NuMI Beam Diagnostics and Control

Steps to 2 MW

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Overview

- Current NuMI 120 GeV primary beam system design is for 0.4 MW beam power. Focus of discussion here is toward the upgrades needed with beam diagnostics and control to extract and transport much more powerful beams to 2 MW or greater beam power.
- Performance of current NuMI primary beam operation is discussed in more detail in Working Group D presentation.
- The very considerable challenges of producing 2 MW beams of ~ 120 GeV and the target hall systems to generate high flux neutrino beams are **not** covered here.

Key NuMI Proton Beam Considerations

A New Regime for Beam Control Requirements

- **The most compelling feature for high energy several hundred kW proton beams is that they can damage most materials very quickly – a few seconds or even one cycle of mis-steered beam**

- **Now we also need millions of pulses!**
  - **NuMI to date has accumulated 24 M beam pulses**

Other NuMI Beam Constraints

- **Targeting**
  - **Maintain beam centered on target to < 0.25 mm (Physics background constraint)**
  - **Preclude 2nd beam pulse at 1.5 mm off center (6.4 mm target width; 11mm baffle ID). Wayward beam at significant angle could hit target cooling or horns**
- **Severe Limits on Allowable Primary Beam Loss**
  - **For 400 kW beam maximum fractional point beam loss allowed is ~ 10-5 for environmental (ground water) protection.**

Keys to NuMI Proton Beam Operation

- **Comprehensive beam permit system**
  - **~ 250 parameters monitored**
- **Open extraction/primary beam apertures – capability of accepting range of extracted beam conditions**
  - **Superb beam loss control**
- **Good beam transport stability**
- **Autotune beam position control**
  - **No manual control of NuMI beam during operation**

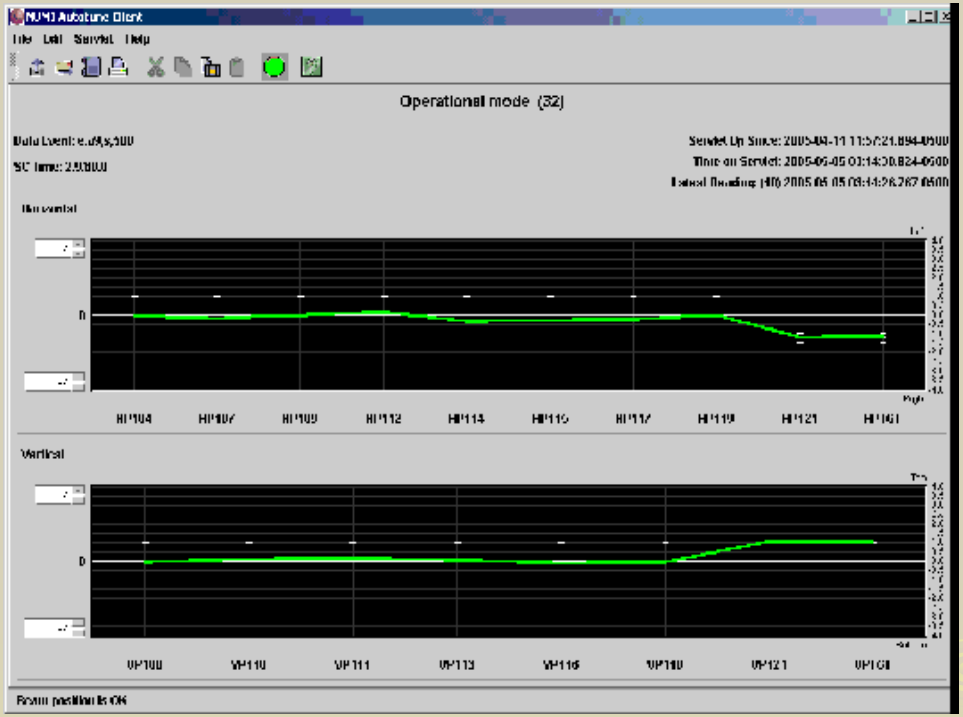
NuMI Beam Permit System

- **Dedicated hardware based on Tevatron fast abort system. Used from 1st beam**
- **Permit to fire NuMI extraction kicker is given prior to each beam pulse, based on good status from a comprehensive set of monitoring inputs**
  - > 250 inputs to NuMI BPS
  - Alarms are maintained for many more parameters, but they do not automatically stop the beam as do BPS inputs
- **Inputs include Main Injector beam quality prior to extraction, NuMI power supply status, target station and absorber status, beam loss and position for previous pulse**

With the very intense NuMI beam and severe beam loss constraints, perhaps our most important operational tool.

Autotune Primary Beam Position Control

- **Automatic adjustment of correctors using BPM positions to maintain primary transport & targeting positions**
- **Commissioned at initial turn on for correctors**
- **Vernier control for targeting. Initiate tuning when positions 0.125 mm from nominal at target**
- **Very robust . Separate corrector files for mixed mode and NuMI only**

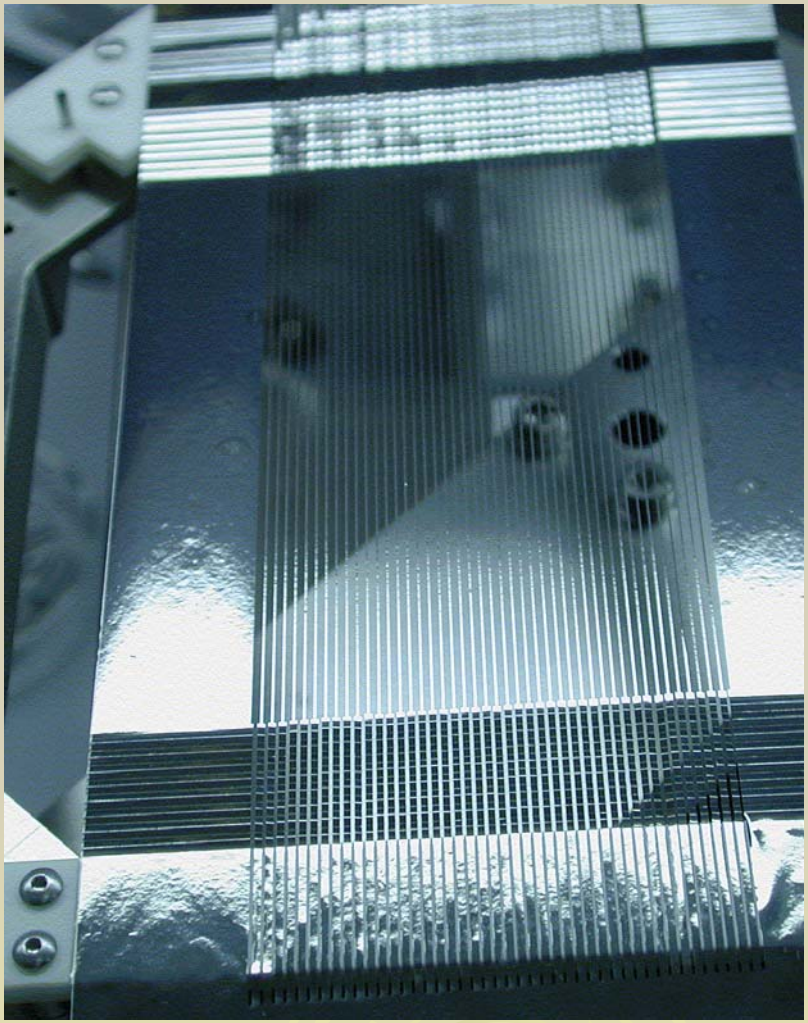


Autotune Beam Control Monitor

Primary Beam-line Instrumentation

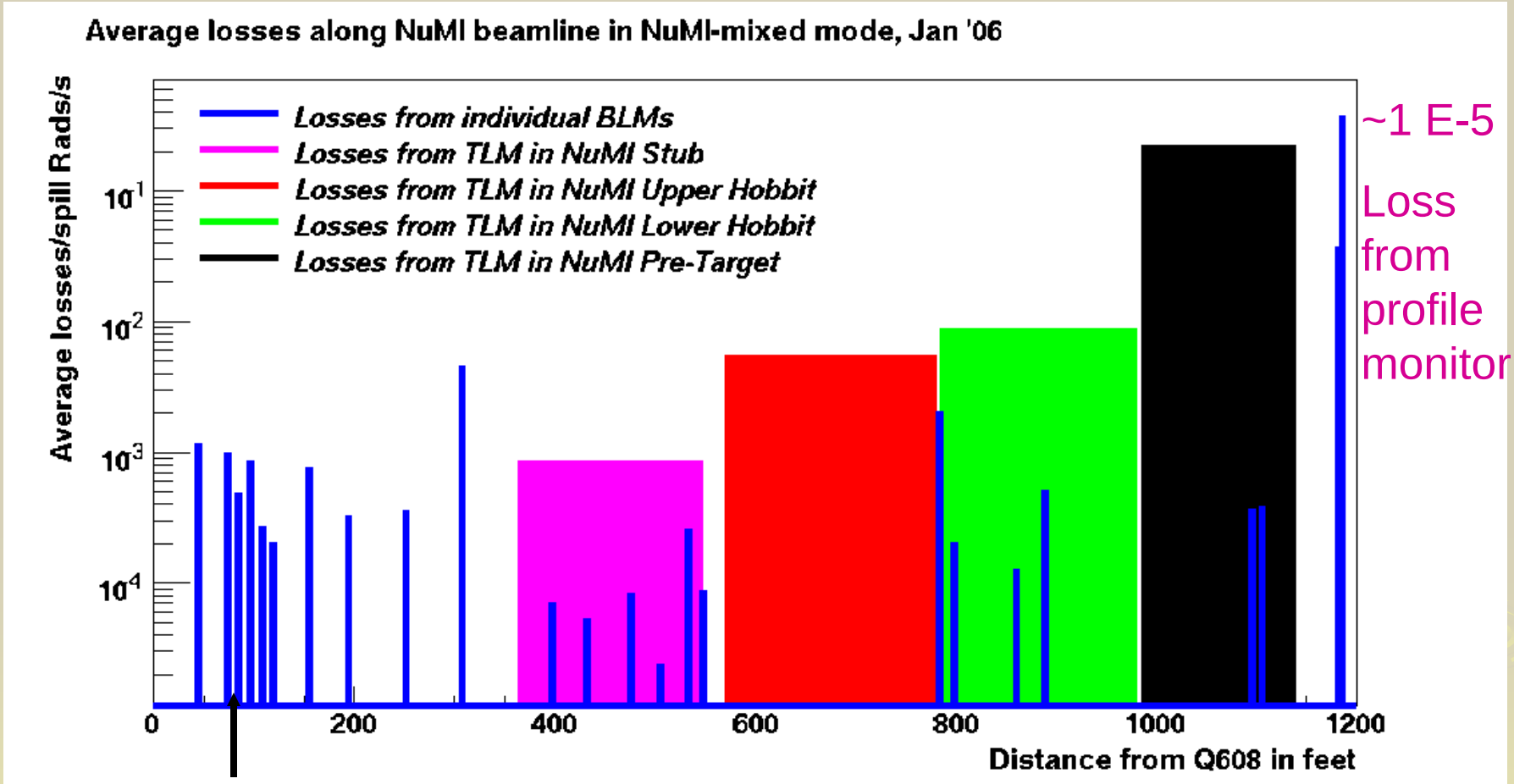


- 2 beam toroids
- 24 beam position monitors
- 54 loss monitors
- 10 thin-foil profile monitors (SEM)
  - **5 micron Titanium foils**

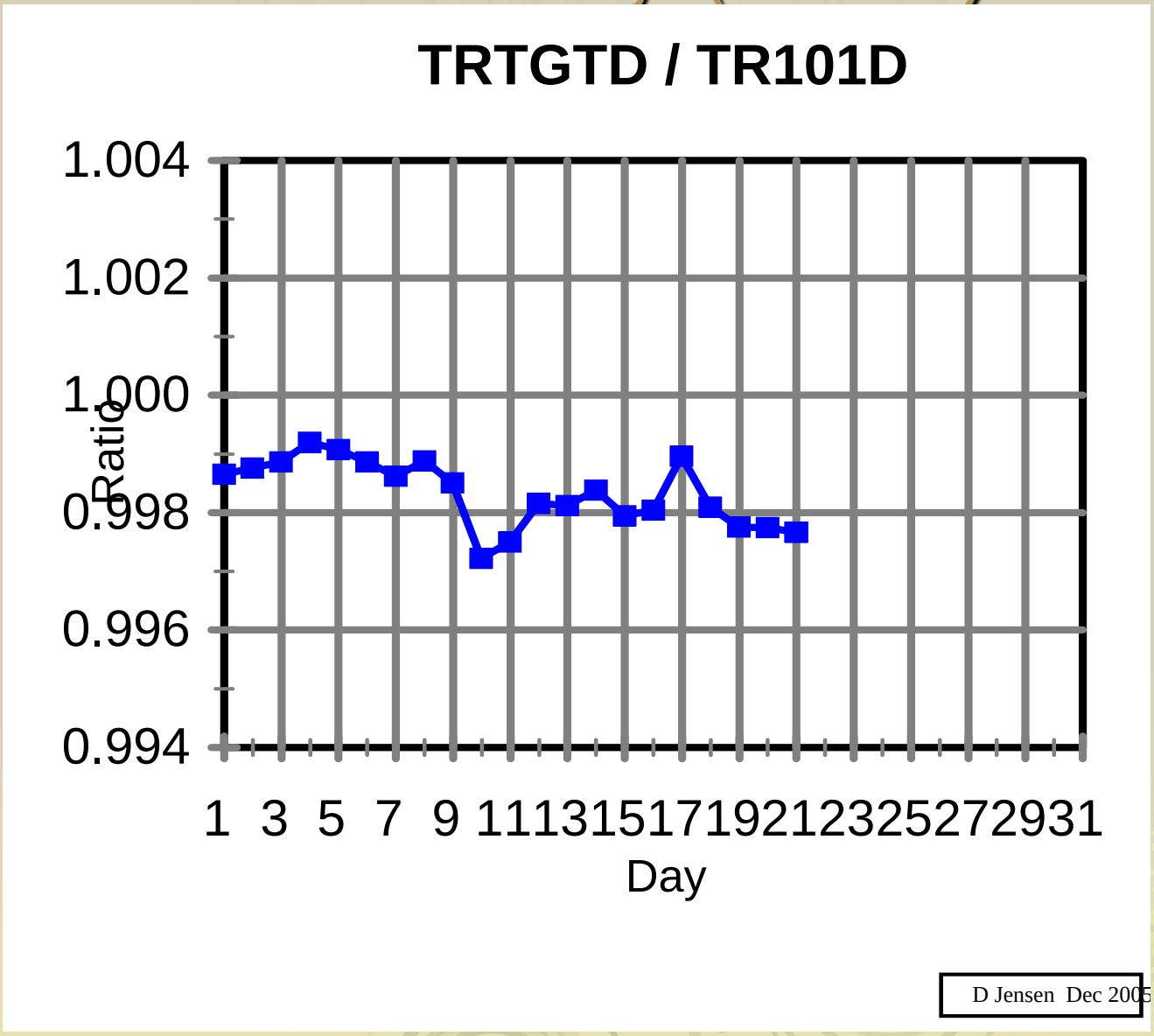


Profile monitor
(0.5,1.0 mm pitch)

Primary Beam Loss – Mixed Mode
Average per Pulse for One Month

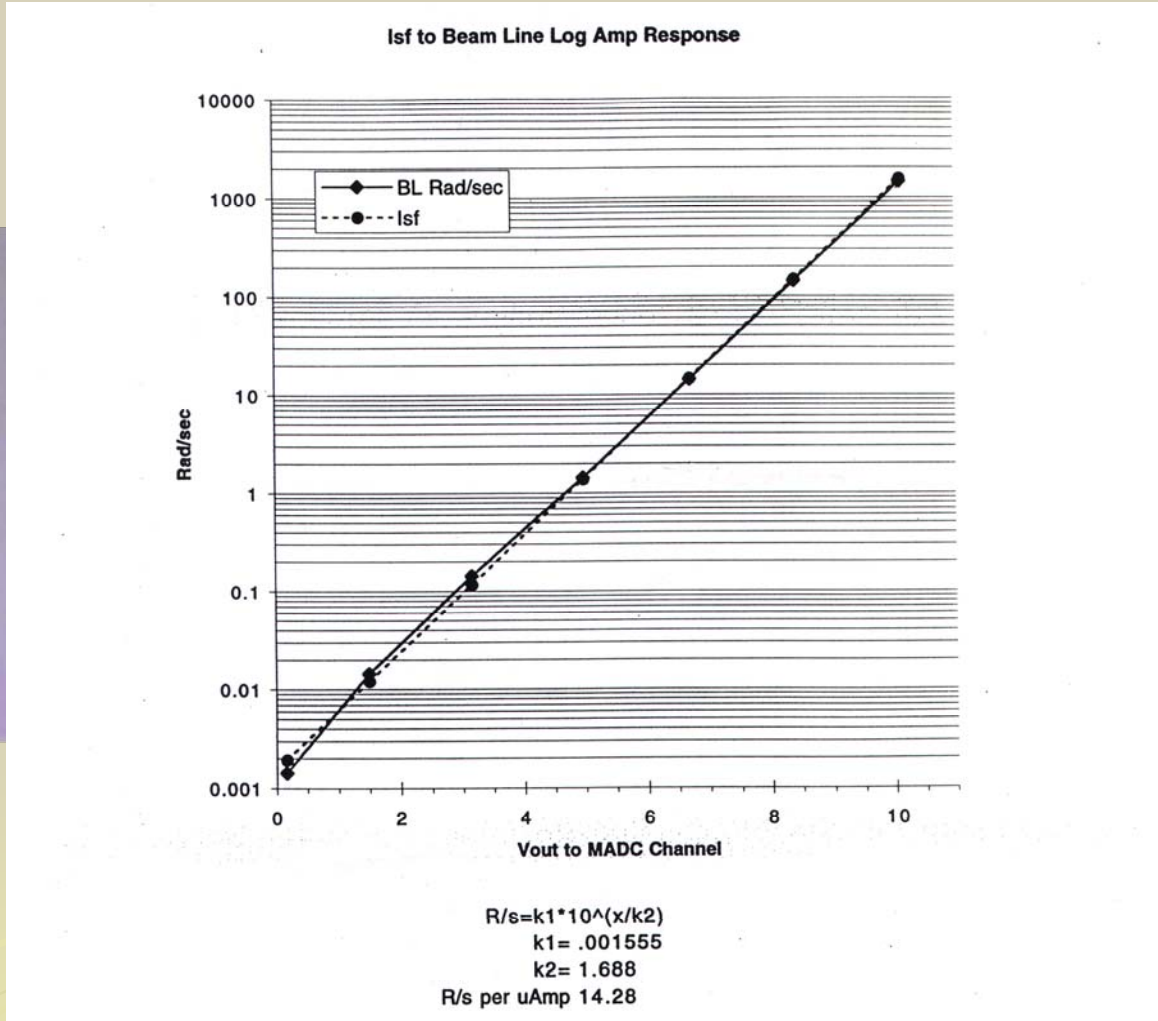


Toroid Stability (Feb 08)

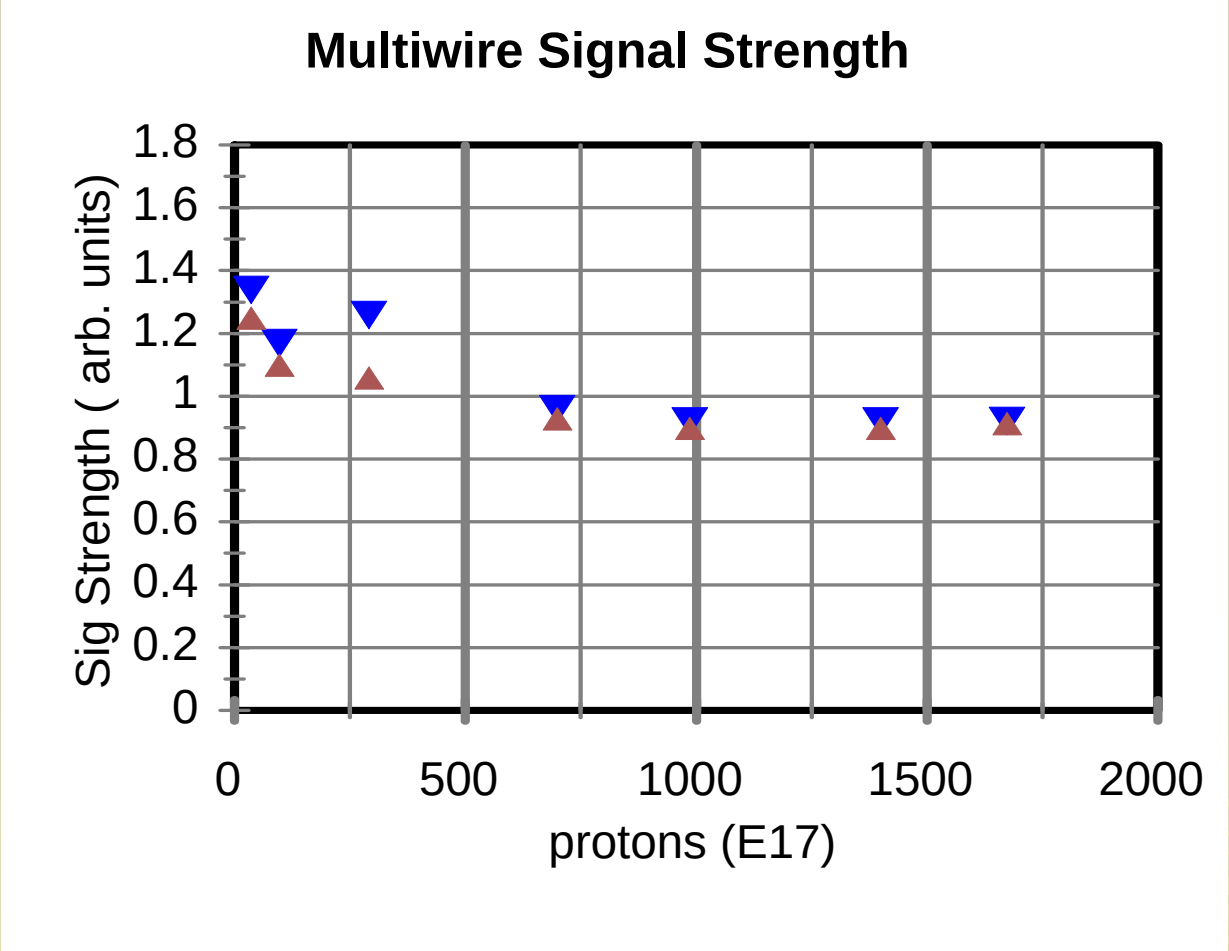


NuMI BLM's & Log Amp Response





Tgt Profile Monitor Stability vs POT



Changes Required for 2 MW beam

Upgrades For MW Proton Beams

- **In large part do the same things we currently do, but ever more carefully! The tolerance for error becomes much smaller.**
- **The most important protection is with a comprehensive and well tested beam interlock (or permit) system. No pulse should be extracted until all parameters are at specifications within tight tolerances.**
- **Robust designs for beam optics and aperture clearance. Beam loss should be very low at normal conditions. For abnormal conditions extraction should be inhibited.**
- **Develop capability for monitoring instrumentation stability during operation. Inaccurate BPM readings are very dangerous. But BPM's are the essential continuously active beam monitors.**
- **A robust automated beam control system can reliably maintain beam targeting to high precision. It's first mission should be to "do no harm".**
- **Something new – we must cool vacuum exit windows.**

2 MW Operation Changes Needed

- Currently some beam permit monitoring accuracies are not precise enough to rigorously preclude one bad beam pulse
  - Example: Dipole PS outputs monitored to only ~ 0.5%, although PS control is 50 ppm. Design plan to monitor to 100 ppm.
- Current BLM trips of permit when fractional beam loss is ~ few x10-5 . This becomes sustained 10-6 at 2 MW. At present loss levels ~ 10-7, this works well. Need to insure these levels are maintained for larger emittance beams in Main Injector
- Improve profile monitors for less material in beam (1 mil titanium wires give fractional loss of ~ 2 x10-6) and rapid drive systems not interacting beam for IN/OUT
  - Prototyping in progress.

2 MW Changes Needed (cont)

- Comprehensive and regular monitoring of BPM and BLM function (using profile monitors)
- Improved monitoring of corrector current limits
  - Never make wrong steps with beam control system
- Sequencer turn up to high intensity after downtimes to mitigate possible drift effects as systems return to operating temperatures.

The current usage of diagnostics and beam control for NuMI is readily adaptable to much higher beam powers

- **We have to be continuously careful !**