Proton Source Status and Plans

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Outline

- "Finley Report"
- Linac status
- Proton Demands
- Major Projects Since Last Review
- Booster Performance
- Near Term Priorities
- Major Work in the Next Year.
- The "Proton Plan"

Proton Team ("Finley 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".

General Comments

- 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.

7835 Status

- Lots of interaction between the lab (Czarapata) and Burle to help them improve their reliability.
- They seem to remember how to make tubes again.
- Present inventory:

Last data update: Wed Feb 18 12:30:08 CST 2004

Station	Tube S/N	Gradient	Filament A	Hours	*Days*	Fraction of median* life	Prob of failure this week
1	N49R6_BNL	1	6393	6126	*255*	0.38	0
2	A1R8	1.02	6800	8474	*353*	0.78	0.021
3	P2R4	1.01	6559	346	*14*	0.03	0
4	A27R6	0.99	6483	6621	*275*	0.61	0.007
5	BK3	1	6530	2940	*122*	0.27	0
7	N16R8	-0.02	184	102	*4*	0	-

Spare 7835 Inventory

- BK1, 214 hours
- A30R6, 0 hours

+ one ready to be tested

Christmas Klystron Woes

- As of Dec. 1, we believed 800 MHz klystrons were not a worry.
  - Very long lifetime (in socket!!)
  - We had six spares
- A few days before Christmas, the klystron in station one failed.
  - Three spares turned out to be bad
  - Tracked down to vacuum problem (and a flaw in our measurement technique).
- Plan
  - We've pulled one good spare from the MuCool project
  - Ralph Pasquinelli put in charge of investigating and acting
  - We think we understand the problem and will work with L3 to address it.
- Current stock
  - Two good spares.
  - One "gassy" tube, probably bad
  - Three bad tubes at L3, one ready to be repaired (no good estimate)
  - Two more bad tubes which will either be shipped or analyzed here.

Klystron Status

Klystron Hours

Manufacturers: Varian VKP-7955 ("V") and Litton L-5859 ("L")

Module	Manuf	S/N	Hours	Days	Years	Internal Vacuum uA
0	V	L122	86406	3600	9.8	0.41
V	V	L113	90337	3764	10.3	0.00
1	L	0005R1	1266	52	0.1	0.02
2	L	0004	89411	3725	10.1	0.00
3	L	0006	73920	3080	8.4	0.12
4	L	0016	4347	181	0.4	0.15
5	L	0007	91910	3829	10.4	0.04
6	L	0013R1	30035	1251	3.4	0.21
7	L	0015	73127	3046	8.3	0.63
D	V	A21	73846	3076	8.4	0.00

Other Linac Projects

- New quad supplies in LEL
  - Discussed under proton plan
- Upgrade High Energy Linac Low Level RF (HEL LLRF)
  - Under way
- Upgrade LEL digitization
  - Under way
- Upgrade LEL LLRF
  - Being discussed
- Upgrade LEL modulator switch
  - Being discussed
- Beam notching at the source
  - Pre-notching
  - 37 MHz laser chopping
  - R&D phase
- Improving beam diagnostics in 400 MeV line
  - Loss monitors
  - Bunch length monitor
  - Automated emittance measurement
- Dealing with MTA
  - Now: preparing to send 200 MHz and 800 MHz RF
  - Future: sending beam

400 MeV Line Work

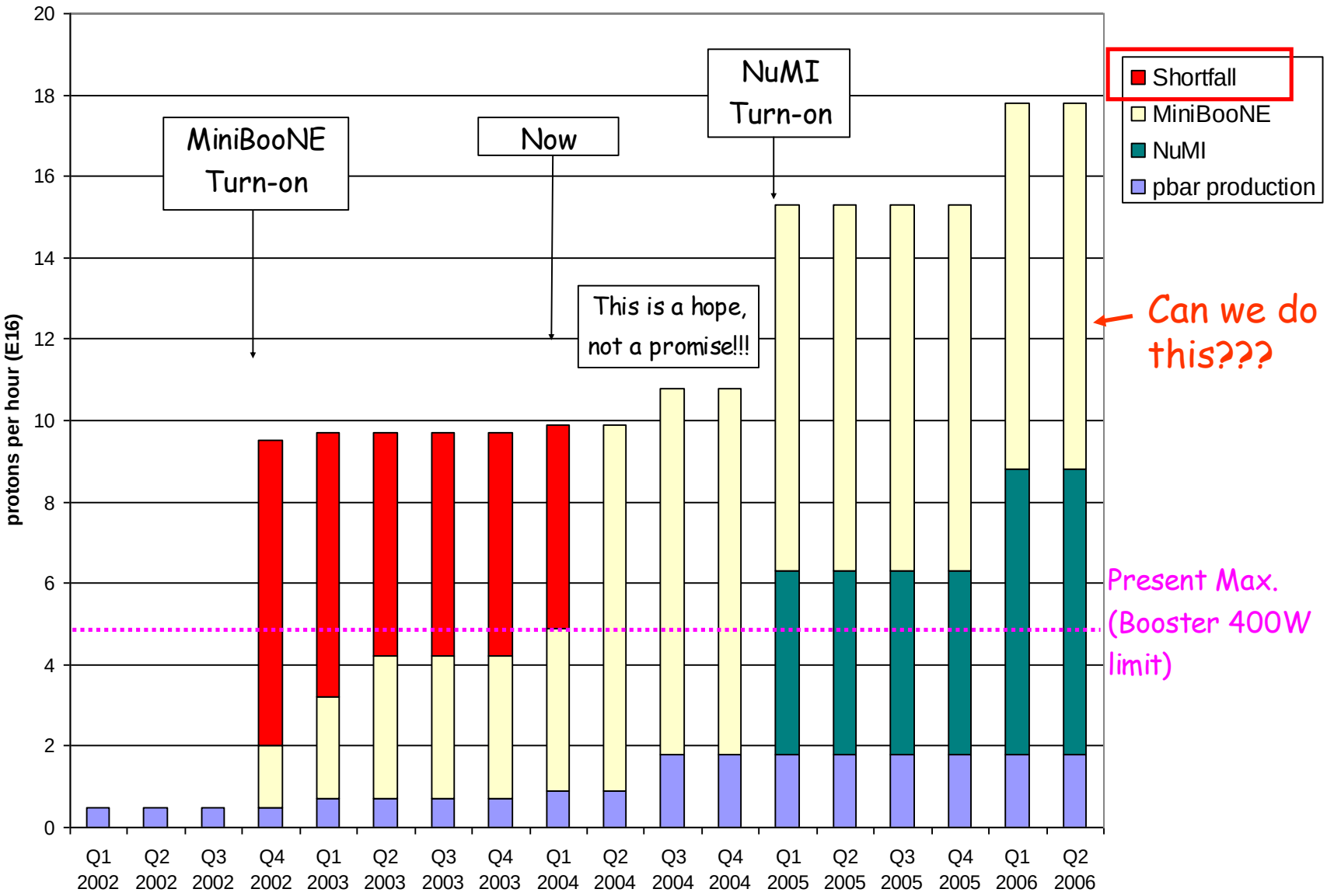
- A new Lambertson was installed during the shutdown to steer beam from the Linac to the Booster
- Although the field qualities of this magnet were vastly superior to the old one, it was a major effort to tune for it.
- This highlighted our lack of understanding of the "400 MeV Line".
- A major effort has gone into studying and optimizing this line.
  - Improved optical model
  - Automated beam line tuning
  - Optimizing optics

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!!!!

Proton Demand

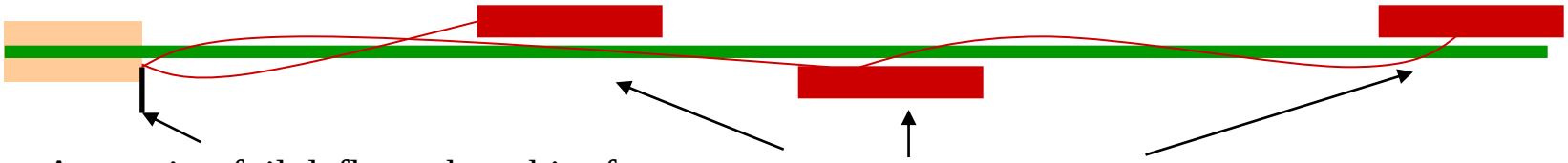


Projects in 2003 (a short list)

- 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…

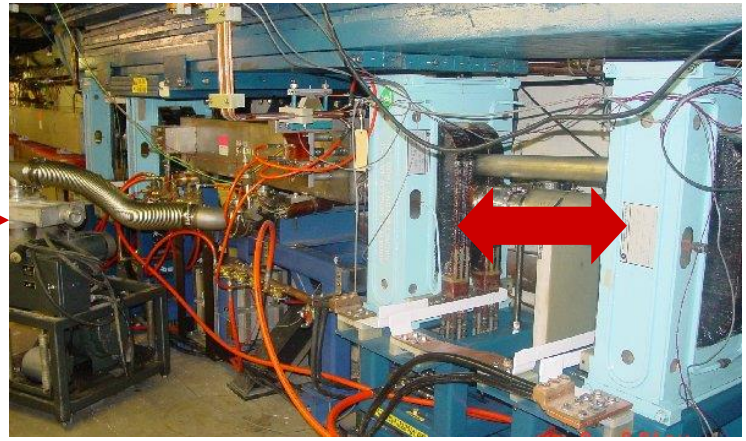


A scraping foil deflects the orbit of halo particles…

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

- Should dramatically reduce uncontrolled losses

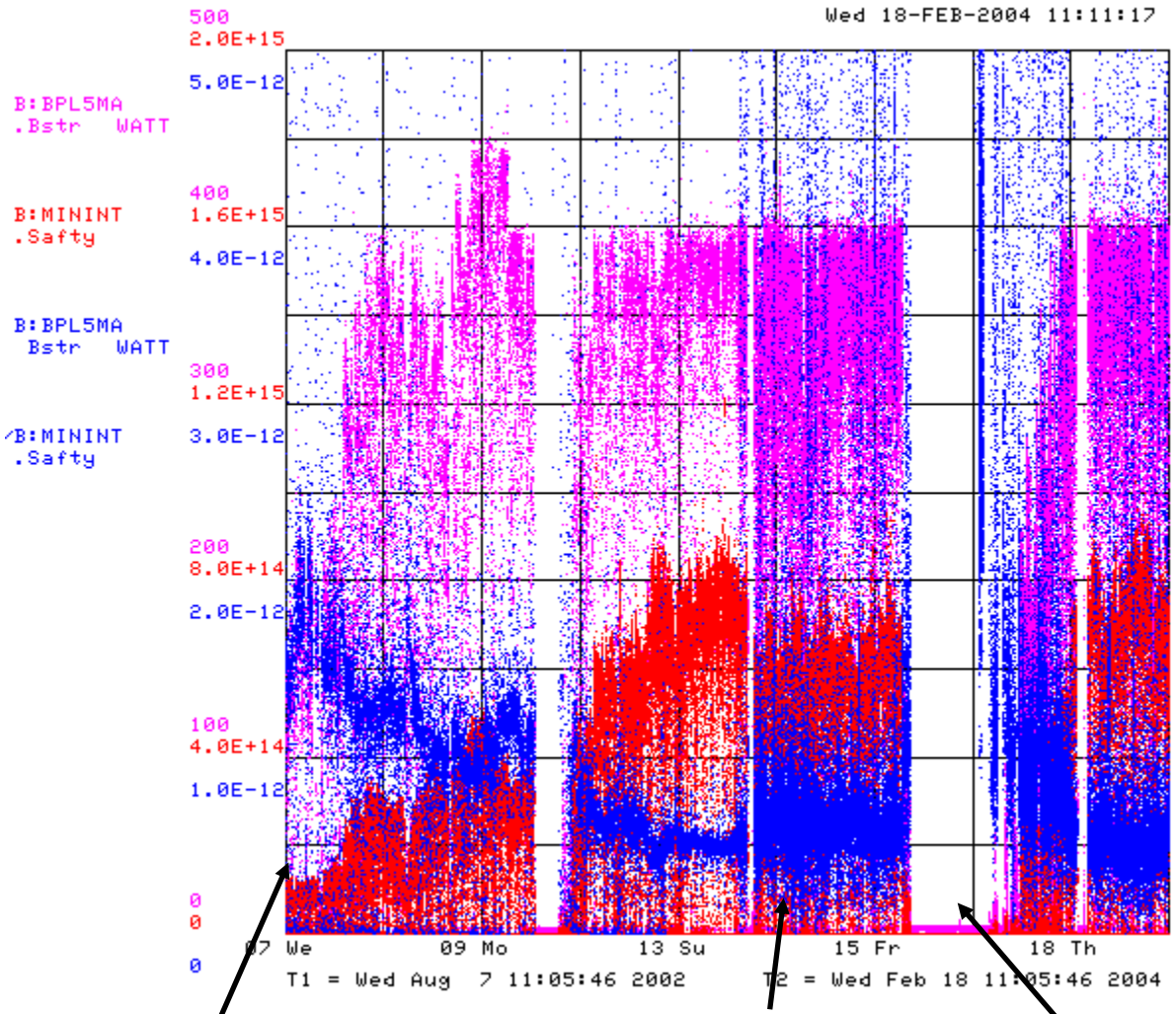
Long 3 Dogleg Work



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)

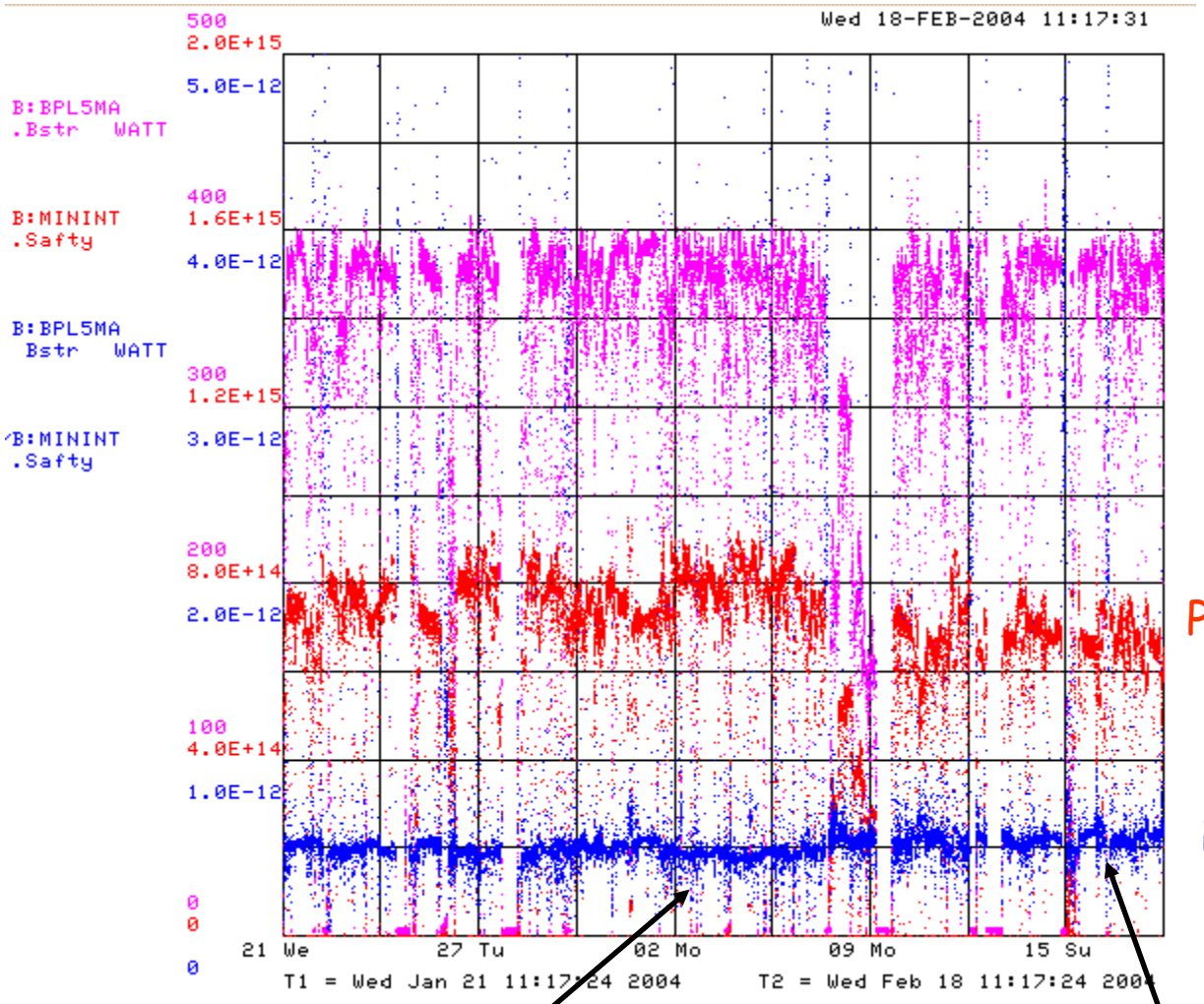
Energy Lost (W-min/p)

BooNE turn-on (Sept. 2002)

"Mysterious" Performance Problems

Big Shutdown

Recent Running (Last 4 Weeks)



Power loss (W)

Protons (p/min)

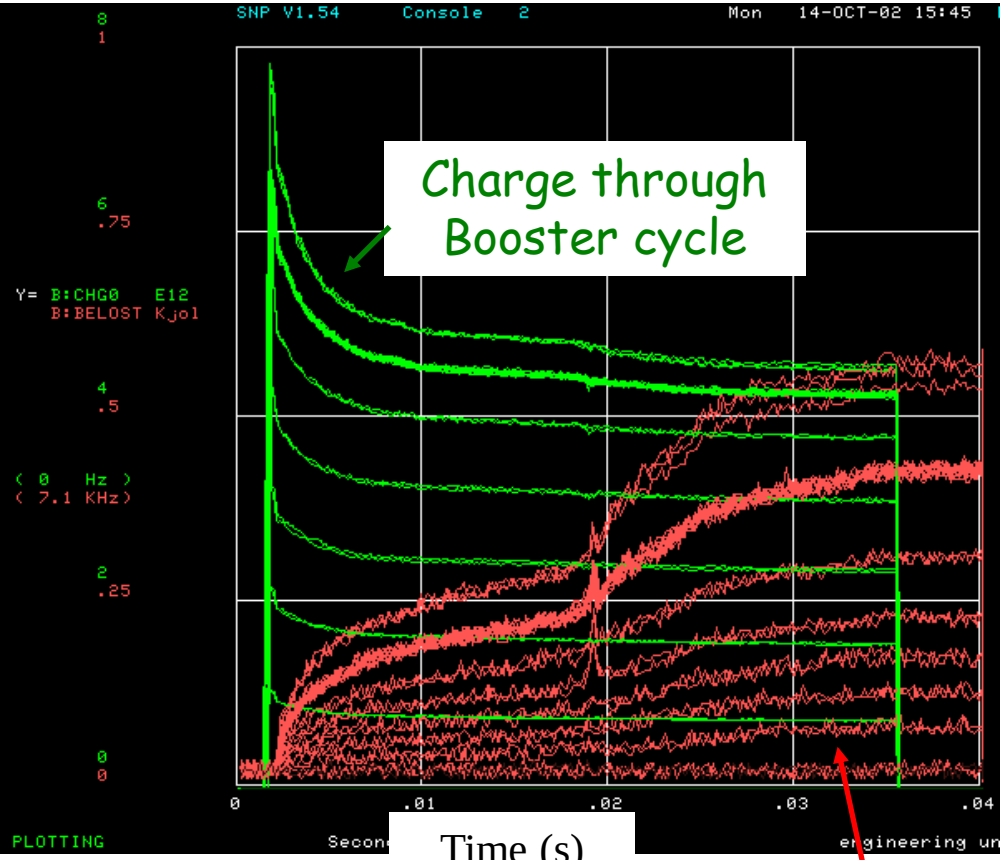
Energy Lost (W-min/p)

Record Performance

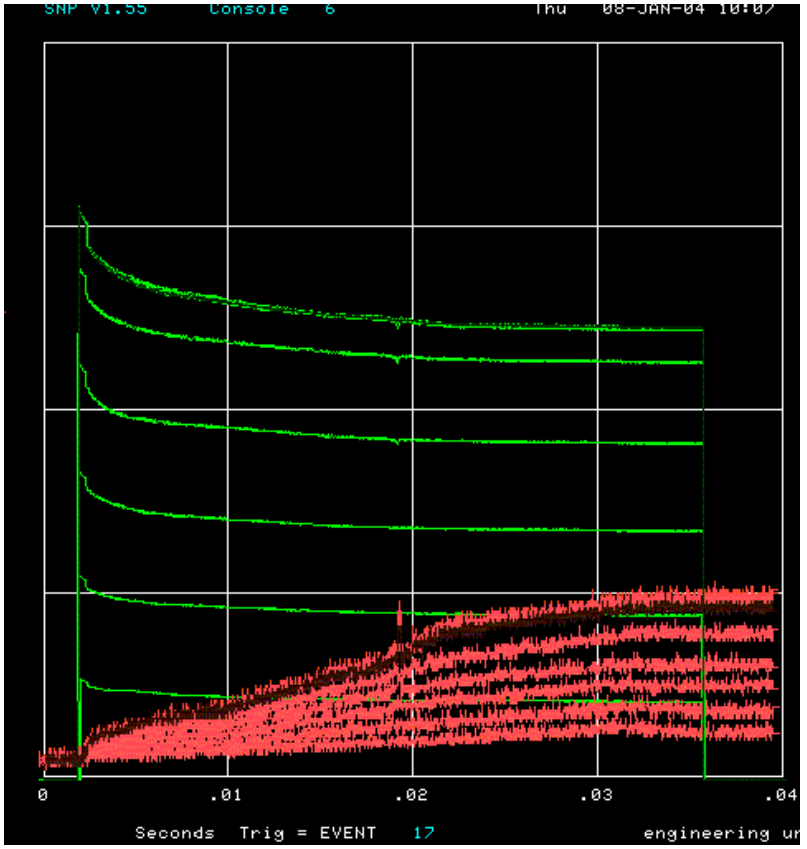
Several Unrelated Problems

How far have we come?

Before MiniBooNE



Now (same scale!!)

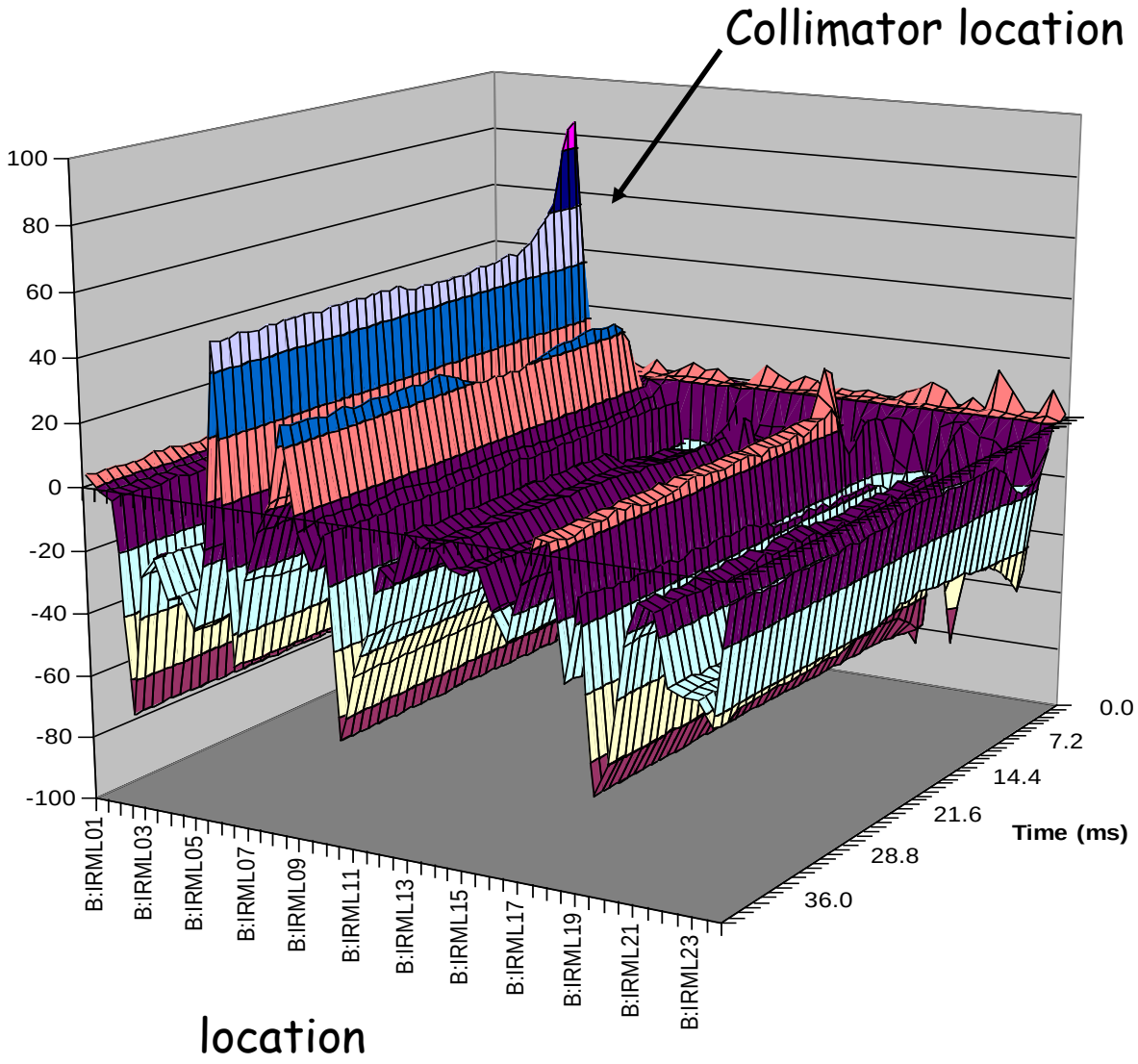


Note less pronounced injection and transition losses

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

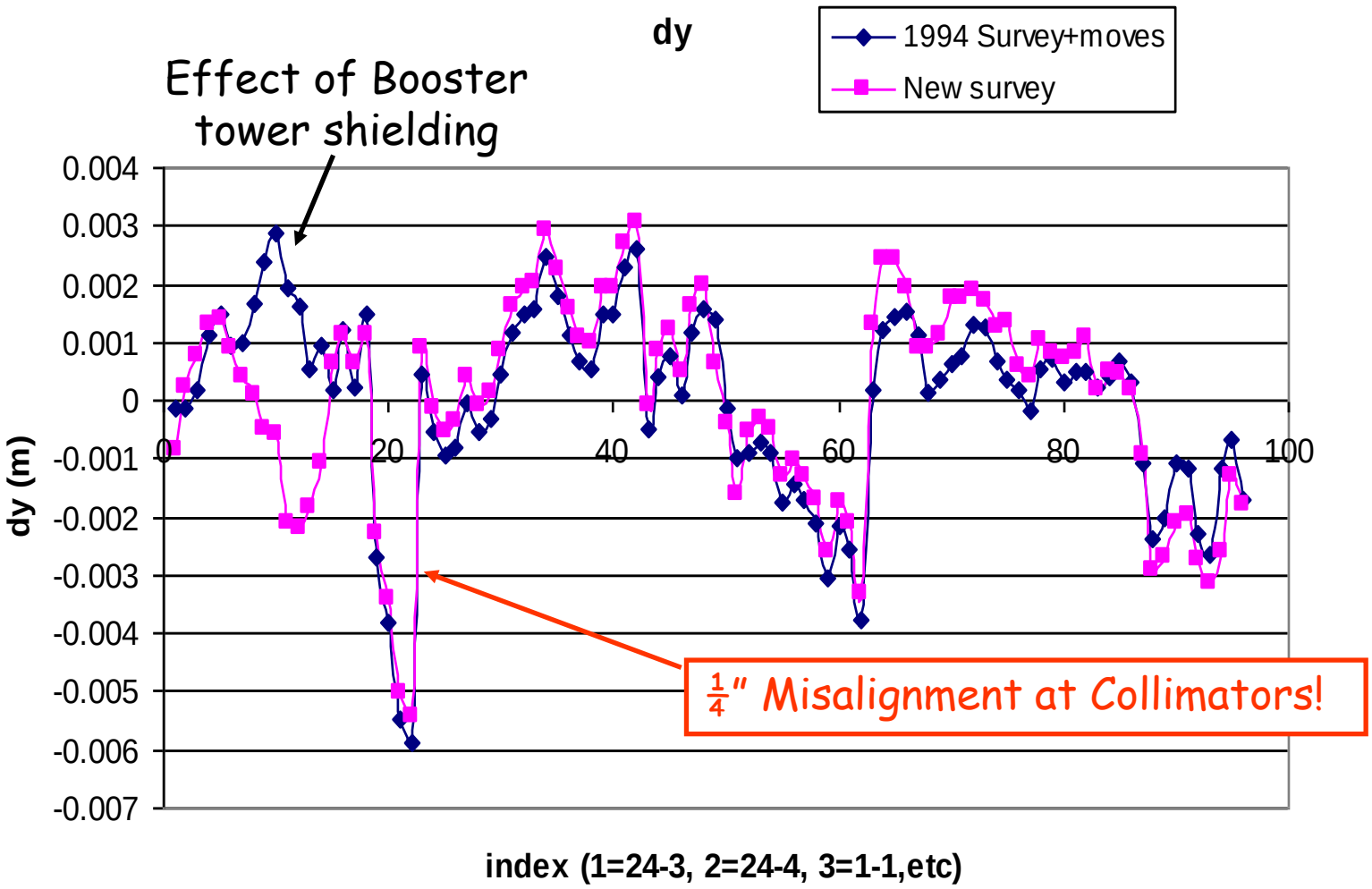


- Shown is the effect of putting in one of the secondary collimators as a percentage change in losses as a function of time around the ring.
- Studies are continuing.
  - "Rapid response team" will be put on problem.
- At present, primary collimators are not optimized to energy loss profile
  - Will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

Alignment in the Booster

- Long been known to be a problem.
- A little over a year ago, we started a vertical as-found of the entire Booster
  - Level run
  - 4 survey points on each magnet (some a bit complicated)
  - (Mostly) completed during the shutdown. Data now in hand.
  - Some big problems!
- Historical difficulties
  - Lack of priority!
  - Lack of a coherent plan, both on our part and alignment.
  - Inefficient use of downtime (response time issues).
- Solution? A task force.

Alignment Results



Alignment Plan

- Peter Kasper put in charge of coordinating alignment on our end.
- O'sheg made task manager on the AMG end.
- Andrew Feld (booster technician) will be trained as a liaison.
- Near term goals (ASAP as opportunities arise)
  - ~~Complete vertical as-found (5-10% to be done or redone)~~ DONE
  - Develop a plan for vertical moves, including both "opportunities" and longer term requests.
  - Align RF cavities and other key elements to optical center of straights.
- Longer term (aim to complete by next big shutdown)
  - Produce a "beam sheet" based on Sasha's MAD file
  - Add non-magnetic elements
  - Complete network, including horizontal.

Priorities over the Next Year

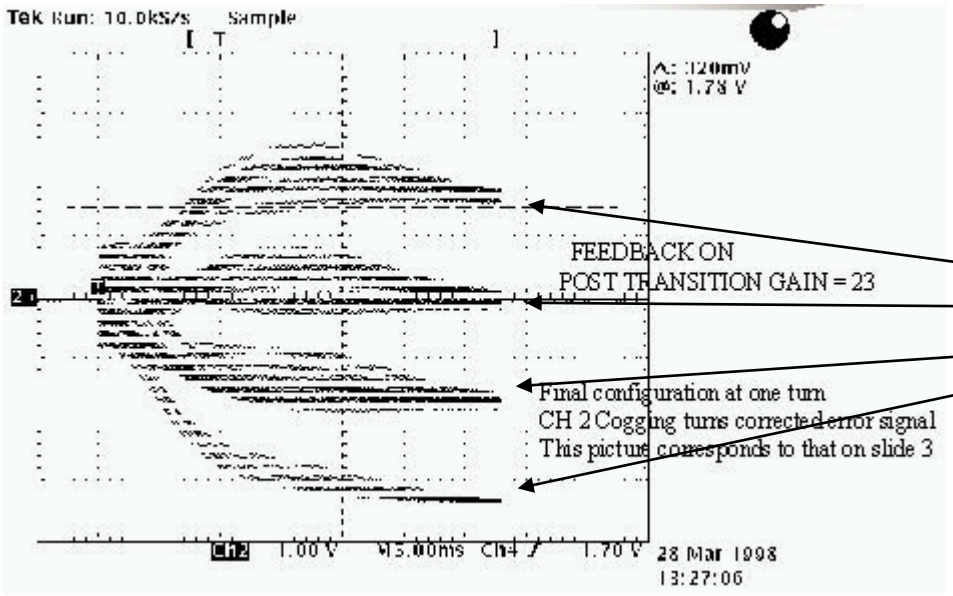
- Linac Characterization and Reliability
  - Increase instrumentation of old linac to study instabilities.
  - Develop set of performance parameters.
- Booster improvements.
  - Prepare for modification of second extraction region
    - New septum
    - Modified dogleg magnets
    - On track for next 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.
      - Aiming for summer shutdown (aggressive, but doable)
    - 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.
      - Aiming for summer shutdown (aggressive, but doable).

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 few months

Planning for the future

- In response to the "Finley 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), under the assumption that a Proton Driver will eventually be built.
- 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
    - Which means there will be very little to do with the Main Injector.
- There are some "big" (>$1M) projects that must be discussed.

Large Projects Under Consideration

- Booster RF system:
  - Commission a design for a new booster RF system
  - Larger aperture, higher gradient cavities
  - Solid state distributed amplifiers
  - Goal to have design by January 2005.
  - Two year timescale to build and install (perhaps solid-state DA's can come sooner).
  - Cost ~all of it.
- Adding two additional cavities
  - Use university prototypes + spare parts
  - Cost ~$500K
- 30 Hz harmonic to booster ramp.
  - Effectively increases RF power
  - Cost of order $1-2M
- New LEL quad power supplies.
  - A significant reliability worry
  - Cost of order $1M.

Schedule for the Plan

- Will proceed with the vital projects for this year.
- Hope to have a skeleton of a plan by the end of this month.
- Will have a more detailed plan and major recommendations by this summer.