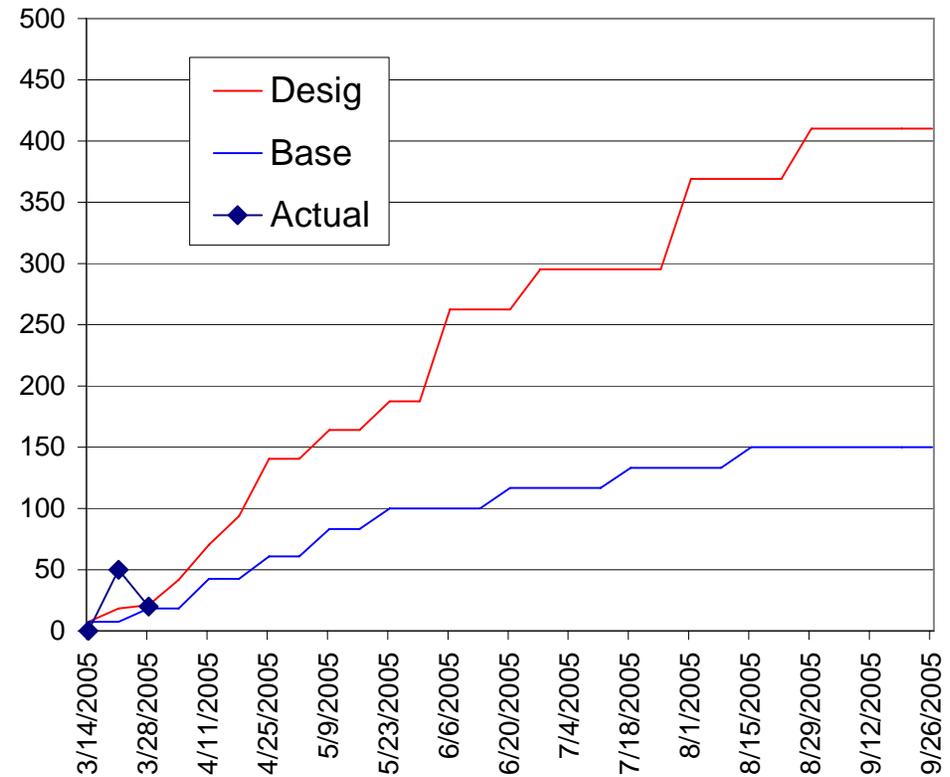
Initial NuMI Progress



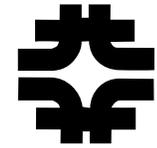
NuMI PoT per Hour (E14)



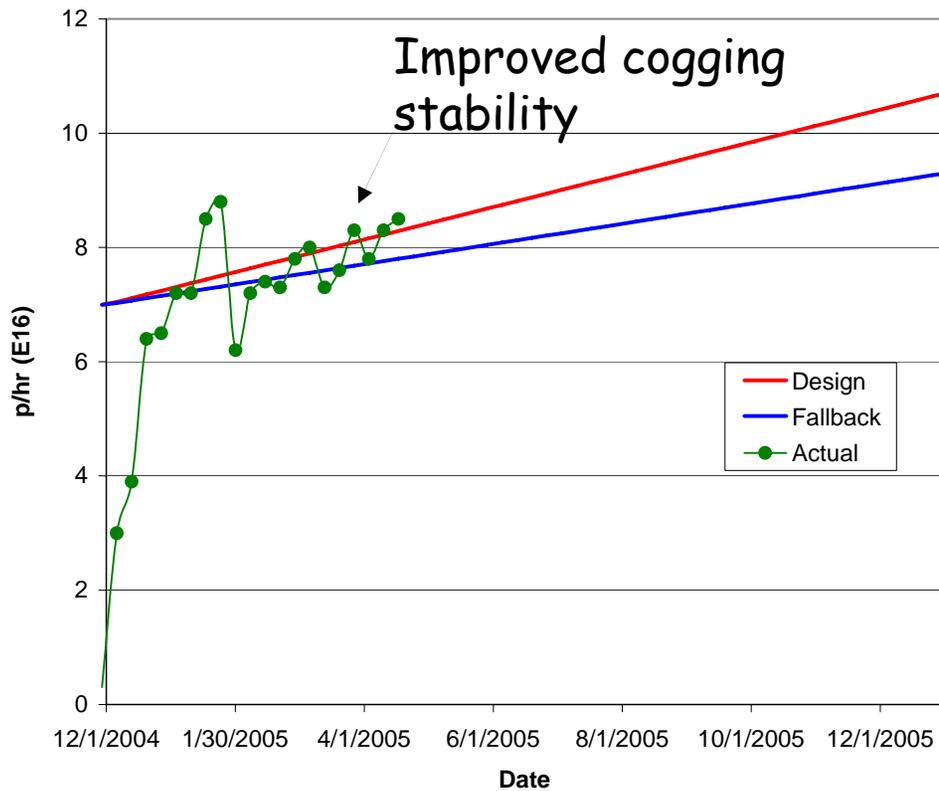
PoT per Week (E16)



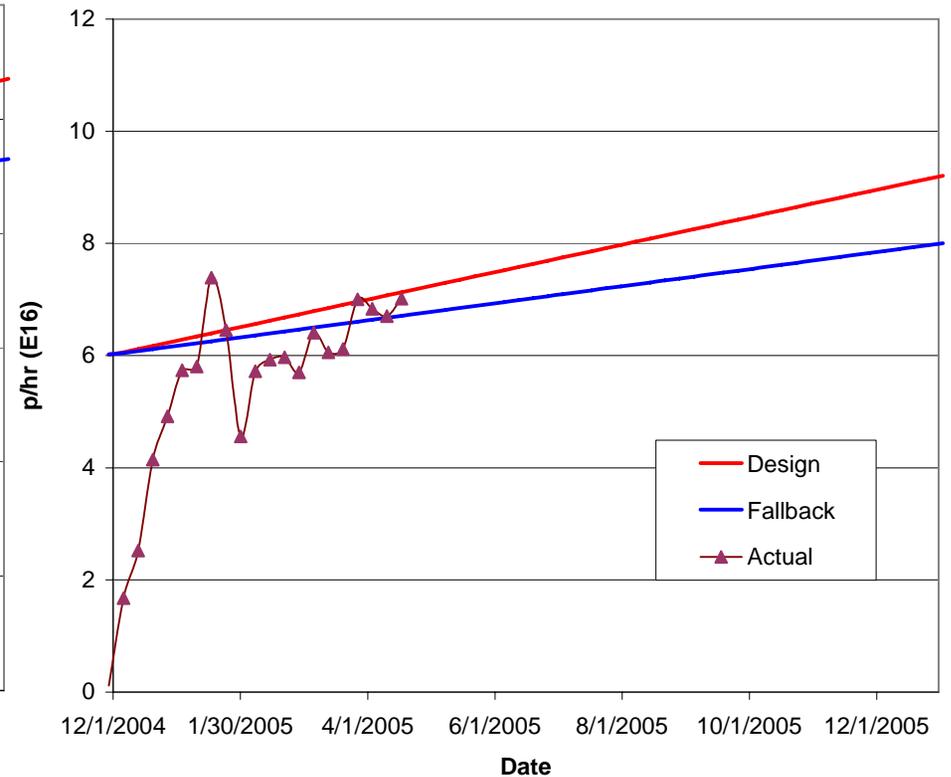
Hourly Proton Rate



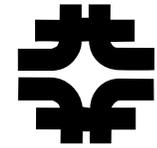
Total Peak Hourly Rate (BNB+NuMI+pbar)



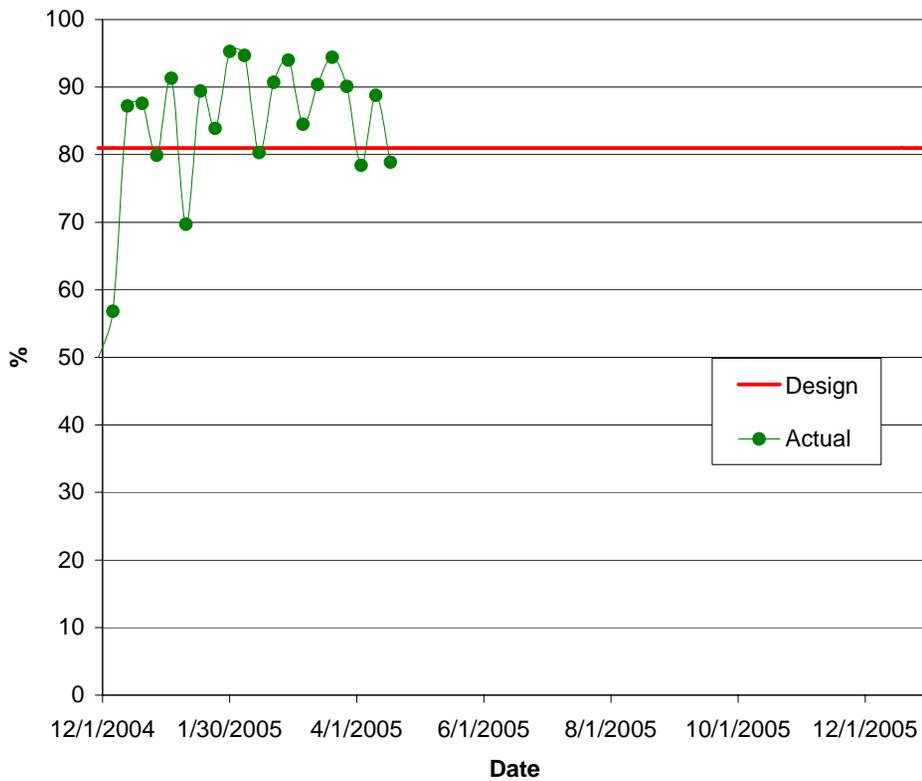
Average Hourly Rate (BNB+NuMI+pbar, while up)



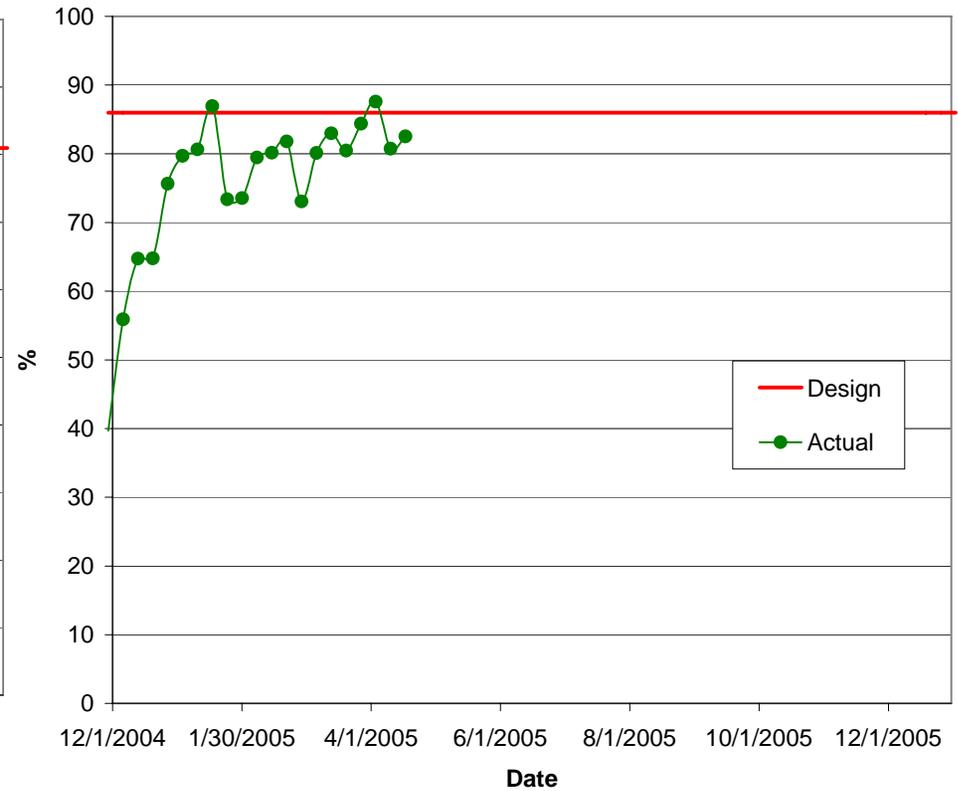
Efficiencies



Uptime

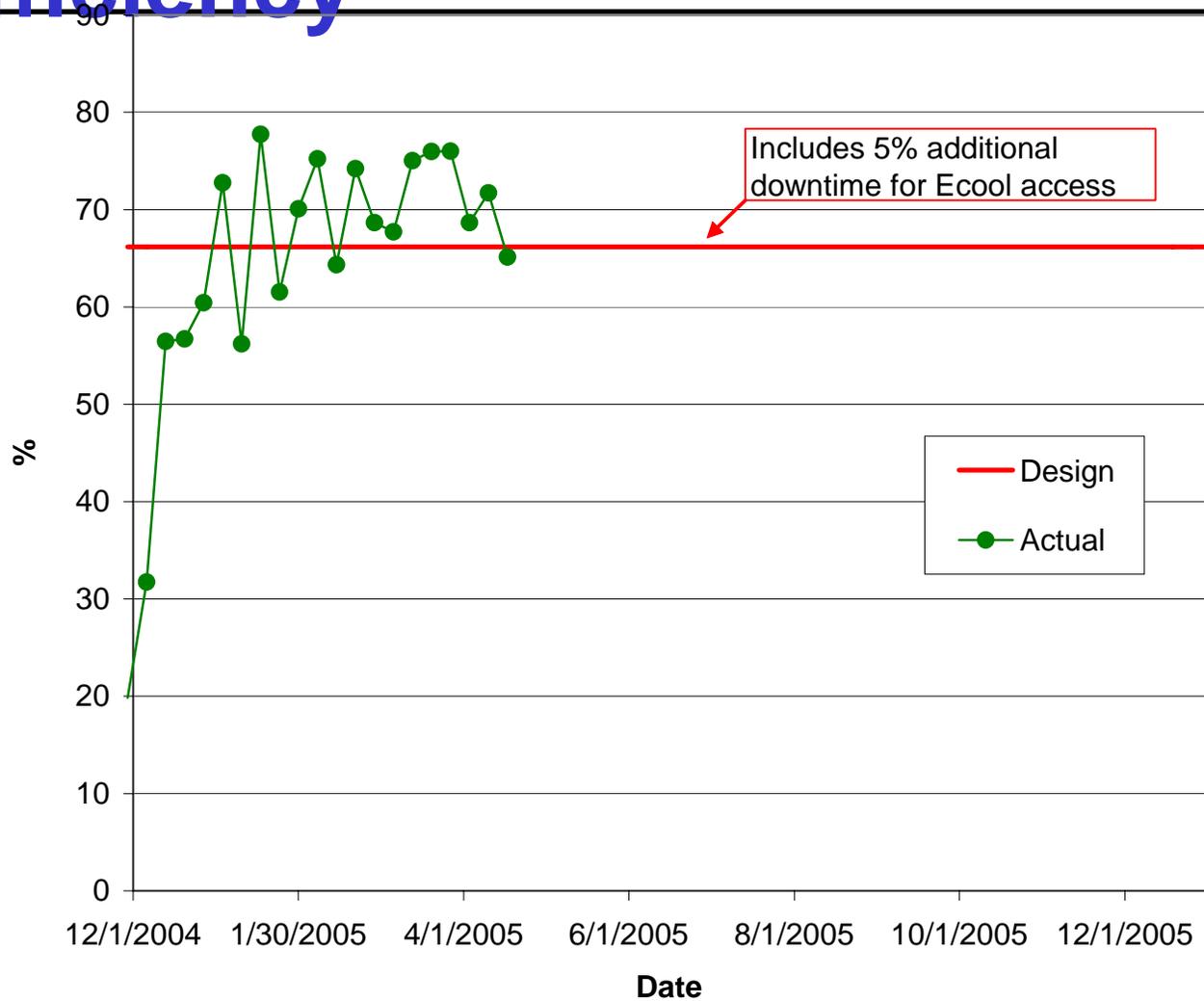
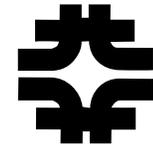


Average to Peak Efficiency (during uptime)

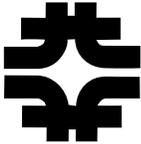


Overall "Peak to Week" Efficiency

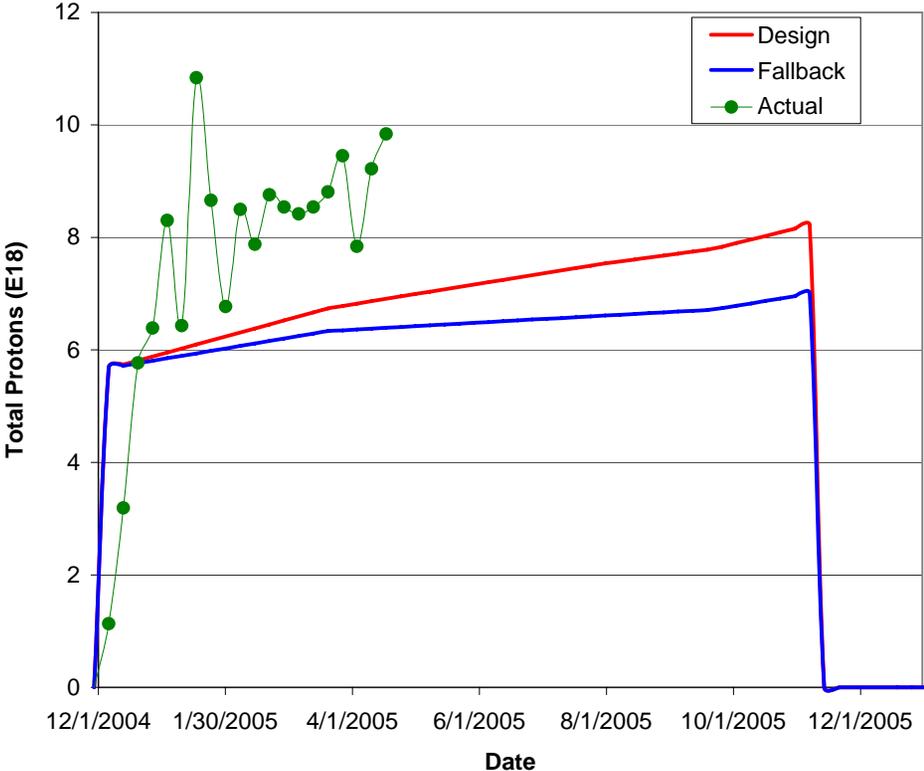
Overall "Peak to Week" Efficiency



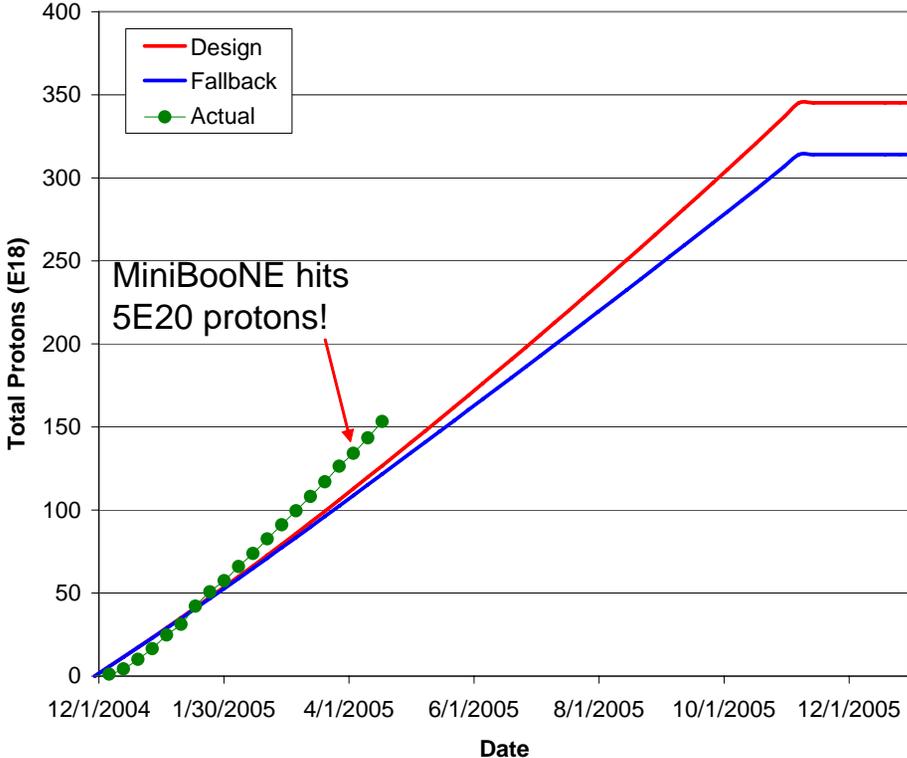
Integrated Delivery (BNB)



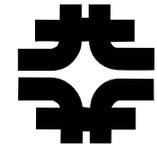
Weekly Proton Totals (BNB+NuMI)



Cumulative Proton Totals (BNB+NuMI)

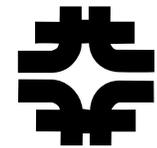


After the Collider



- A number of suggestions have been made for ways to maximize proton output after Tevatron operation ceases:
 - Stage II in my earlier slide
- While these are beyond the scope of the present plan, we have begun a working group (WBS 1.5) to investigate them and present a report to the Division Head on June 1.

Summary



- The Proton Plan encompasses accelerator improvements to maximize protons to NuMI and the 8 GeV line over the next 10 years
- The implementation of the Plan will provide
 - $\sim 7E16$ p/hr to NuMI ($\sim 3E20$ p/yr)
 - Up to $\sim 4E16$ p/hr ($1-2E20$ p/yr) for the 8 GeV line
- We are studying concepts for further improvements in the post collider era (for example using the Recycler as a preloader)
- We are working diligently toward a properly baselined, resource loaded project and schedule.