Proton Planning

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Promises for this Talk

- At least 10% original content since the last four times I've given it.
- I won't refer to the Proton Team Report as the "Finley Report".

Proton Team Report

- Group formed in early 2003 to study proton demands and needs for the "near" future (through ~2012 or so), in the absence of a proton driver.
- Work culminated in a report to the director, available at www.fnal.gov/directorate/program_planning/studies/ProtonReport.pdf
- No big surprises [see P. Kasper "Getting Protons to NuMI (It's a worry)", FNAL Beams-doc-1036, 2001].
- This work will form the basis of "The Proton Plan".

What Limits Total Proton Intensity?

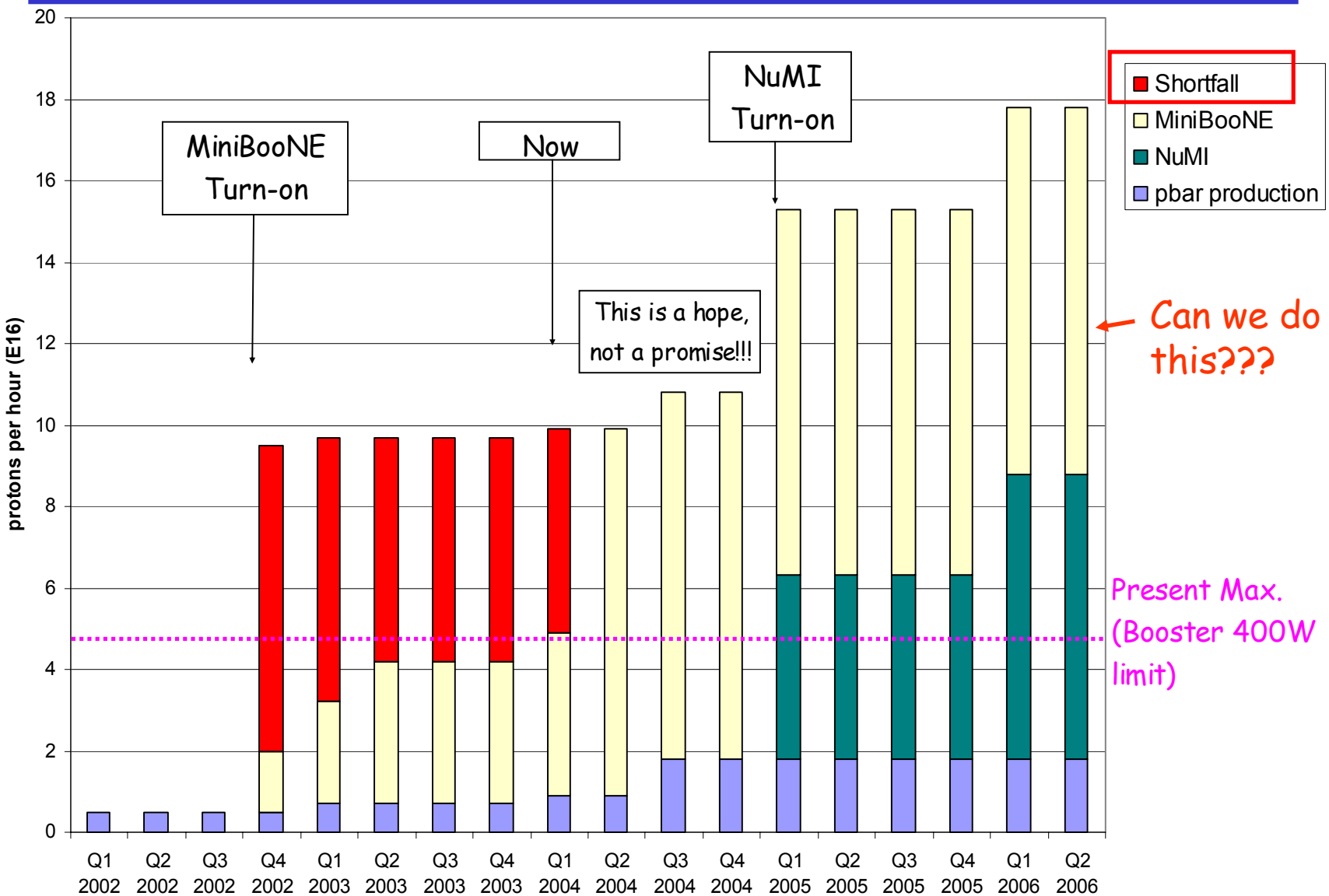
- Maximum number of Protons the Booster can stably accelerate: 5E12
- Maximum average Booster rep. Rate: currently 7.5 Hz, may have to go to 10 Hz for NuMI+ *(full)* MiniBooNE
- (NUMI only) Maximum number of booster batches the Main Injector can hold: currently 6 *in principle*, possibly go to 11 with 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!!!!

What about the Linac?

- The linac is not currently a performance bottleneck for the complex *when it is running stably.*
- There are ongoing longevity and reliability concerns in the linac
  - General state of instrumentation is inadequate to characterize linac behavior
  - The 7835 tubes from Burle continue to be a major concern, although the situation is better than it was a year ago.
  - There are new worries about the klystrons, which we formerly believed were not an issue.
  - There are some other longevity issues, if we expect the linac to last another ~10 years.

Proton Demand

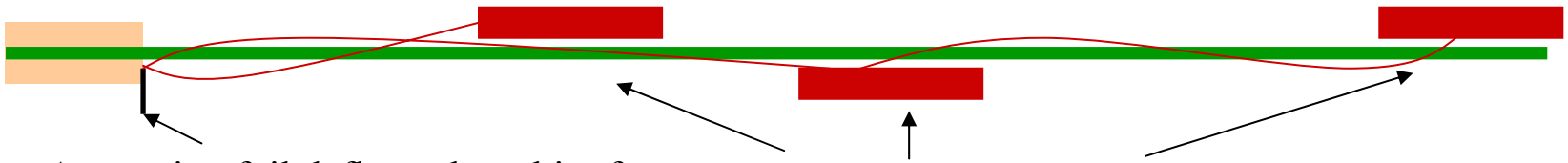


Projects in 2003 (a short list)

- 2003 Activities centered around preparation for the September shutdown:
  - Linac water system upgrade
  - New Linac Lambertson
    - Better optics in 400 MeV line
  - Booster two-stage collimation system
    - In the works a long time
    - Now in place.
  - Major modifications at main extraction region
    - Address "dogleg problem" caused by extraction chicane system.
  - New, large aperture magnets in extraction line:
    - Should reduce above-ground losses
  - Major vacuum system upgrade.
  - Lots of smaller jobs.

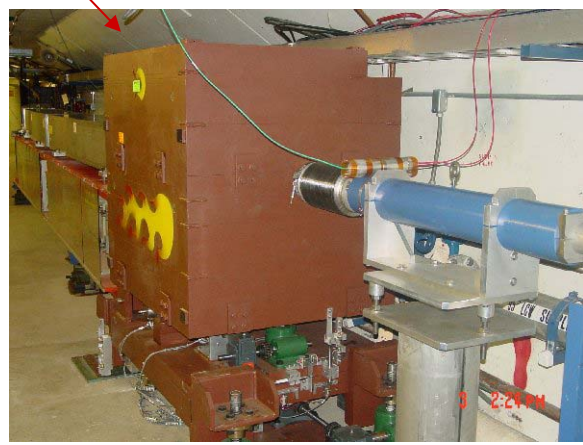
New Collimator System

Basic Idea…



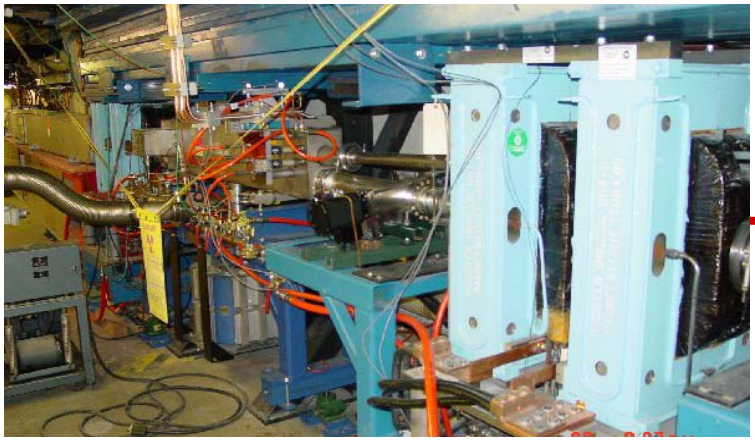
A scraping foil deflects the orbit of halo particles…

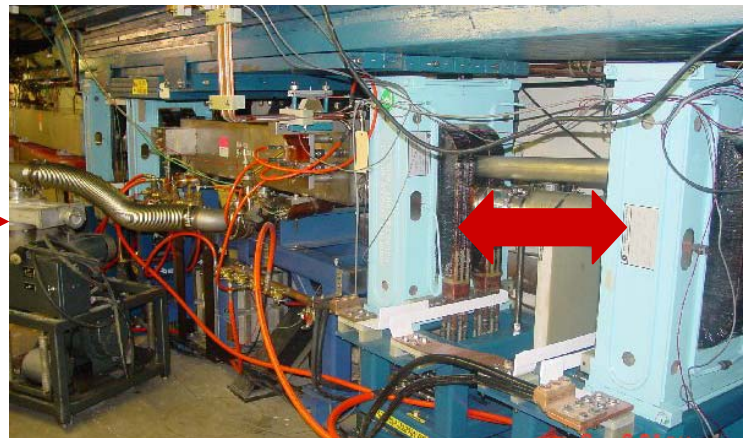
…and they are absorbed by thick collimators in the next periods.

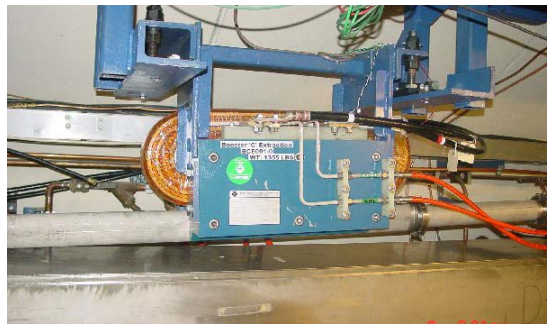


- Should dramatically reduce uncontrolled losses

Long 3 Dogleg Work



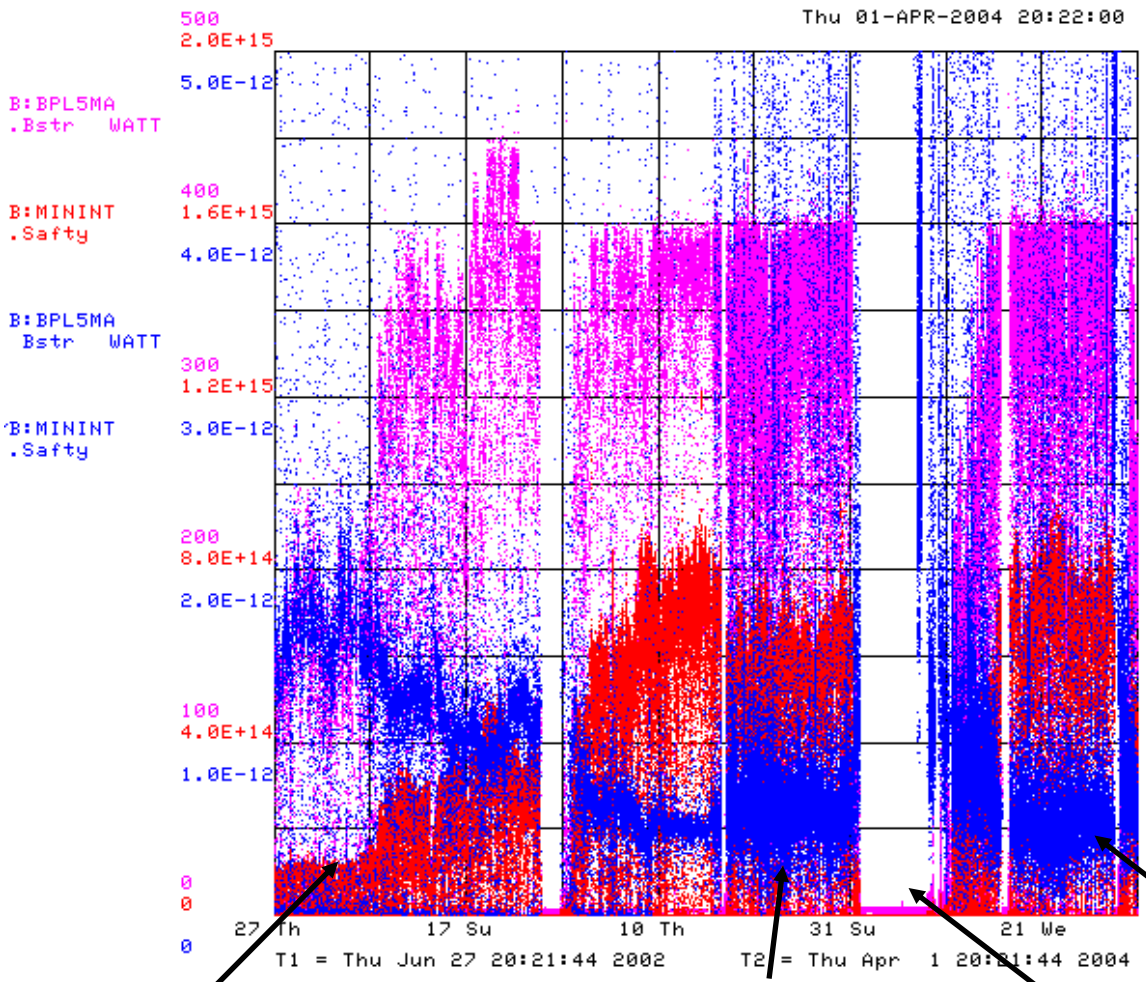




New magnet to match extraction line

- Increase spacing between dogleg pairs from 18" to 40" to reduce lattice distortions at injection.

How are We Doing?



Power loss (W)

Protons (p/min)

Energy Lost (W-min/p)

Record Performance

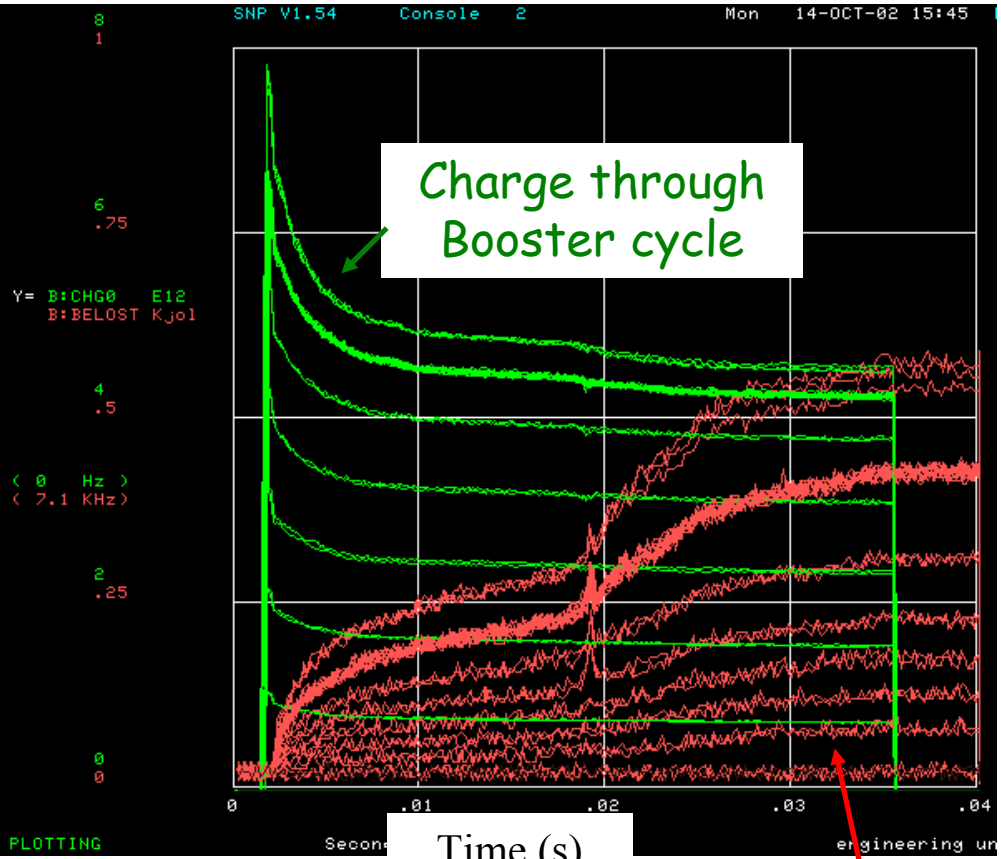
BooNE turn-on (Sept. 2002)

"Mysterious" Performance Problems

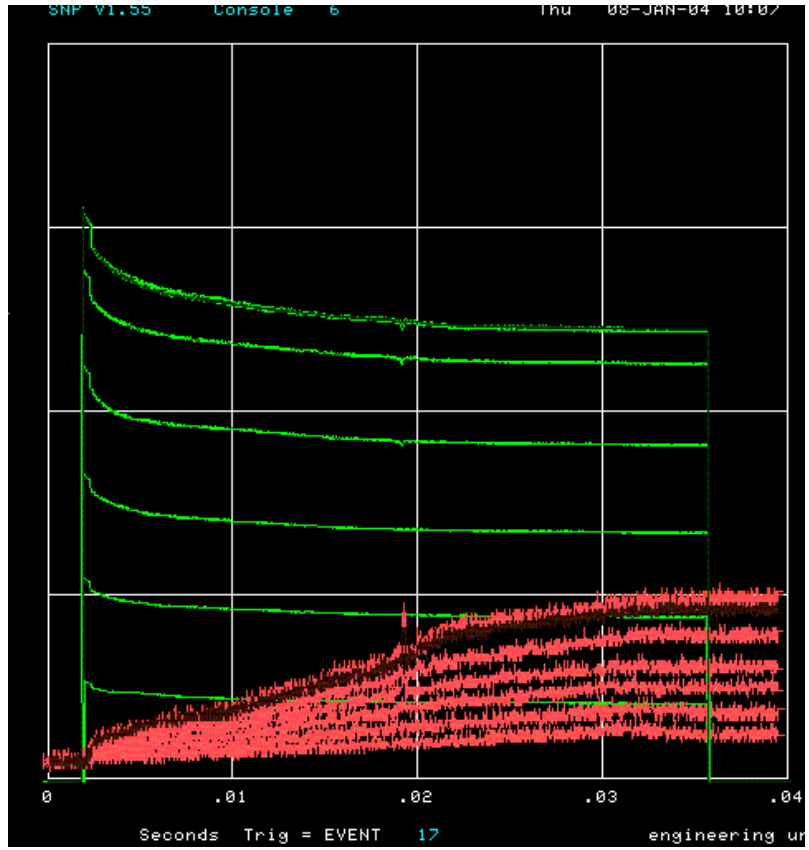
Big Shutdown

How far have we come?

Before MiniBooNE



Now (same scale!!)

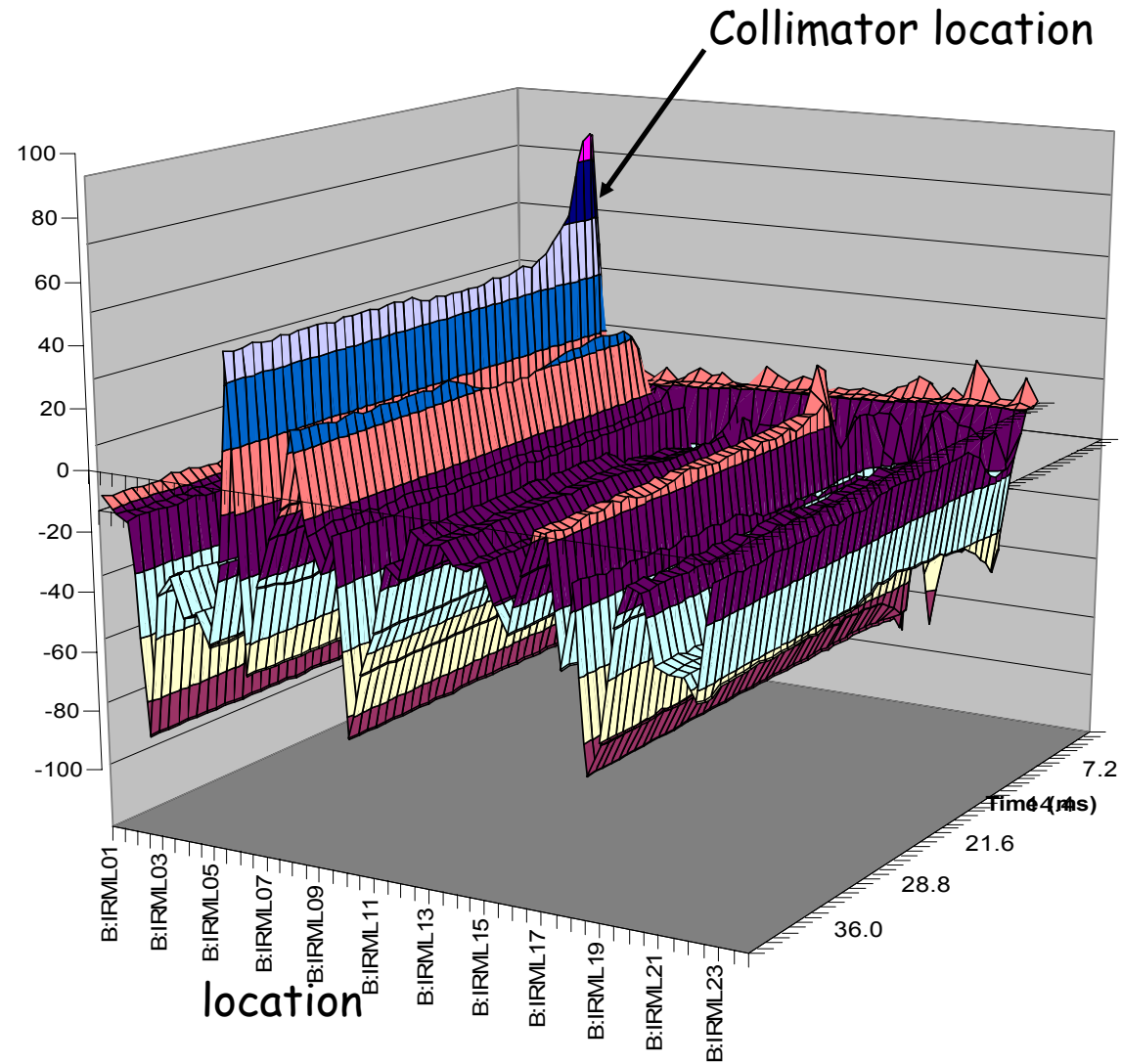


Note less pronounced injection and transition losses

Near Term Priorities (Booster)

- Optimizing Booster for improved lattice:
  - Tuning and characterizing 400 MeV line (Linac to Booster).
  - Tuning Booster orbit to minimize losses.
- Commission Collimators:
  - Estimate another month or so to bring into standard operation. (discussed shortly)
- Aperture Improvments:
  - Alignment (discussed shortly)
  - Orbit control
    - Abandoning our original global plan in favor of local control at problem spots for the time being.
  - Prototype RF Cavities
    - Two large aperture prototype cavities have been built, thanks to the help of MiniBooNE and NuMI universities.
    - We will install these as soon as they are ready to replace existing cavities which are highly activated.
- Multibatch timing: Beam cogging (discussed shortly)

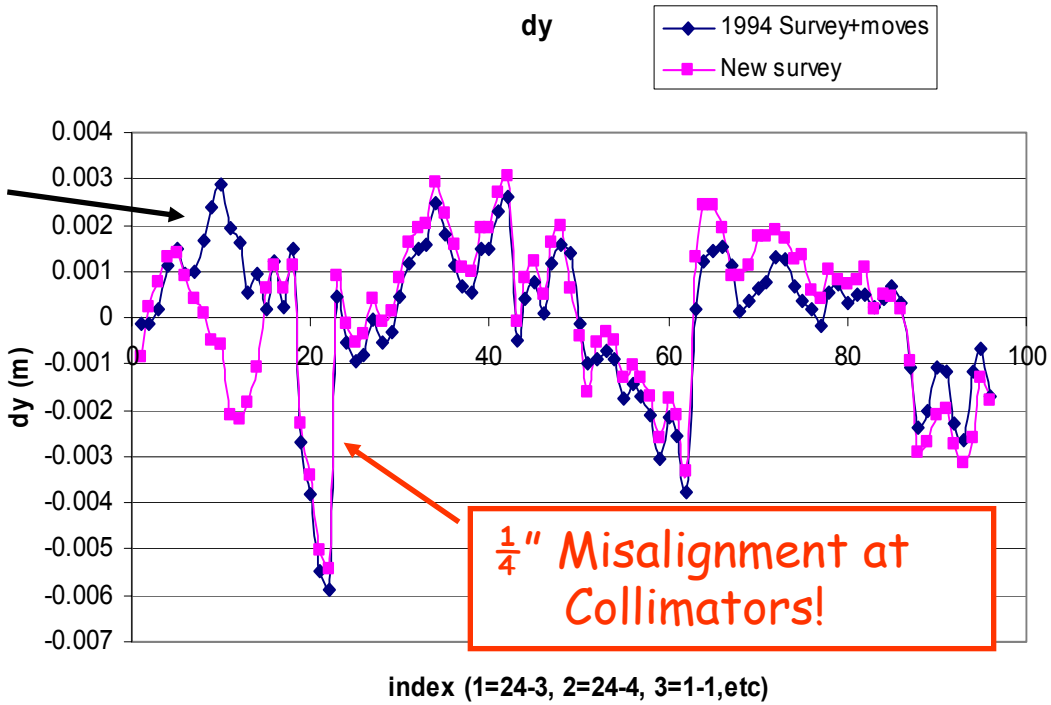
Collimator Studies



- Shown is the effect of putting in one of the secondary collimators as a percentage change in losses as a function of time around the ring.
- Studies are continuing.
  - "Rapid response team" will be put on problem.
- At present, primary collimators are not optimized to energy loss profile
  - Will replace in upcoming shutdown.

Alignment Problems

Effect of Booster tower shielding



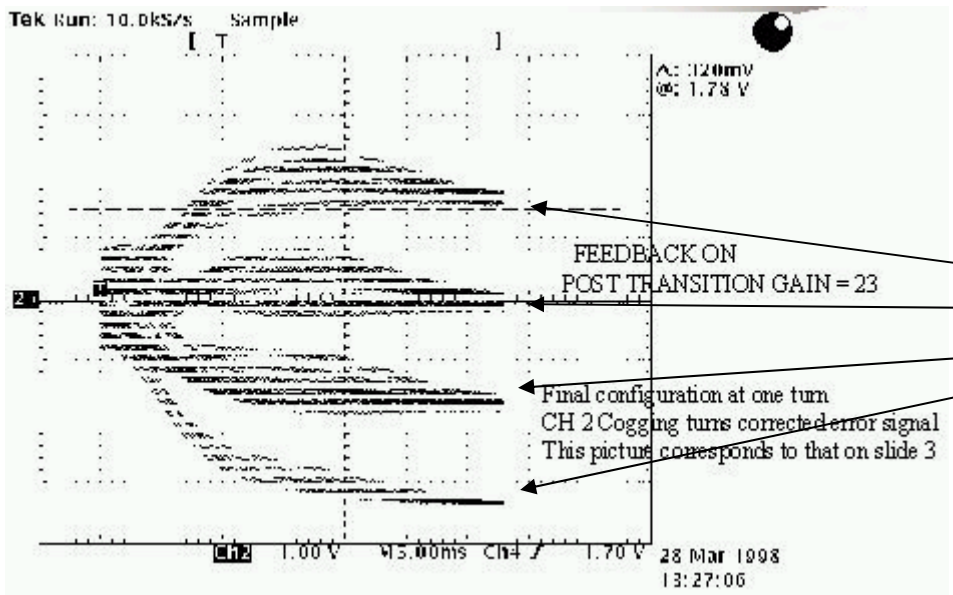
- Working closely with AMG
- As opportunity allows
  - Fix vertical orbit
  - Align RF cavities
- Over the next year
  - Complete network
  - Integrate with MAD
  - Make a horizontal plan.

Multibatch Timing

- In order to Reduce radiation, a "notch" is made in the beam early in the booster cycle.
- Currently, the extraction time is based on the counted number of revolutions (RF buckets) of the Booster. This ensures that the notch is in the right place.
- The actual time can vary by > 5 usec!
- This is not a problem if booster sets the timing, but it's incompatible with multi-batch running (e.g. Slipstacking or NuMI)
- We must be able to fix this total time so we can synchronize to the M.I. orbit.
- This is called "beam cogging".

Active cogging

- Detect slippage of notch relative to nominal and adjust radius of beam to compensate.



Allow to slip by integer turns, maintaining the same total time.

- Efforts in this area have been recently increased, with the help of a Minos graduate student (R. Zwaska).
- Aim to get working in the next month or so.

Planning for the future

- In response to the "Proton Team Report", the lab management has asked for a "Proton Plan" for the proton source over the next few years, analogous to the Run II plan, but much lower in scope.
- The plan is to do what we can reasonably do to maximize the throughput and reliability of the existing proton source (incl. MI), assuming:
  - a Proton Driver *will* eventually be built.
  - There will be no shutdowns longer than 2 months or so.
- Beyond the things I have already mentions, the scope is largely determined by the budgetary guidance:
  - FY04: $0-2M
  - FY05: $6M
  - FY06: $5M
  - FY07: $5M
  - FY08: $2.5M

Comment on the Budget

- This budget is more than enough to do the basic things that we must do to keep the proton source going, provided some of it appears this year!
- It *precludes* certain ideas that have been suggested:
  - New Linac front end, or any significant 200 MHz upgrade.
  - Decreasing the Main Injector ramp time
- There are some "big" (>$1M) projects that must be discussed.

Projects over the Next Year

- Linac Characterization and Reliability
  - Increase instrumentation of old linac to study instabilities.
  - Develop set of performance parameters.
- Booster improvements.
  - Prepare for modification of second extraction region
    - New septum
    - Modified dogleg magnets
    - On track for next year's shutdown.
  - Injection bump (ORBUMP) improvements:
    - Injection Bump (ORBUMP) Power Supply
      - Existing supply a reliability worry.
      - Limited to 7.5 Hz
      - Building new supply, capable of 15 Hz.
    - New ORBUMP Magnets
      - Existing magnets limited by heating to 7.5 Hz
      - Working on a design for cooled versions.
      - These, with a new power supply, will make the Booster capable of sustained 15 Hz operation.

Projects over the next year (cont'd)

- Prototype RF cavities
  - Add the two university-build RF cavities as 19th and 20th Booster cavities.
- Transition crossing
  - Now that injection efficiency is up, we seem to be limited by transition issues
  - Working closely with Fermilab Beam Physics, as well as people from Argonne to understand the issues.
  - Resurrecting the transition crossing (gamma-t) system.

Longer Term Projects

- Booster RF System
  - New solid state PA's
    - Increase reliability.
    - Decrease time in hot areas
    - Cost ~$7M
    - Will almost certainly recommend
    - Could build by end of 2005.
  - New RF system
    - Larger aperture
    - Higher gap envelope
    - Reduced HOM
    - Cost ~$7M
    - Work out a design by end of 2004
    - Possibly recommend
    - Aggressive schedule would be by end of 2006.

Long Term Projects (cont'd)

- Booster Corrector System
  - Each of the 48 subperiods has a corrector package, consisting of
    - Horizontal dipole
    - Vertical dipole
    - Quad
    - Skew quad
  - These are not powerful enough to control the orbit or the tune through the acceleration cycle
  - Working with the TD to design a new corrector system approx. 3 times as powerful.
  - Will have a design by end of 2004
  - Will almost certainly recommend
  - Cost ~$3M
  - Could have by end of 2006.

Longer Term Projects (cont'd)

- Booster Harmonic
  - Adding a 30 Hz harmonic to the Booster ramp could reduce the maximum dE/dt and therefore effectively increase the RF power.
  - Working on a prototype choke this year.
  - Will make a decision by the end of the year.
  - Could be done by end of 2005.
  - Cost ~$1-2M
- New quad supplies for the Low Energy Linac (LEL)
  - Reliability worry
  - Will certainly recommend
  - Cost ~$1M

Closing Comments: Expectation Management

- What we really think we can achieve:
  - Slipstacking to provide 1E13 protons per pulse for pbar production.
  - 5E20 protons to MiniBooNE by the time NuMI fully comes on in early 2005
  - 2-2.5E20 p/yr to NuMI in the first year of operation.
  - Increasing that over the next few years, to something over 3E20 p/yr.
- What we might achieve:
  - Continuing to operate the 8 GeV line at some significant level *after* NuMI comes on, ultimately delivering 1E21 protons to MiniBooNE and possibly supporting other experiments (e.g. FINESSE).
  - Delivering as many as 4E20 p/yr to NuMI, at which point things will be limited by Main Injector aperture and cycle time (with the present source, anyway).
- It would be unrealistic to believe:
  - We will ever send more than 4E20 p/yr to NuMI without significant (~$100M) investment in the existing complex.
  - That would be direct competition for resources with the current Proton Driver proposal.