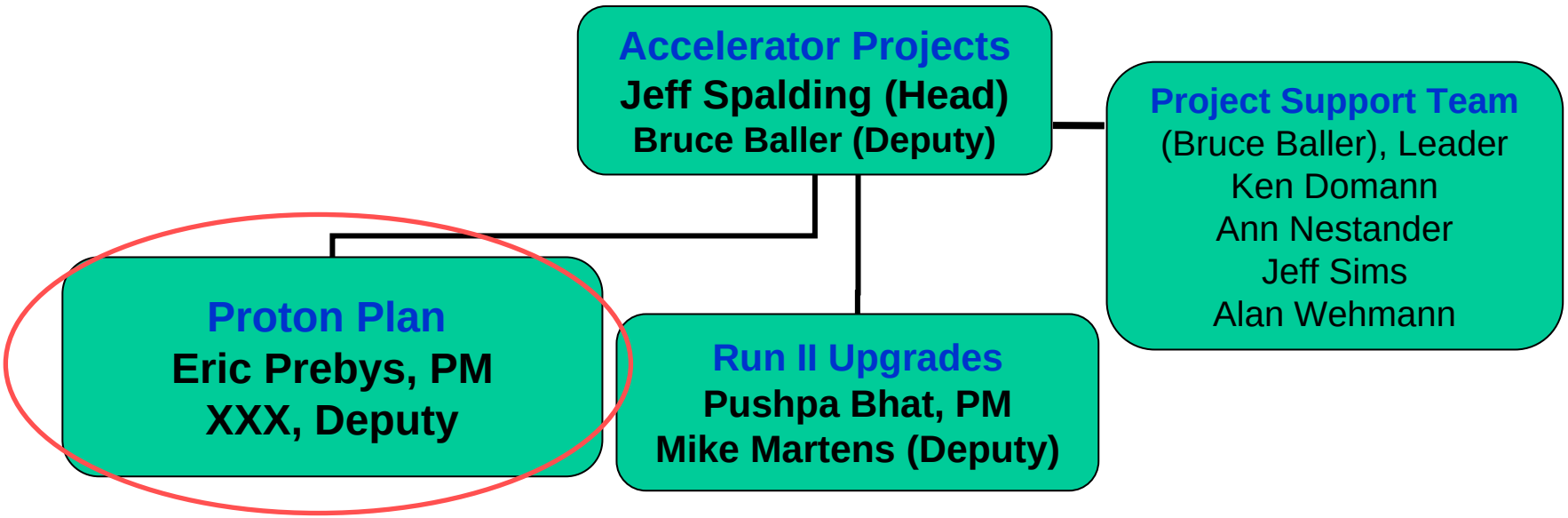
Status of Proton Plan

Eric Prebys

Management Re-organization



- 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

Review: What Limits Total Proton Intensity?

- Maximum number of Protons the Booster can stably accelerate: 5E12
- Maximum average Booster rep. Rate: currently 7.5 Hz, may have to go to 10 Hz for NuMI+ *(full)* MiniBooNE
- (NUMI only) Maximum number of booster batches the Main Injector can hold: currently 6 *in principle*, possibly go to 11 with fancy loading schemes in the future
- (NUMI only) Minimum Main Injector ramp cycle time (NUMI only): 1.4s+loading time (at least 1/15s* *nbatches*)
- Losses in the Booster:
  - Above ground radiation
  - Damage and/or activation of tunnel components

Our biggest worry at the moment and probably forever

The Proton Plan

- A set of physical improvements and operational initiatives to maximize the delivery of protons to NuMI and the 8 GeV Booster Neutrino Beam (BNB) over the next ~10 years.
- Facets:
  - Increasing the total proton output of the Proton Source (Linac+Booster)
  - Develop loading schemes for the Main Injector (+ associated hardware improvements)
  - Increase reliability, characterizablility and repeatability
- Assumed to be independent of a Proton Driver.

Phased Approach to Neutrino Program

- Phase 0 (now):
  - Goal: deliver 2.5E13 protons per 2 second MI cycle to NuMI (~2E20 p/yr), limited by MI RF system.
  - Deliver 1-2E20 protons per year to Booster Neutrino Beam (currently MiniBooNE)
- Phase 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 to NuMI (~3E20 p/yr).
  - This will increase by ~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.
- Phase 2 (post-collider):
  - In this phase, we will consider using the recycler as a preloader to the Main Injector and possibly reducing the Main Injector cycle time.
  - The exact scope and potential of these improvements is under study.
- Phase 3 (proton driver)
  - Main Injector RF must accommodate 1.5E14 protons every 1.5 seconds
  - NuMI beamline and target must also be compatible with these intensities.

Initial Plan (BEAMS-DOC-1441, 11/04)

- **Strategy (highlights)**
  - Increase maximum repetition rate of Booster:
    - ORBUMP magnets and PS
    - RF cavities
  - Reduce losses in Booster
    - New Corrector System
    - Gamma-t commissioning
    - 30 Hz harmonic (reduce max. acceleration rate)
    - Extra RF cavity
  - Commission multibatch operation in Main Injector
    - Mixed mode operation
    - Slip stacking
    - RF upgrade (??)
    - Loss mitigation and monitoring
  - Increase reliability
    - Old Linac PA tubes (7835)
    - Replace Linac pulsed quad power supplies
    - Instrumentation upgrade
    - Booster RF solid state upgrade

Current Status of Plan

- Since the initial release of the plan, we have worked to re-scope it to reflect:
  - Funding guidance (pre and post BTeV cancellation)
  - Feedback from those knowledgeable and/or responsible for the individual projects.
  - Suggested additions.
- WBS
  - We are working with project support to build a bottoms-up, resource loaded WBS
    - All major projects have at least realistic timelines to level 3.
    - Good faith M&S and SWF estimates
    - Working to refine and baseline project.
  - In many cases, we are integrating projects which were already underway prior to The Plan.

Likely Response to Current Budget Guidance

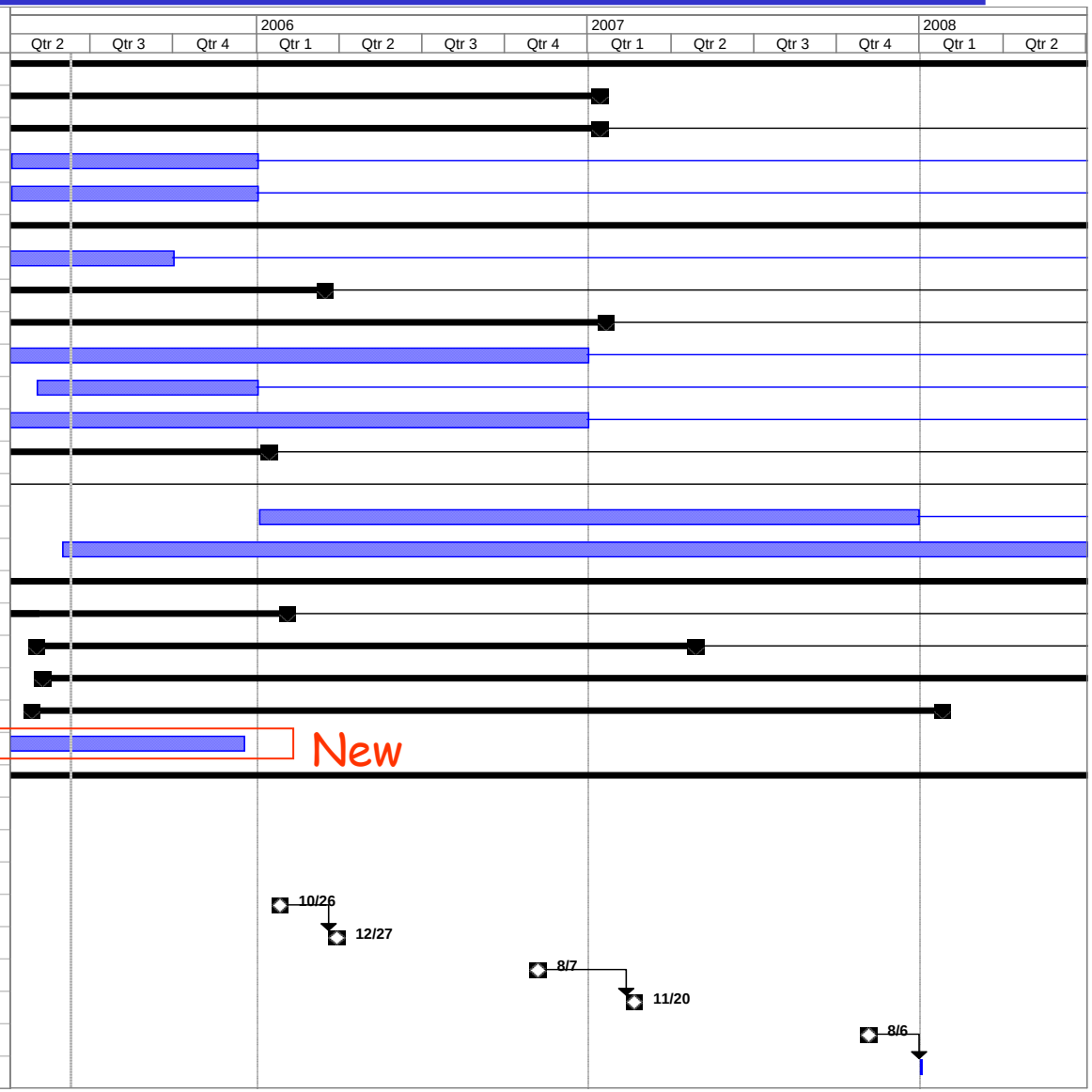
- After the cancellation of BTeV, we have the following budget guidance (M&S):

	FY05	FY06	FY07	FY08	Subt.	Total
Present Guidance	3854	5917	5016	5717	20504	20504

- Most Likely Scenario
  - Main Injector RF project and Booster Corrector System get delayed by one year, relative to the original plan.
  - Booster RF Solid State PA upgrade deferred indefinitely.

Existing Plan (not fully rescoped)

Uniq	WBS	Name
1	**0**	**Proton Plan**
2	**1**	**Linac Upgrades**
6	**1.1**	**Linac PA Vulnerability**
7	1.2	Linac Instrumentation Upgrade
8	1.3	Linac Quad Power Supplies
3	**2**	**Booster Upgrades**
9	2.1	Determine Rep Rate Limit
10	**2.2**	**OrBump System**
11	**2.3**	**Corrector System**
12	2.4	30 Hz Harmonic
13	2.5	Gamma-t System
14	2.6	Alignment Improvements
15	**2.7**	**Drift Tube Cooling**
16	**2.8**	**Booster RF Cavity #20**
17	2.9	Booster Solid State RF PAs
18	2.10	Booster Instrumentation
4	**3**	**Main Injector Upgrades**
19	**3.1**	**Large Aperture Quads**
20	**3.2**	**Main Injector Loss Mitigation**
21	**3.3**	**NuMI Multibatch Operation**
22	**3.4**	**Main Injector RF Upgrade**
202	5	Recycler Preloader Working Group
5	**4**	**Management**
23	4.1	Completion of Phase A
24	4.2	Completion of Phase B
25	4.3	Completion of Phase C
59	4.4	Start 2005 Shutdown
81	4.5	Finish 2005 Shutdown
79	4.6	Start 2006 Shutdown
80	4.7	Finish 2006 Shutdown
82	4.8	Start 2007 Shutdown
83	4.9	Finish 2007 Shutdown



Status of Major Work

- Linac (1)
  - (1.1) 7835 Task force (Rich Andrews)
  - (1.3) LEL quad power supplies
    - Working on prototype, based on HEL supplies
- Booster (2)
  - (2.2) ORBUMP System
    - Magnets:
      - First magnet built and tested, proceeding with the rest
    - Power Supply
      - Procuring and assembling
  - (2.3) Corrector System
    - Conceptual design complete
    - Working on detailed design
    - Working on PS specs
  - (2.4) 30 Hz
    - Work Proceeding on Prototype

Status of Major Work (cont'd)

- (3) Main Injector (except RF)
  - (3.1) Large Aperture Quads
    - In fabrication. Will be ready for 05 shutdown
  - (3.2) Loss mitigation/collimator system
    - Working group formed
    - Identifying collimator candidates for MI-8
    - Starting ring collimator system design based on Booster
  - (3.3) Multi-batch operation
    - Demonstrated maximum of 2.5E13 (6x4.2E12 batches) load to NuMI
    - Demonstrated mixed mode (2+5) operation w/ 5x1E12 batches to NuMI

Main Injector RF Issues

- Our present system:
  - Number of cavities: 18
  - Total Power Available: 175 kW/cavity (single PA)
  - Total Power dissipated: 58.6 kW/cavity
  - Power available for acceleration: 116.4 kW/cavity
  - Maximum acceleration rate: 200 GeV/s
- In the absence of beam loading compensation, an RF system is stable until the energy expended in accelerating the beam is *equal* to the energy dissipated in the cavity.
- Feed forward loops can increase this stability threshold
- For our system
  - Maximum guaranteed stable intensity: 3.3E13 protons
  - Power limited intensity: 6.5E13 protons
- -> Only guarantee phase 0

MI RF (cont'd)

- By adding an additional (175/2 – 58.6 =) 28.9 kW passive load to each cavity, we could ensure 87.5 kW of power for stable acceleration
  - ~$2M
  - Assure 4.9E13 proton per load limit
  - Not guaranteed to be enough for Phase 1/2.
- Each cavity has an additional port for a second PA, potentially giving 350 kW of total power.
  - ~$12M
  - This would insure 9.8E13 protons/load in the most conservative case (175 kW power dissipation)
  - Possibly higher with feedback loops
  - Definitely enough for Phase 1 and 2
  - Unlikely to be enough for a proton driver.

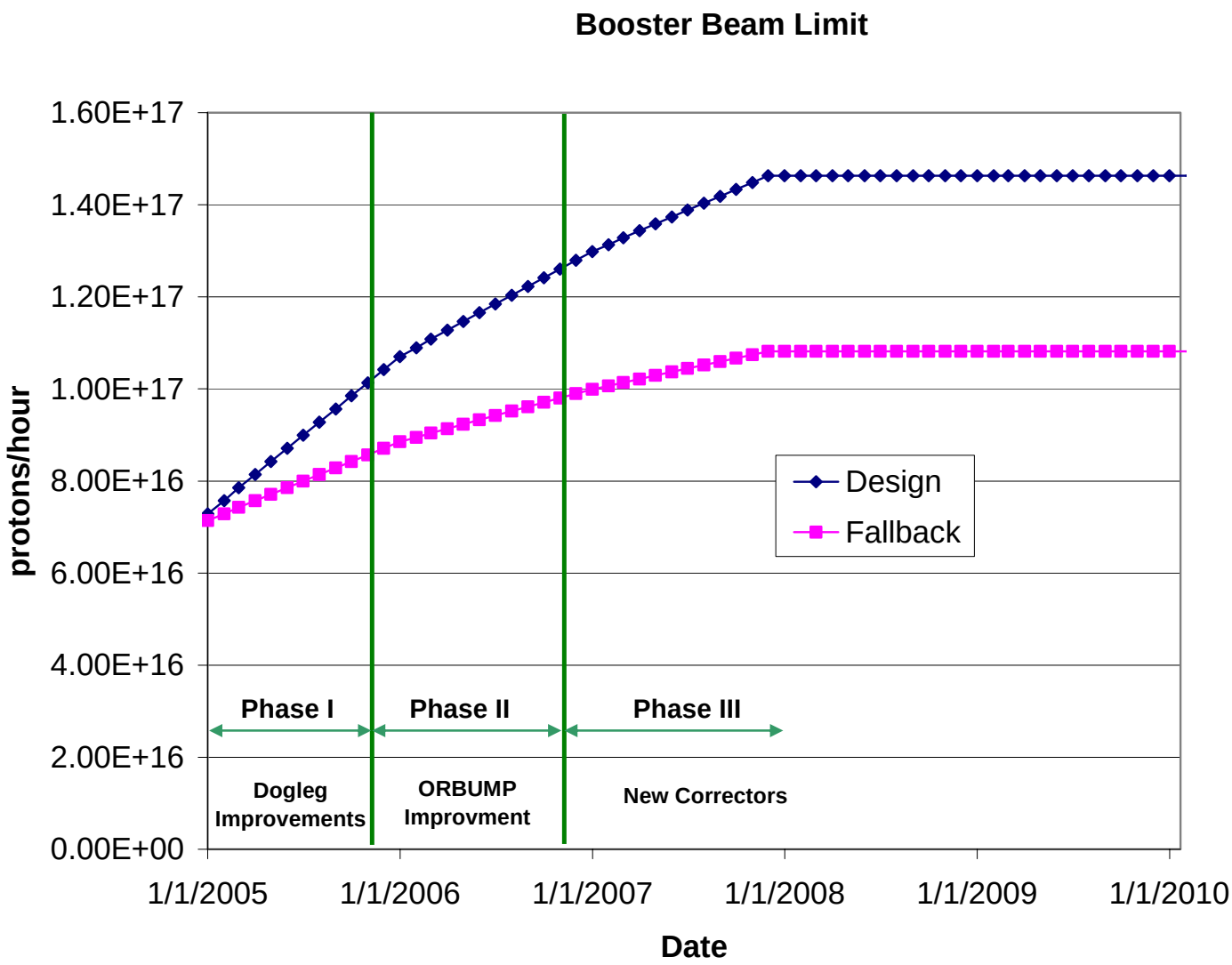
Main Injector RF in FY05 (3.4)

- Build prototype cavity
  - Passive load:
    - Existing port?
    - Cut new port?
  - Second PA
- Carry out a series of studies in the Main Injector
  - Determine effectiveness of feed-forward loops
  - Determine optimal passive load and predict intensity limit for one- and two- PA scenarios
- Refine cost estimate for passive load and PA upgrades.
- Use this information to determine longer range plan.

Proton Projections

- Phases of Operation
  - Phase I
    - After this shutdown
    - Dogleg problem ameliorated
    - Booster limited to 7.5Hz total repetition rate
    - Main Injector limited to 4E13 protons (2+5 operation)
  - Phase II
    - After 2005 shutdown
    - ORBUMP replaced
    - RF cooling finished
    - Booster capable of 9Hz operation
    - MI still limited
  - Phase III
    - After ~~2006~~ 2007 shutdown
    - MI RF upgrade complete
    - 2+9 operation to NuMI

Predicted Proton Intensity Limits



Estimating PoT

- Even the fallback proton scenario accommodates NuMI operation.
- Total proton output continues to be limited by radiation losses, rather than Booster repetition rate.
- We assume:
  - NuMI and antiproton production get what they need
  - The BNB gets whatever it can beyond that, within the total output limit of the Booster
  - Note: This is a programmatic decision.
- The BNB PoT estimates are extremely sensitive to the total proton limit, which is uncertain.

Calculating NuMI PoT

- Even the fallback scenario accommodates NuMI operation.
- Assume the following
  - Booster batch intensity rises steadily to 5.5E12 over the next three years.
  - Ramp up to full 2+5 operation by April 2005
  - Ramp up to full 2+9 batch slipstacked operation a few months after MI RF upgrade.
  - 90% efficiency for slip stacking.
  - 10 month operation each year.
  - 81% total uptime for remainder of year
    - based on MiniBooNE. Includes scheduled and unscheduled downtime
  - 90% avg/peak operating efficiency
  - 10% down time for shot setup
  - 5% down time for fast Recycler transfers
  - 5% down time during 2005 for Ecool accesses.
  - Does NOT include SY120

Calculating BNB PoT

- Trickier:
  - Still limited by beam loss, NOT rep. rate.
  - Assume antiproton and NuMI have priority, so
  - BNB VERY sensitive to proton limit and its fluctuations.
- Use:

(avg pph) = (pph lim.)*η – (NuMI pph) – (pbar pph)

Booster output limit, as discussed

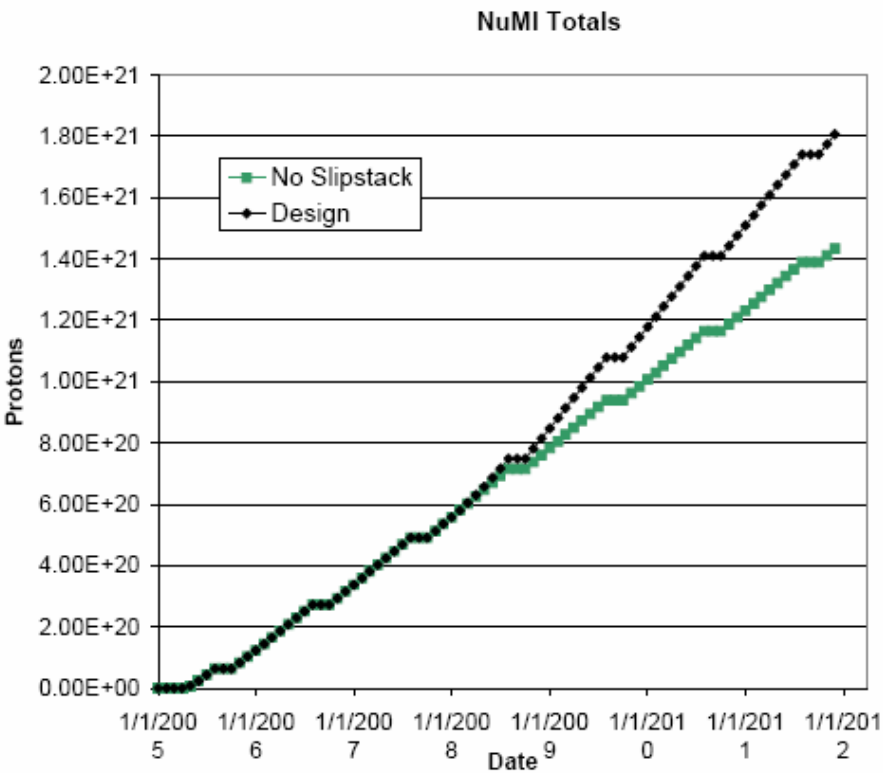
Avg/pk ~ 86% from July 2004 MiniBooNE operation

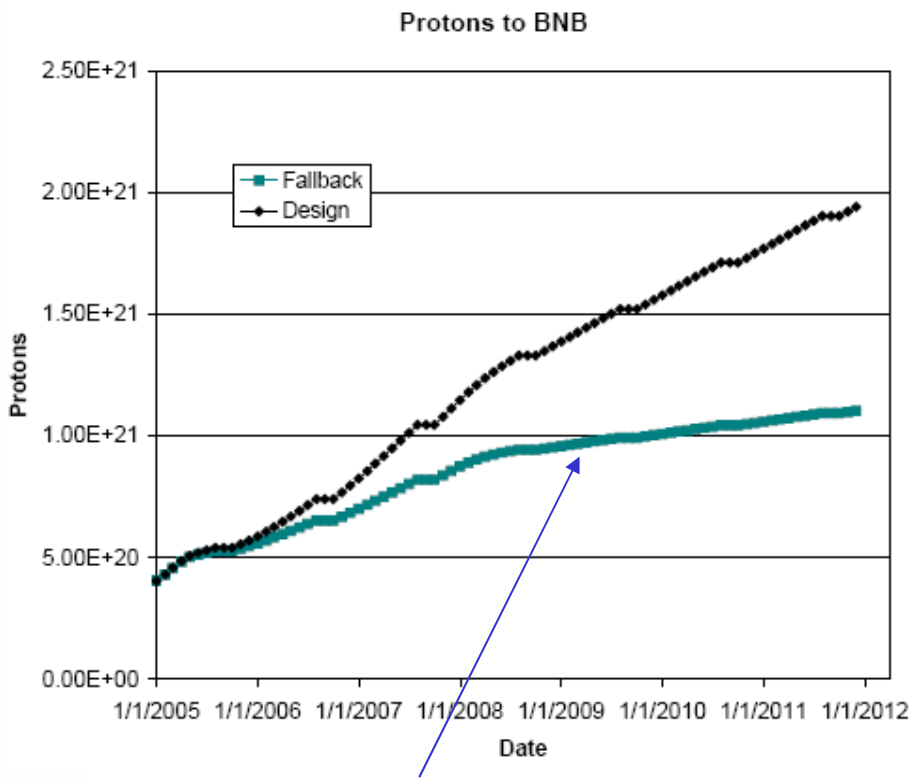
- Also assume:
  - 10 month operation
  - 81% up time (based on 2004)
  - 5% downtime in 2005 for ECool access
  - BNB gets all the beam during shot setup (10% of the time)

"Design" PoT

	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

Projections ("delayed" scenario in document)





BNB only runs during shot setup