Proton Source Status and Plans

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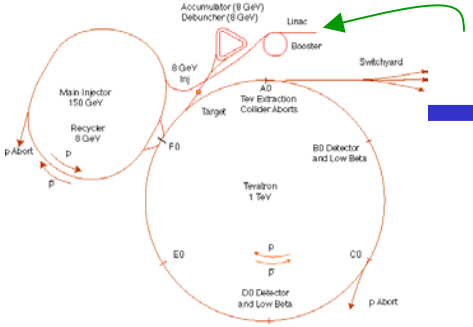
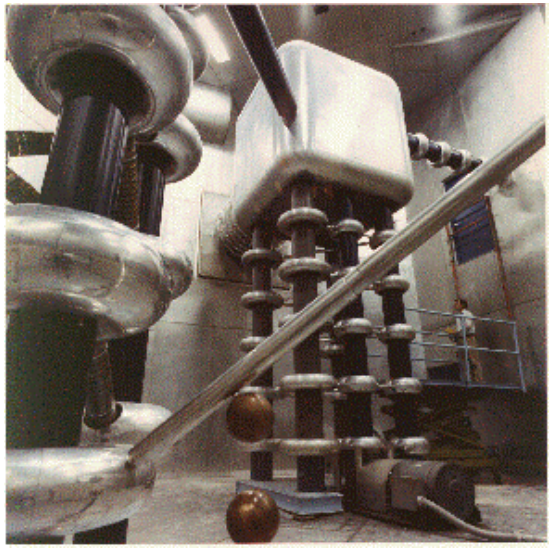
Proton Team ("Finley Report")

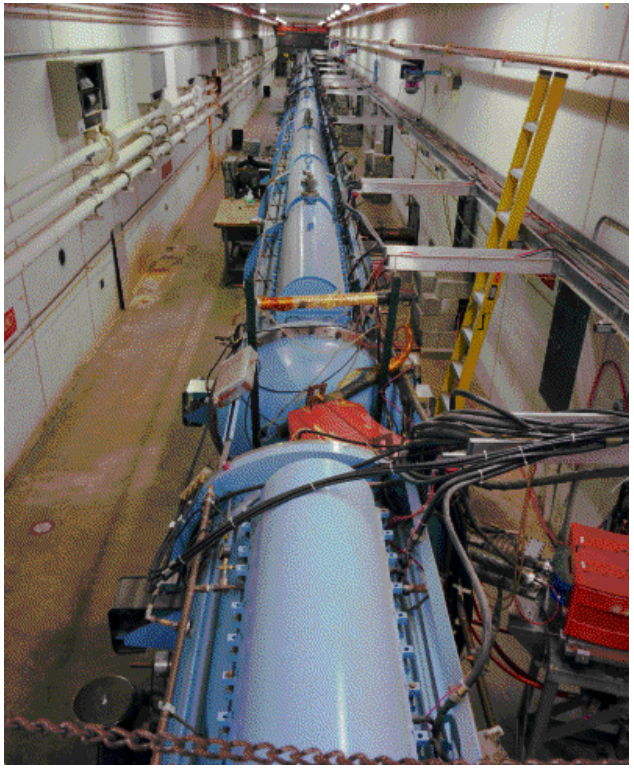
- Group formed in early 2003 to study proton demands and needs for the "near" future (through ~2012 or so), in the absence of a proton driver.
- Work culminated in a report to the director, available at www.fnal.gov/directorate/program_planning/studies/ProtonReport.pdf
- No big surprises [see P. Kasper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

Preac(cellerator) and Linac



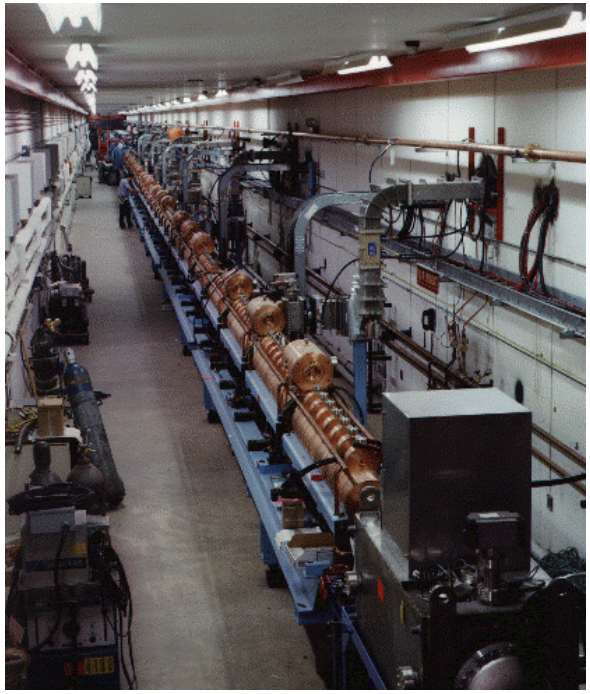


"Preac" - Static Cockroft-Walton generator accelerates H- ions from 0 to 750 KeV.



"Old linac"- 200 MHz "Alvarez tubes" accelerate H- ions from 750 keV to 116 MeV

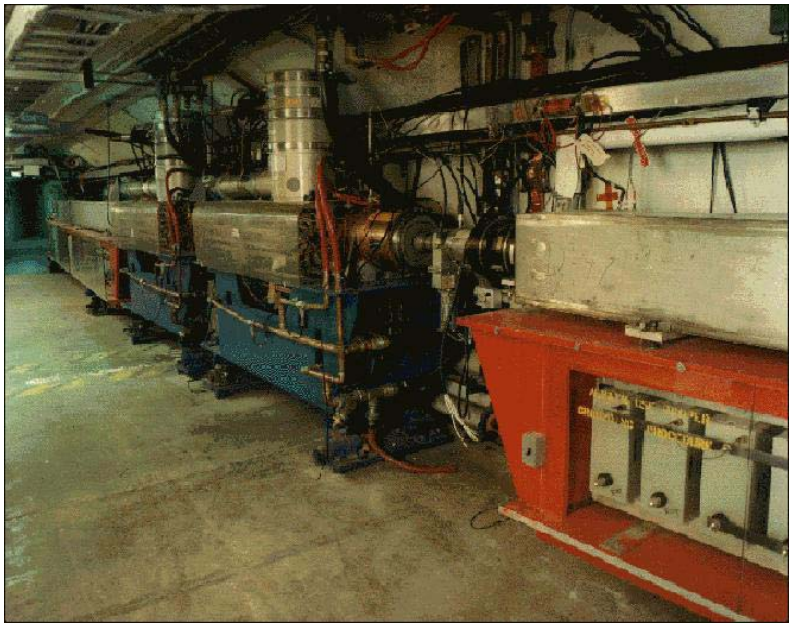
"New linac"- 800 MHz "π cavities" accelerate H- ions from 116 MeV to 400 MeV



Preac/Linac can deliver about 45 mA of current for about 40 usec at a 15 Hz repetition rate (not a bottleneck)

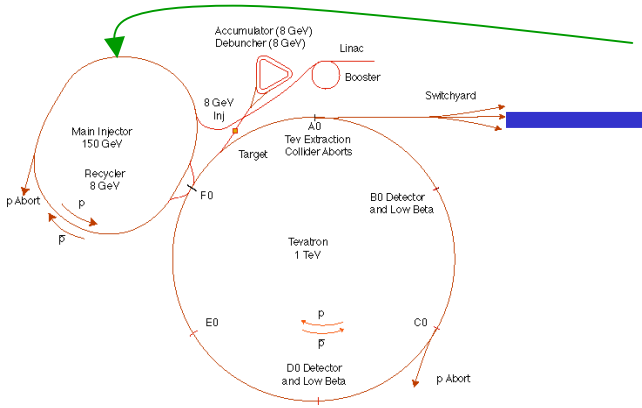
Booster

- 400 MeV Linac H- beam is injected into booster.
- The lattice magnets in the Booster form a 15 Hz resonant circuit, setting the instantaneous cycle rate, but ramped elements limit the average repetition rate to somewhat lower.
- From the Booster, beam can be directed to
  - The Main Injector
  - MiniBooNE
  - The Radiation Damage Facility (RDF)
  - A dump.



- The 15 Hz cycle sets a fundamental clock rate for the entire complex.
- One full booster "batch" sets a fundamental unit of protons throughout the accelerator complex (max 5E12).

Main Injector



- The Main Injector can accept 8 GeV protons OR antiprotons from
  - Booster
  - The anti-proton accumulator
  - The Recycler (which shares the same tunnel)
- It can accelerate protons to 120 GeV (in a minimum of 1.4 s) and deliver them to
  - The antiproton production target.
  - The fixed target area.
  - (soon) The NUMI beamline.
- It can accelerate protons OR antiprotons to 150 GeV and inject them into the Tevatron.

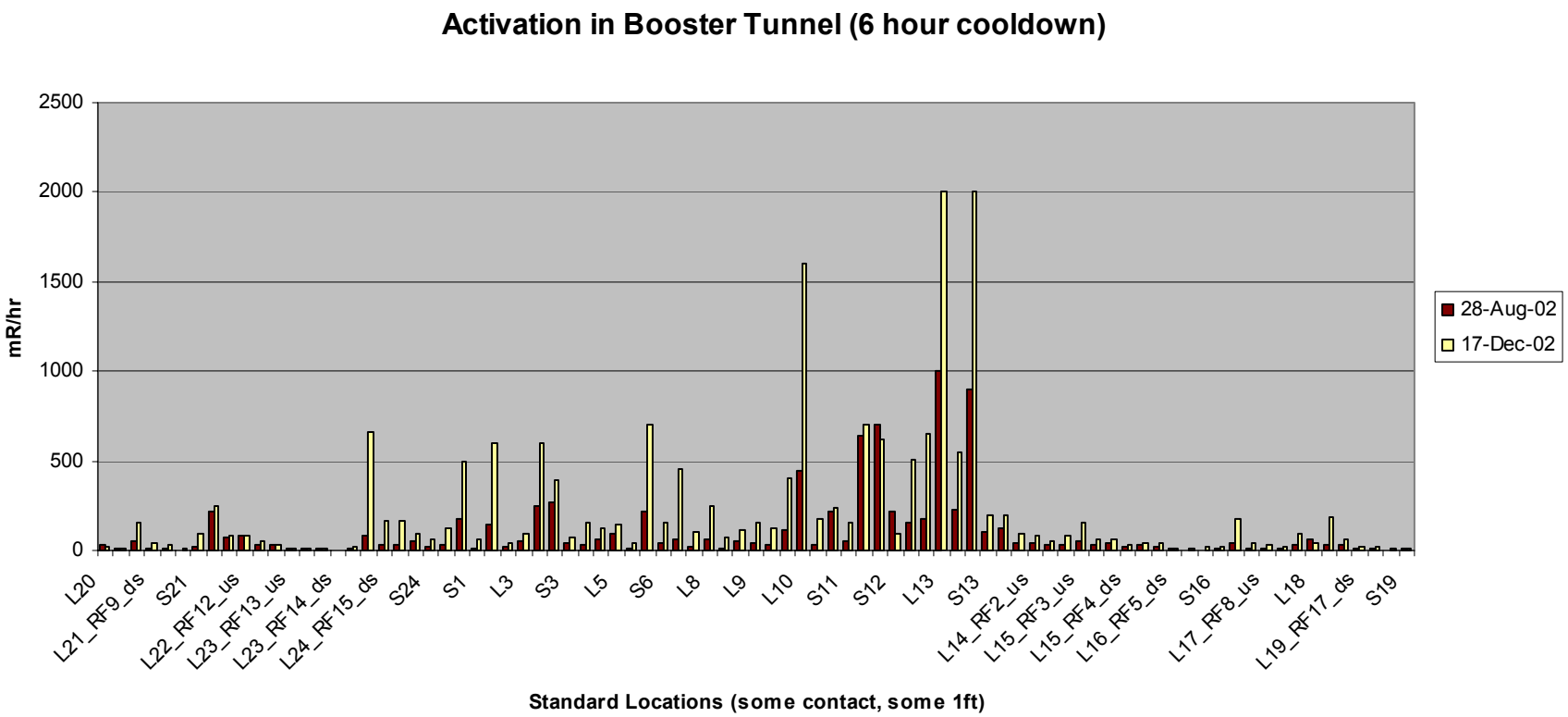
- The Main Injector holds six booster batches, in the absence of exotic loading schemes (slip stacking, RF barrier, etc).
- It's envisioned that two slipstacked batches will be used for stacking and the rest for NUMI and/or switchyard 120.

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

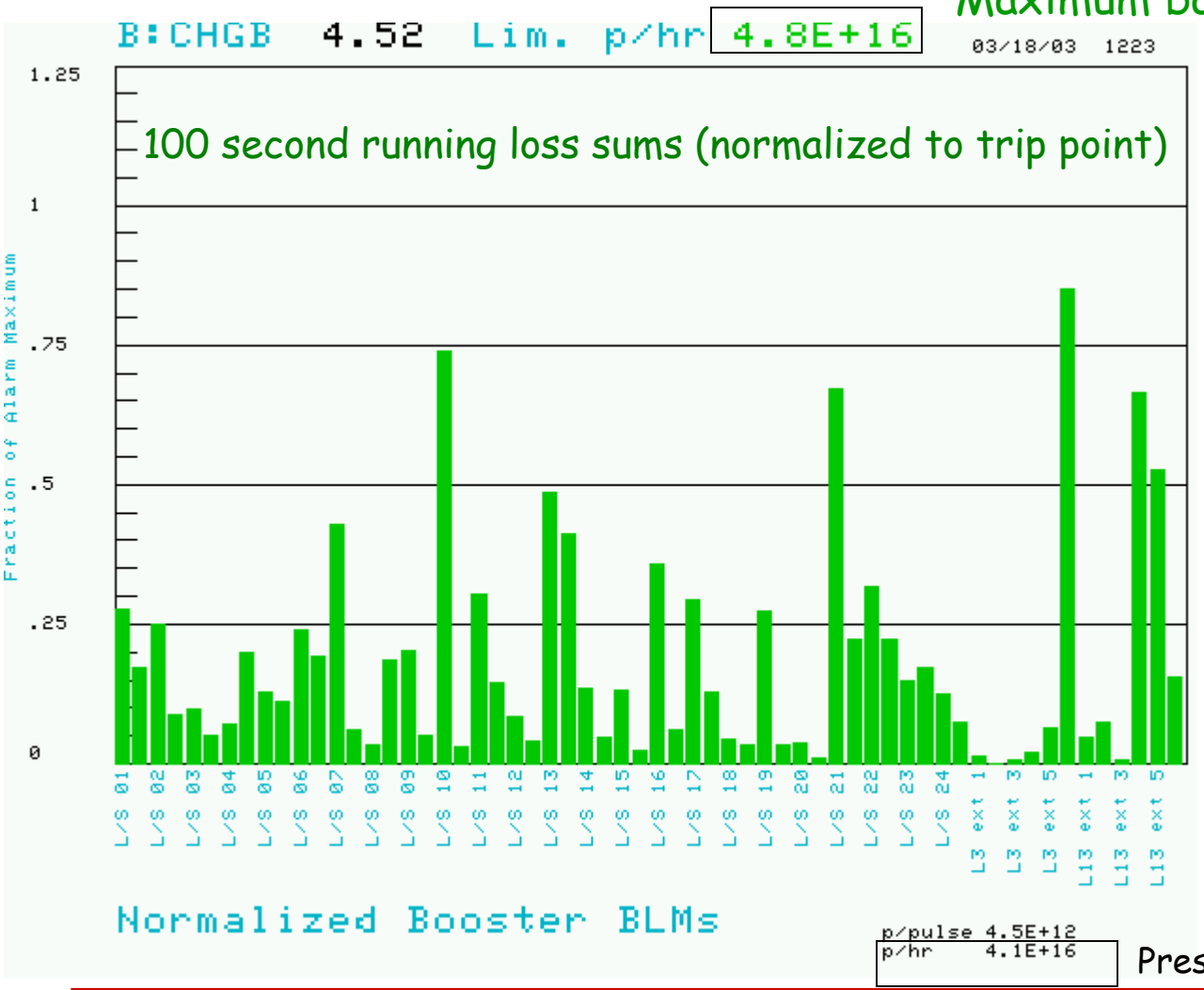
Our biggest worry at the moment!!!!

The Bad News: Booster Tunnel Radiation Levels



Any further increase in protons must come without increasing losses.

Operational Issues: Limiting Booster Losses

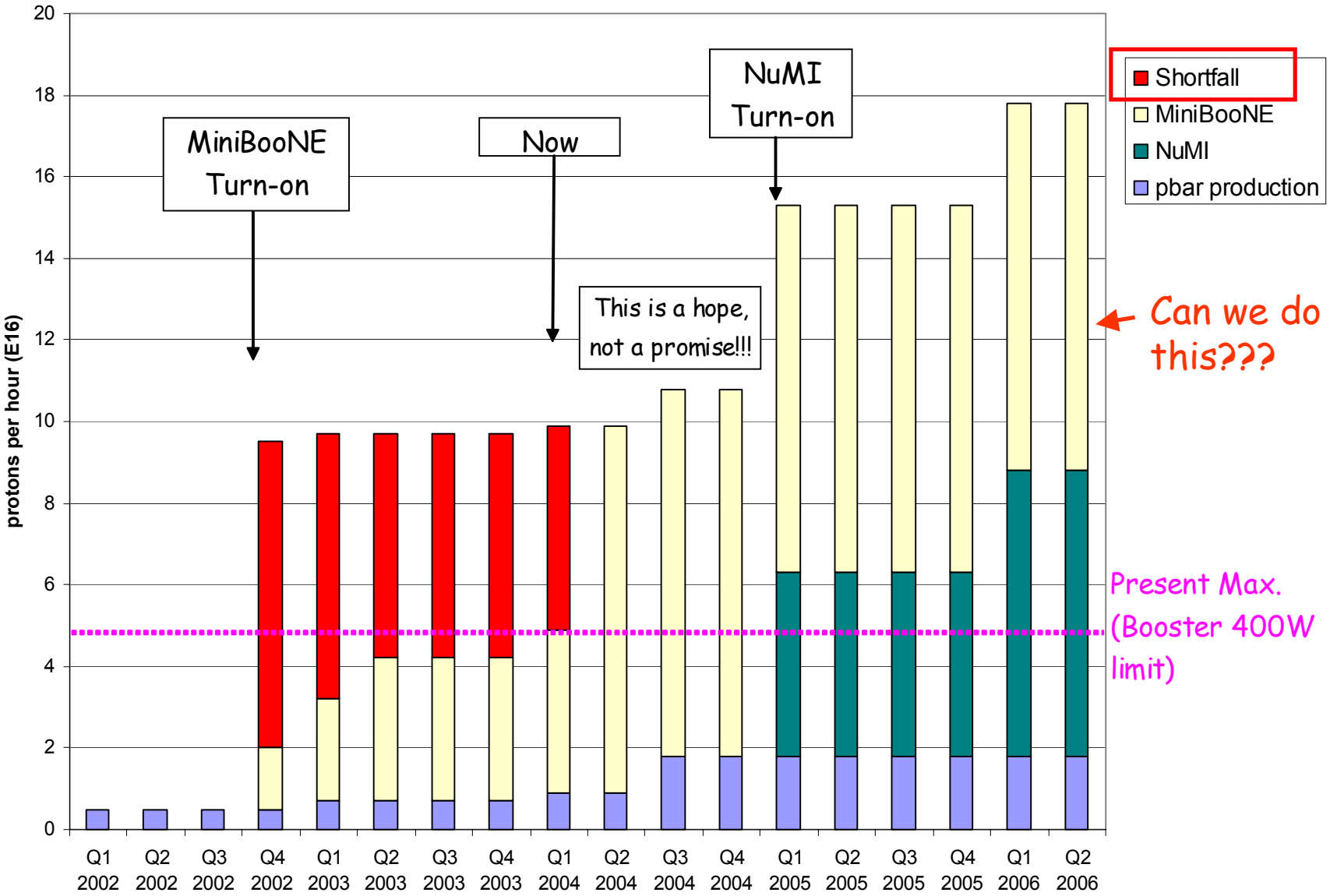


Maximum based on trip point

Present rate

Also limit total booster average power loss (B:BPL5MA) to 400W.

Proton Demand

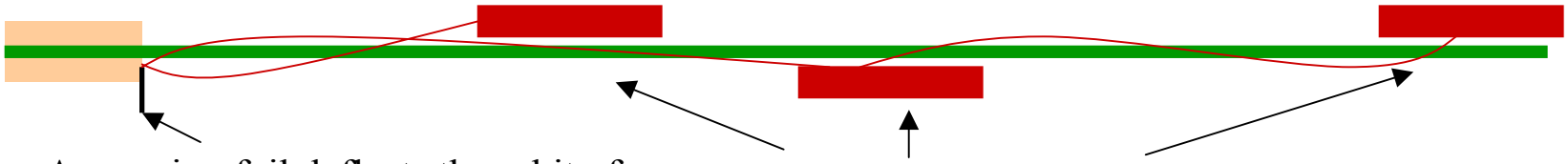


Projects in 2003 (a short list)

- 2003 Activities centered around preparation for the September shutdown:
  - Linac:
    - Major water system upgrade
    - New Lamberston to steer beam to Booster
      - Better optical qualities
  - Booster
    - two-stage collimation system
      - In the works a long time
      - Suffered major setbacks, but 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.

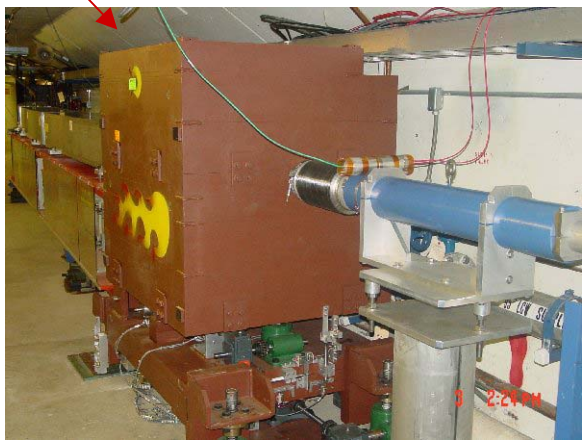
New Collimator System

Basic Idea…



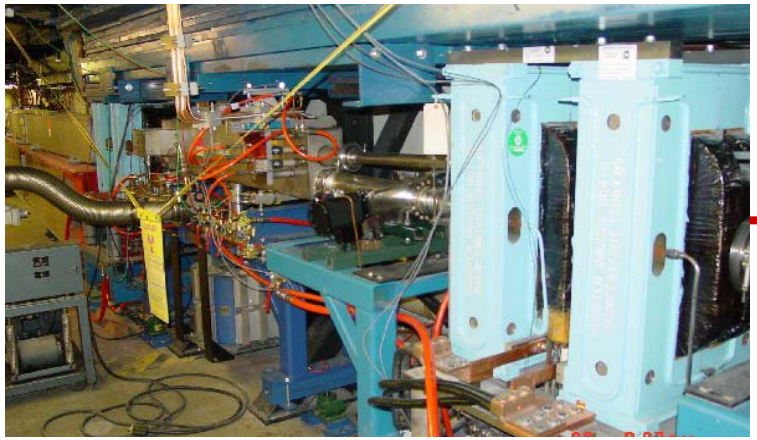
A scraping foil deflects the orbit of halo particles…

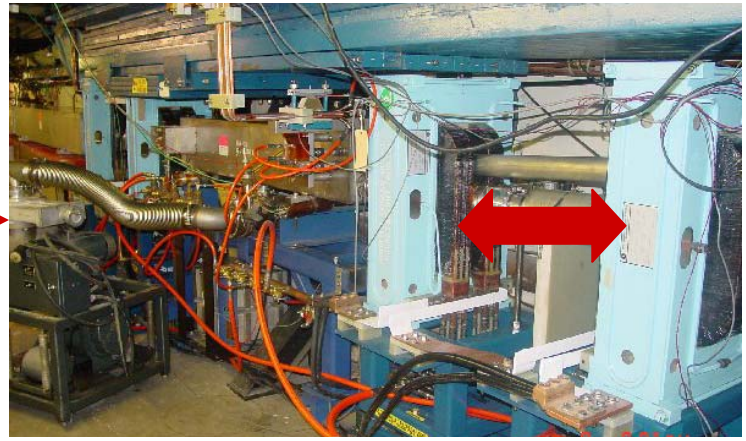
…and they are absorbed by thick collimators in the next periods.



- Should dramatically reduce uncontrolled losses

Long 3 Dogleg Work

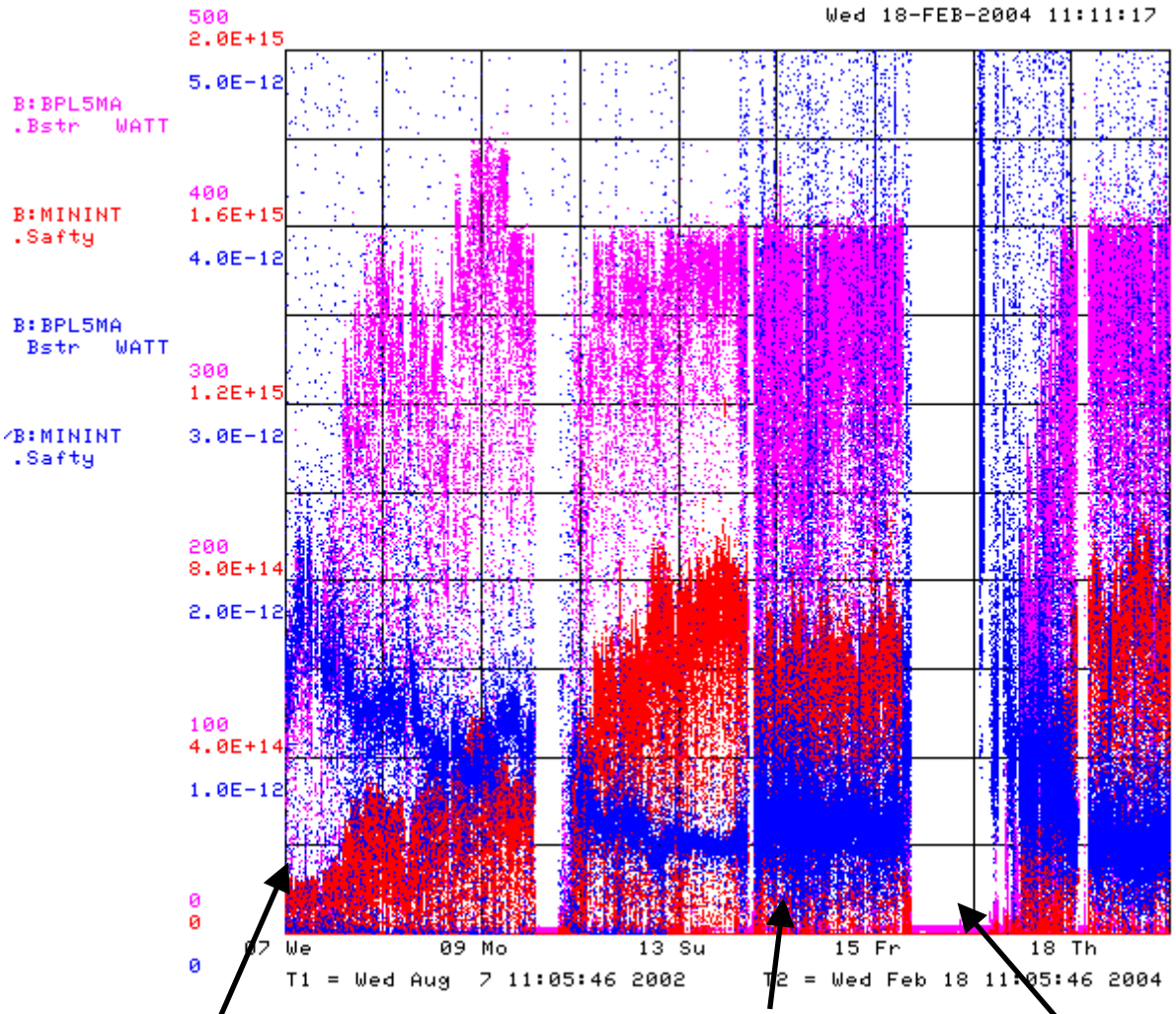




New magnet to match extraction line

- 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)

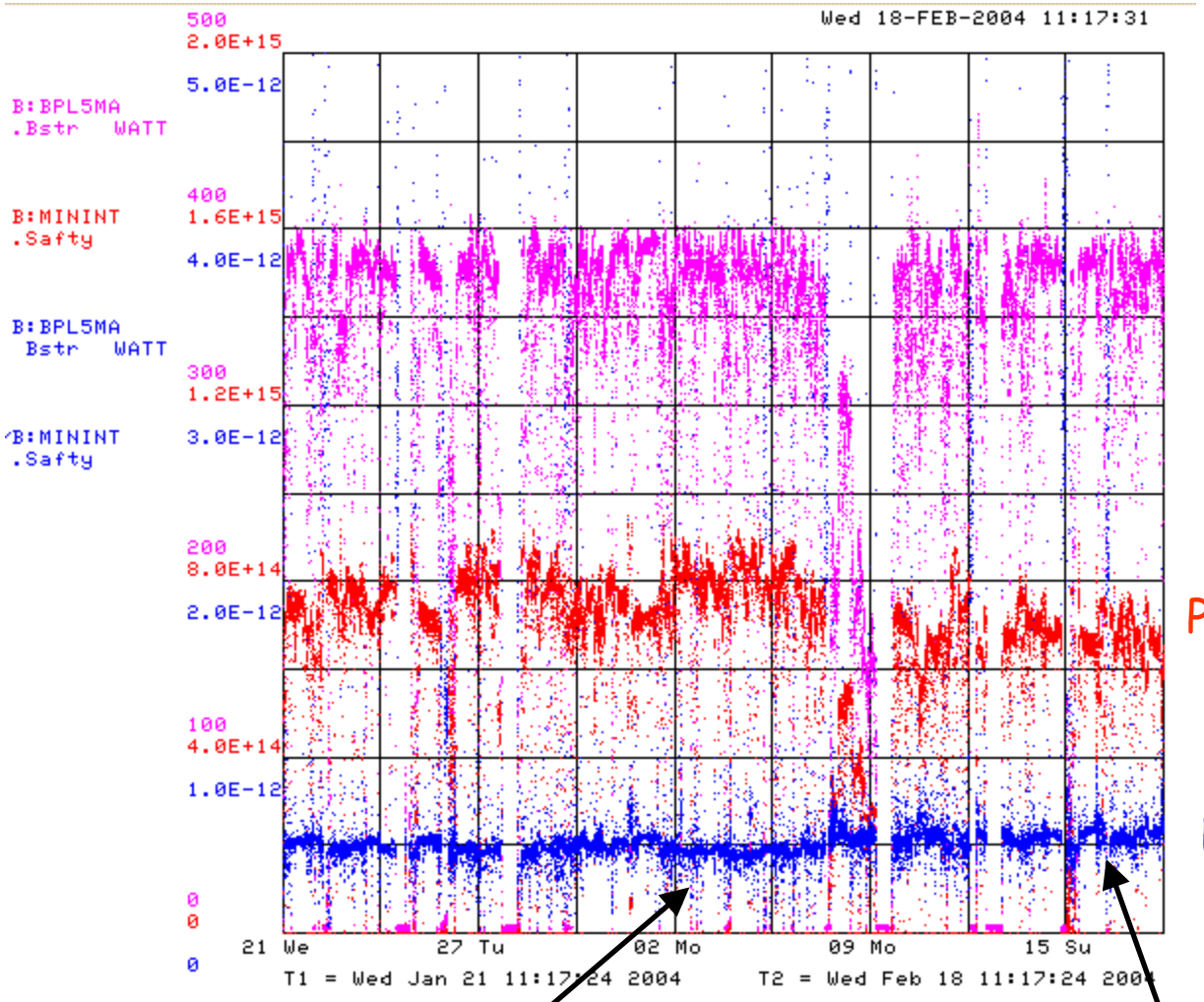
Energy Lost (W-min/p)

BooNE turn-on (Sept. 2002)

"Mysterious" Performance Problems

Big Shutdown

Recent Running (Last 4 Weeks)



Power loss (W)

Protons (p/min)

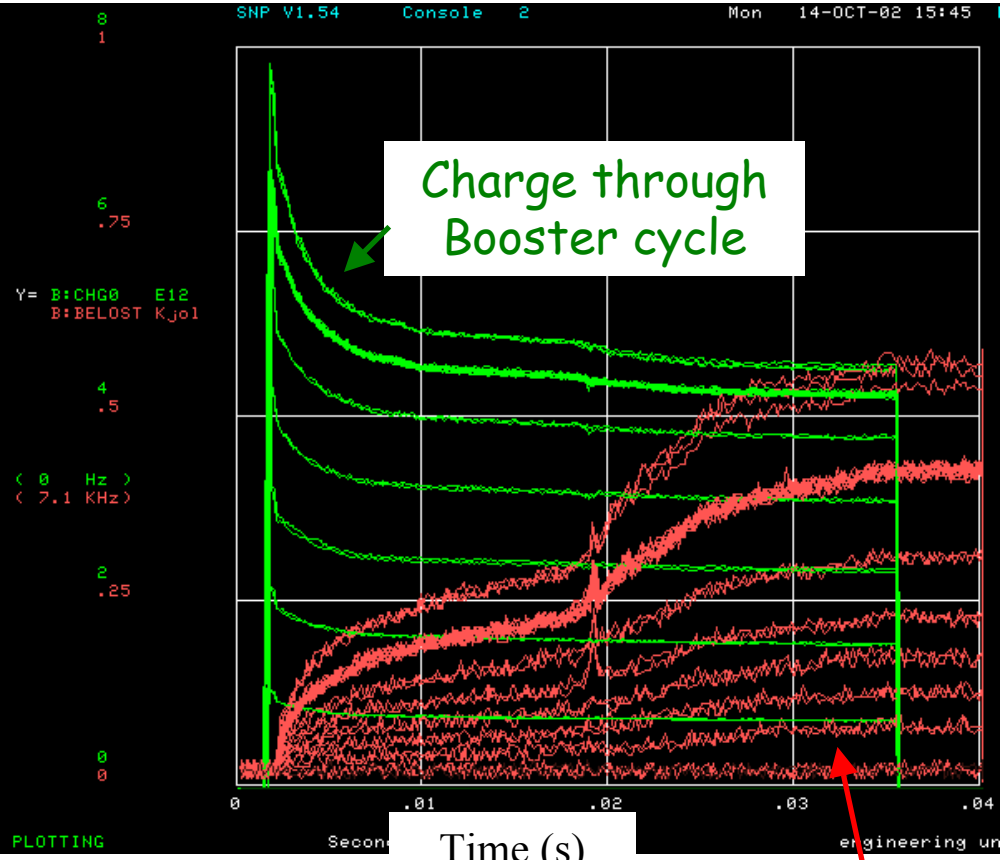
Energy Lost (W-min/p)

Record Performance

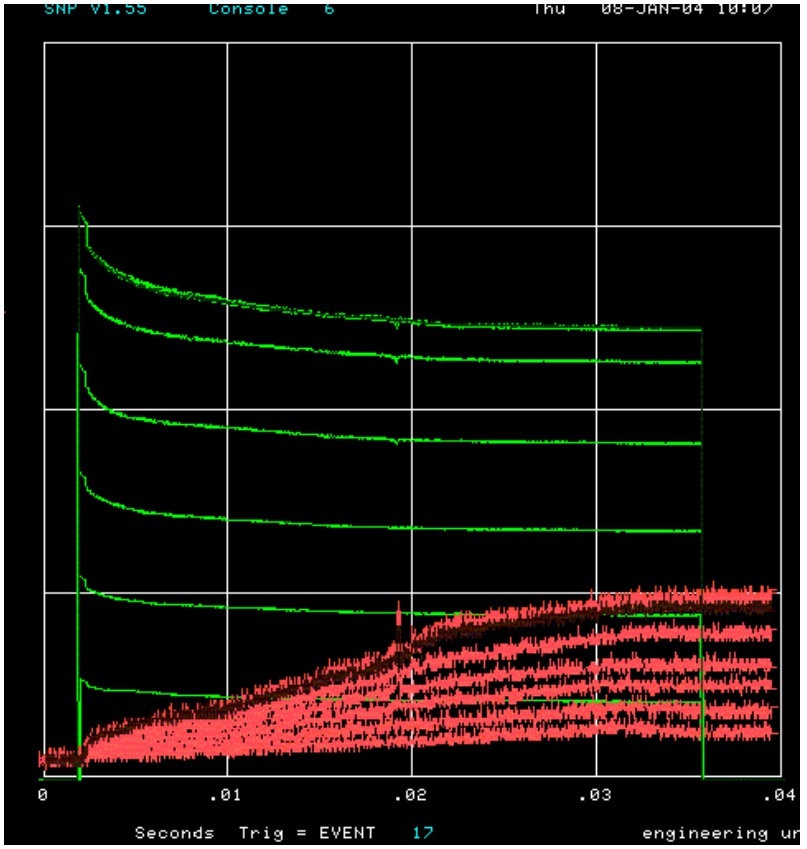
Several Unrelated Problems

How far have we come?

Before MiniBooNE



Now (same scale!!)

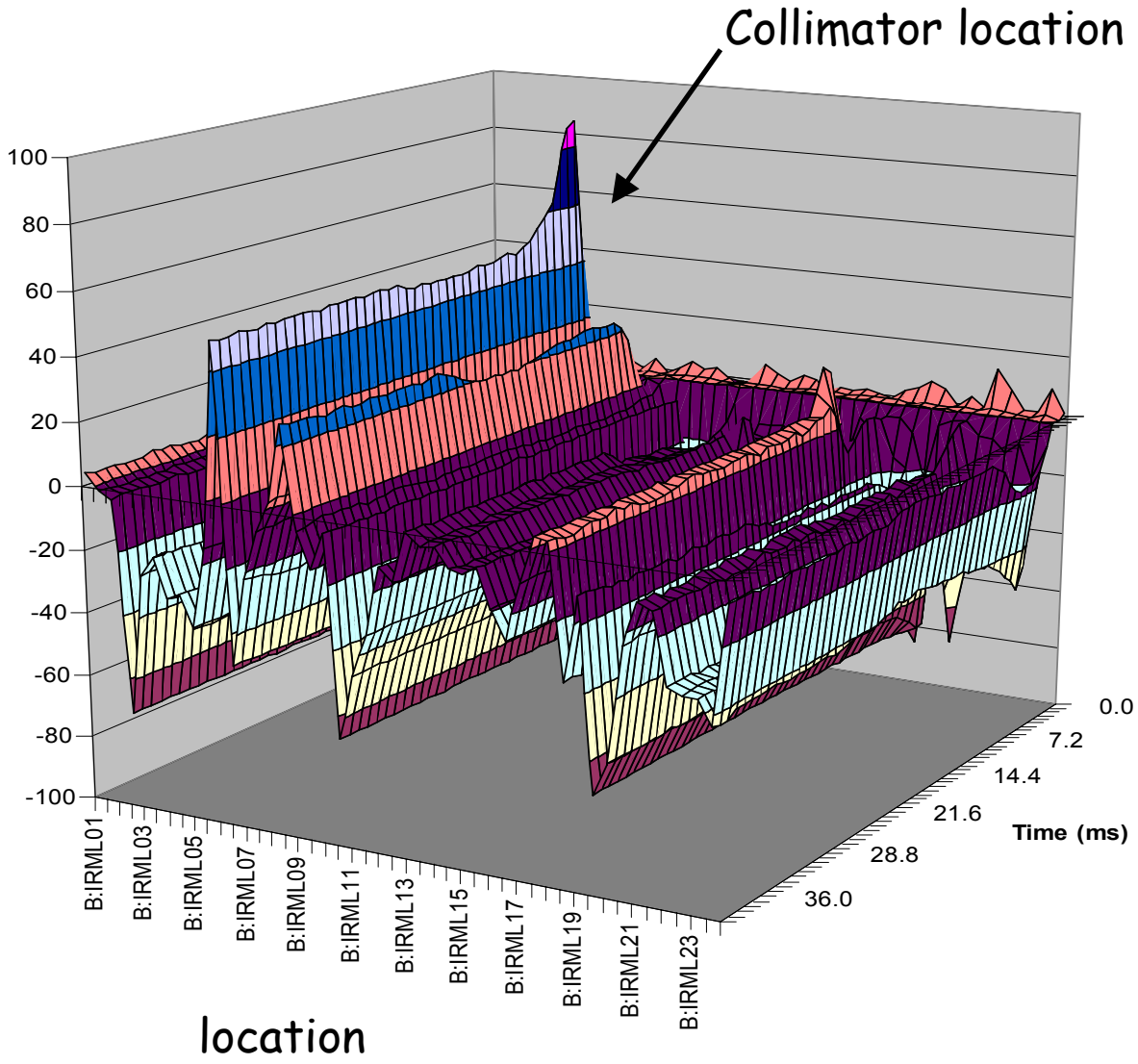


Note less pronounced injection and transition losses

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)
- Studies:
  - RF capture
  - Transition crossing
  - Space charge effects

Collimator Studies

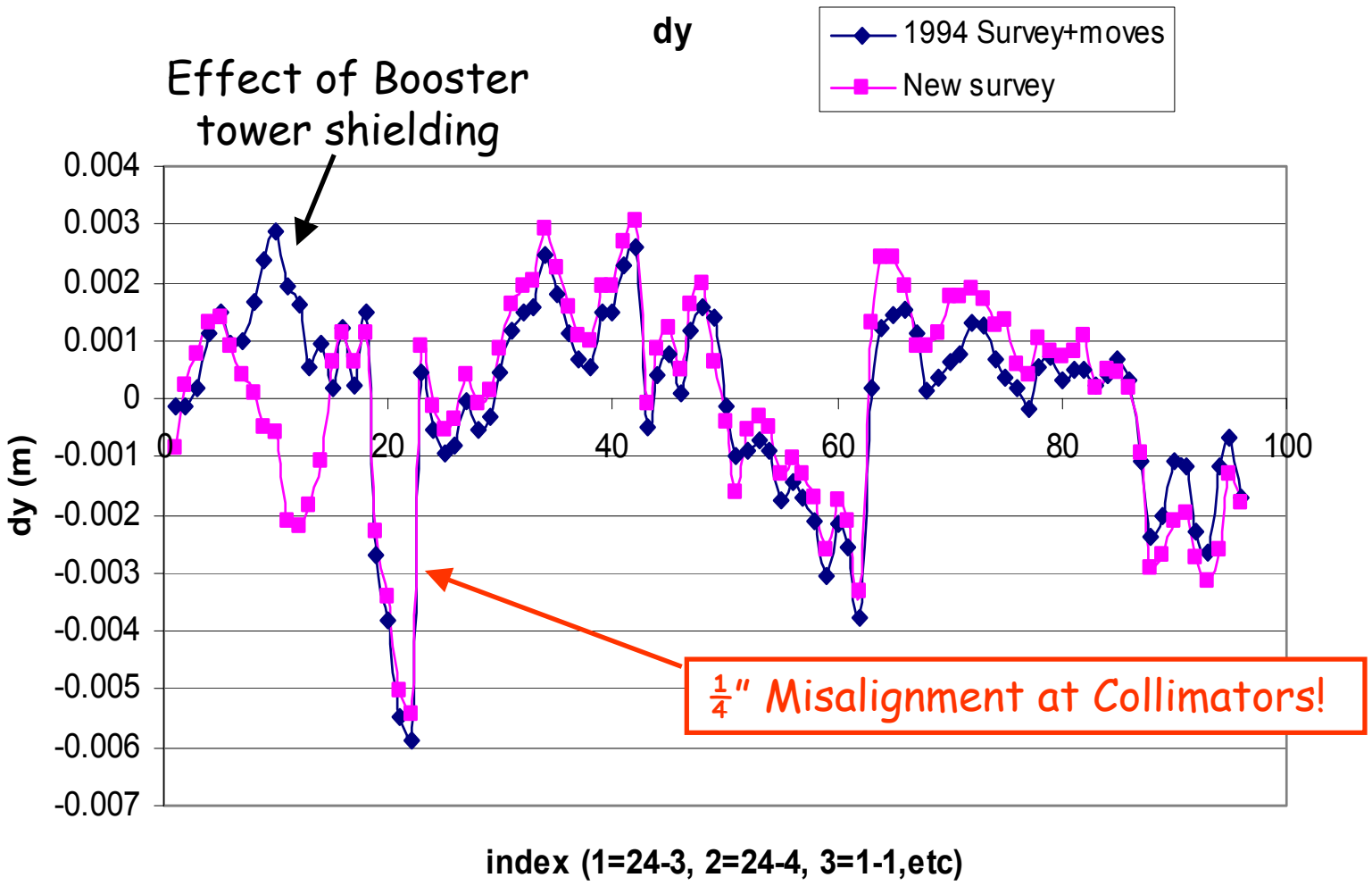


- Shown is the effect of putting in one of the secondary collimators as a percentage change in losses as a function of time around the ring.
- Studies are continuing.
  - "Rapid response team" will be put on problem.
- At present, primary collimators are not optimized to energy loss profile
  - Will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

Alignment in the Booster

- Recognized as a problem for some time.
- 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? What else – 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 network (5-10% to be done or redone)
  - 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

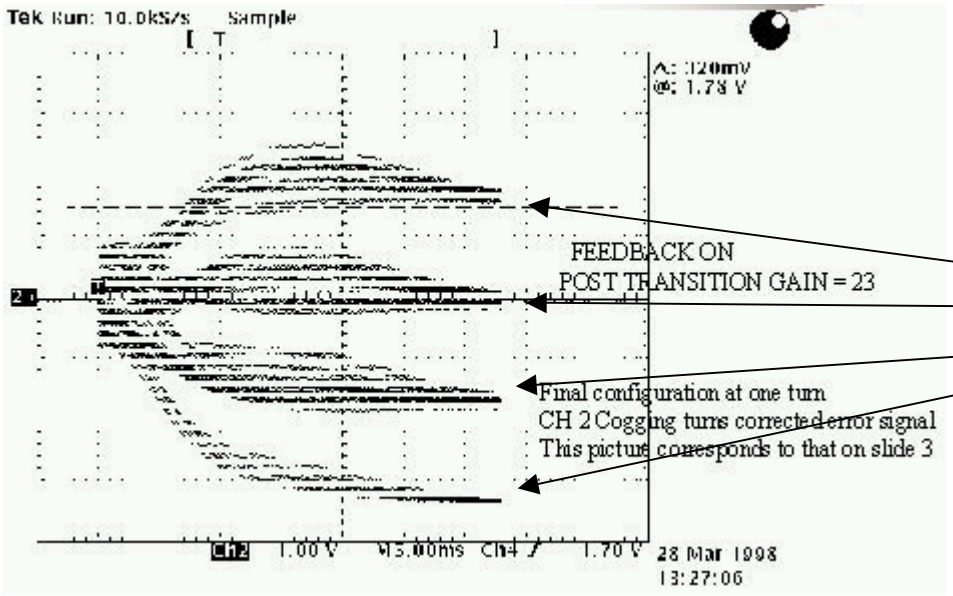
- Linac Characterization and Reliability
  - Increase instrumentation of old linac to study instabilities.
  - Develop set of performance parameters.
- Booster improvements.
  - Prepare for modification of second extraction region
    - New septum
    - Modified dogleg magnets
    - On track for next 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 (NOTE: will get better slide, here)

- 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

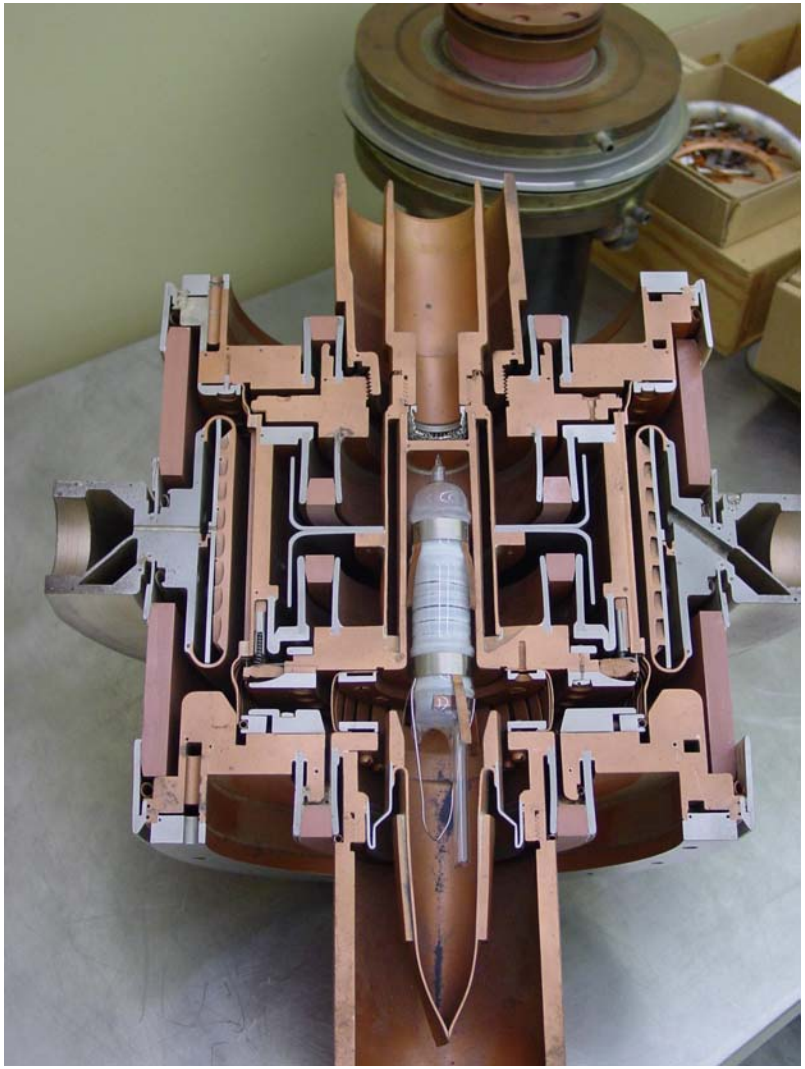
- In response to the "Finley Report", the lab management has asked for a "Proton Plan" for the proton source over the next few years, analogous to the Run II plan, but much lower in scope.
- The plan is to do what we can reasonably do to maximize the throughput and reliability of the existing proton 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.

The 7835 Power Triode – A BIG Worry

- 5 needed for old linac
  - One vendor (Burle)
  - No viable substitute.
- Very complex technology
  - RF, material science, vacuum, chemistry
- Similar to other tubes made by Burle
  - 4617
- 7835 only used in the scientific community.
  - ANL, BNL, LANL
  - One military user for 4617
- Quality varies from decade to decade



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

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.
- Two additional booster RF cavities
  - Can use large aperture prototypes, and mostly spare parts.
  - Would increase efficiency and reliability (can't run well with one station down, at the moment).
  - Cost ~500K.
  - Might happen in the summer shutdown.
- 30 Hz harmonic to booster ramp.
  - Effectively increases RF power
  - Cost of order $1-2M
- New LEL quad power supplies.
  - A reliability concern.
  - Cost of order $1M.

Schedule for the Plan

- Must proceed with the "vital" projects for this year.
- Hope to have a skeleton of a plan by the end of this month.
- We need to make a decision on the extra RF cavities soon
- Will have a more detailed plan and major recommendations by this summer.

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.