NuMI Primary Beam

November 7, 2003

NuMI Primary Beam
FNAL Site

Beam enclosure entrances thru Main Injector and NuMI Target Service Building (completed Oct)

NuMI Primary Design Parameters

Proton beam energy	120 GeV
Spill cycle time	>= 1.87 sec
Bunch length	3-8 nsec
Batch length	84 batches
Batch spacing	18.8 nsec (53 MHz)
Transverse emittance	40π mm-mr expected (95%) 500 π mm-mr maximum envelope
Momentum spread	2×10^{-4} δp/p 2σ expected 3×10^{-3} δp/p 2σ max
NuMI spill (pbar operation) NuMI spill (**no** pbar operation)	5 batches = 8.14 μsec 6 batches = 9.78 μsec
Maximum intensity	4×10^{13} ppp (protons/spill)
Total beam power	404 kW at maximum intensity

NuMI Primary Priorities: 2002-03

- Finalize extraction & primary transport beam design
- 3-D modeling to understanding fitting in Main Injector – Recycler region
- Completion of magnet refurbishment & corrector fabrication
- Kicker magnet construction
- Completion of large magnet installation in tunnels accessed thru Main Injector (Sept-Oct shutdown – our top priority)
- Accelerator systems 'NuMI mode' beam tests (Bob Zwaska presentation)
- Instrumentation design / construction
  - New BPM electronics
  - New SEM profile monitors (Sacha Kopp presentation)
- Understand beam sensitivity to error sources

NuMI

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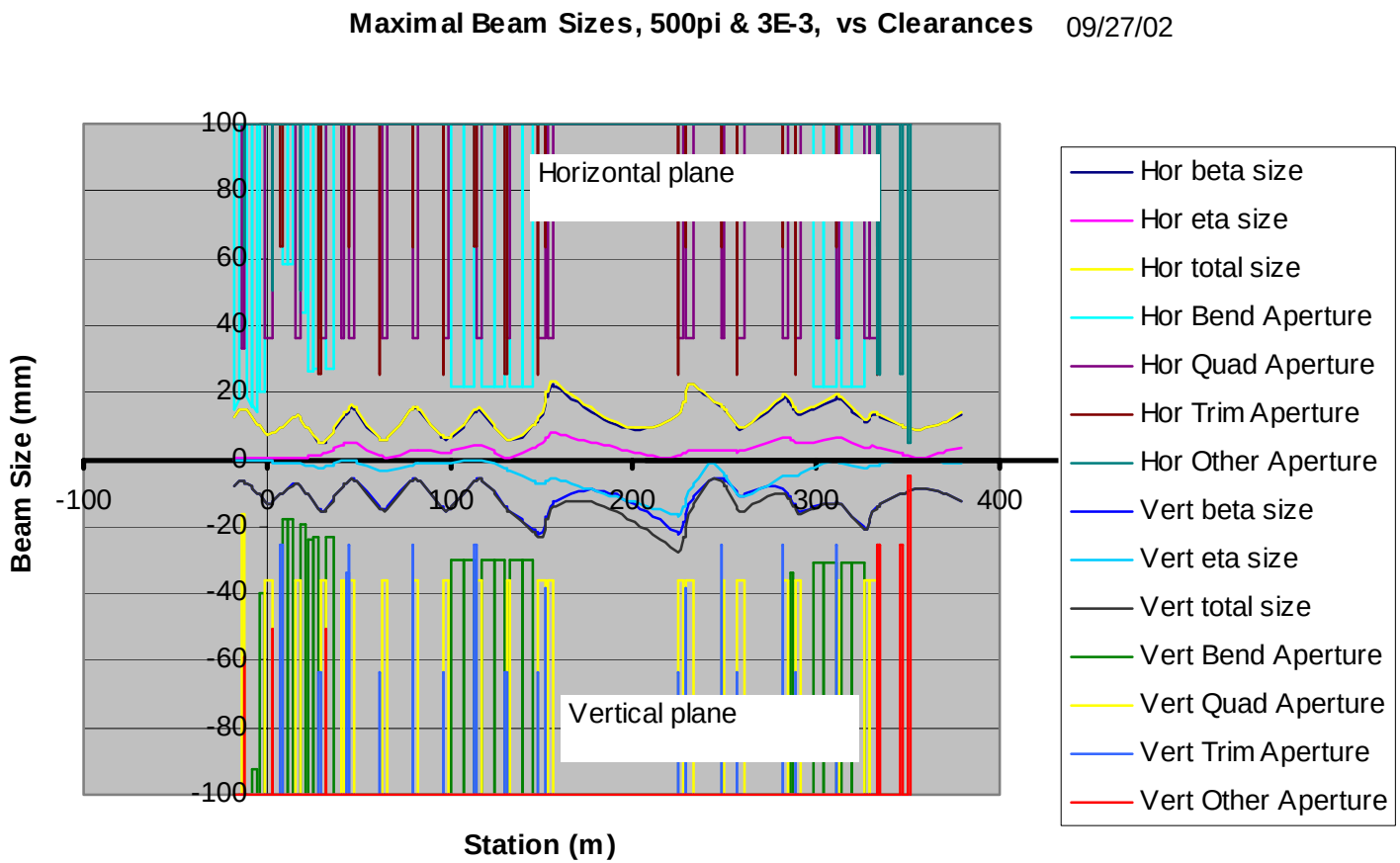
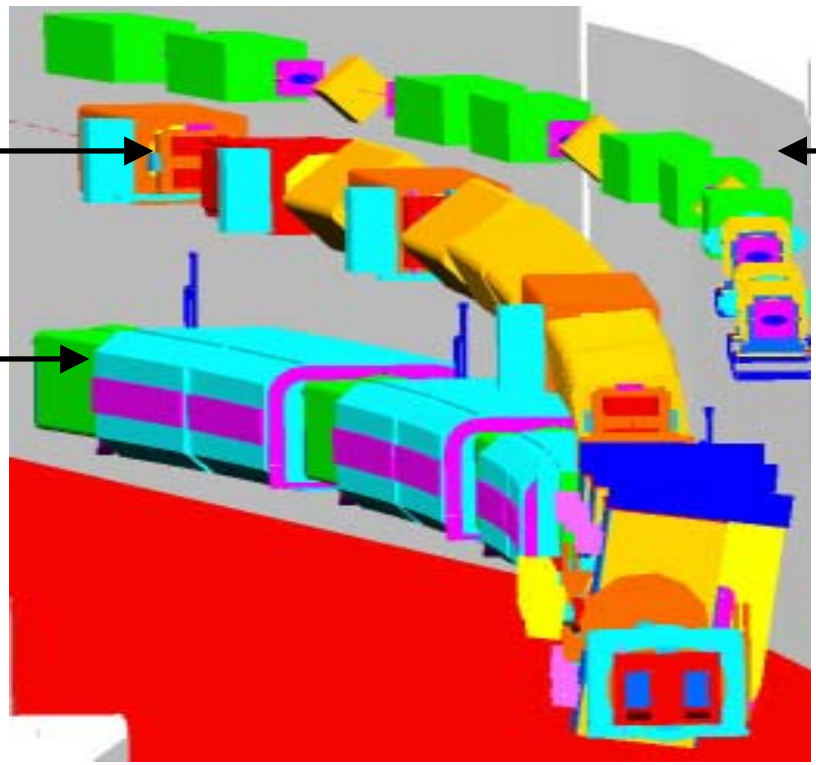
Beam Transport & Aperture Clearance

NBI03
Nov. 7-11, 2003
NuMI Primary Beam
S. Childress (FNAL)



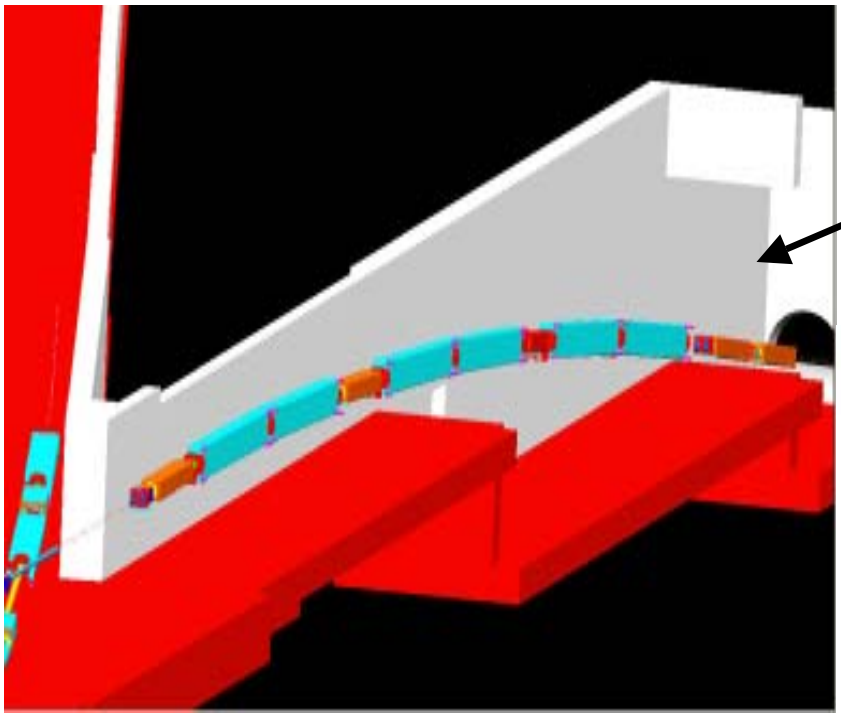
Main Injector Tunnel – MI60



3-D model essential to be compatible with other beams. Initially many uncertainties > tolerances

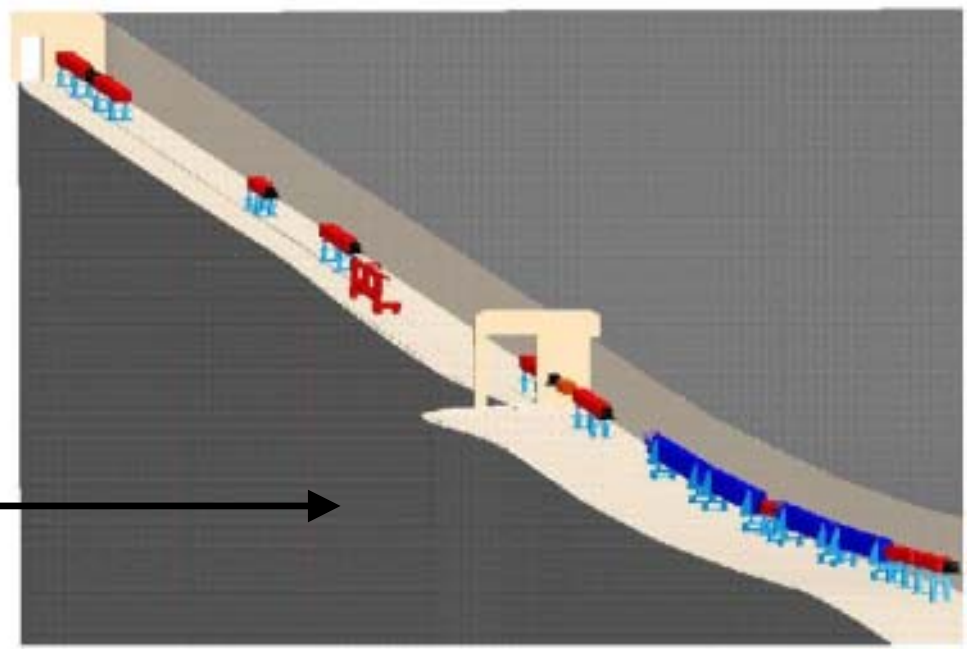
Extraction & Pretarget Enclosures

NBI03
Nov. 7-11, 2003
NuMI Primary Beam
S. Childress (FNAL)



Extraction Enclosure

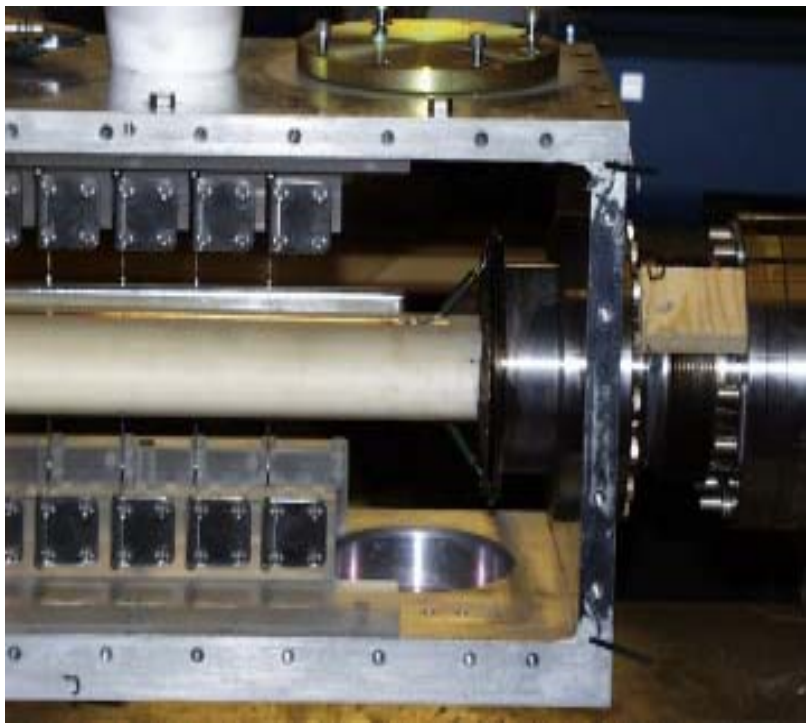
156 mrad down-bend



Pretarget Enclosure

98 mrad up-bend & target focus

Kicker Construction



- 3 kicker Magnets
  - Each 2.2 m length
  - 60 kV max.
  - 4.0 kG-m at nominal 48 kV
- 2 magnets complete, 3rd well advanced
- Testing in progress

NuMI

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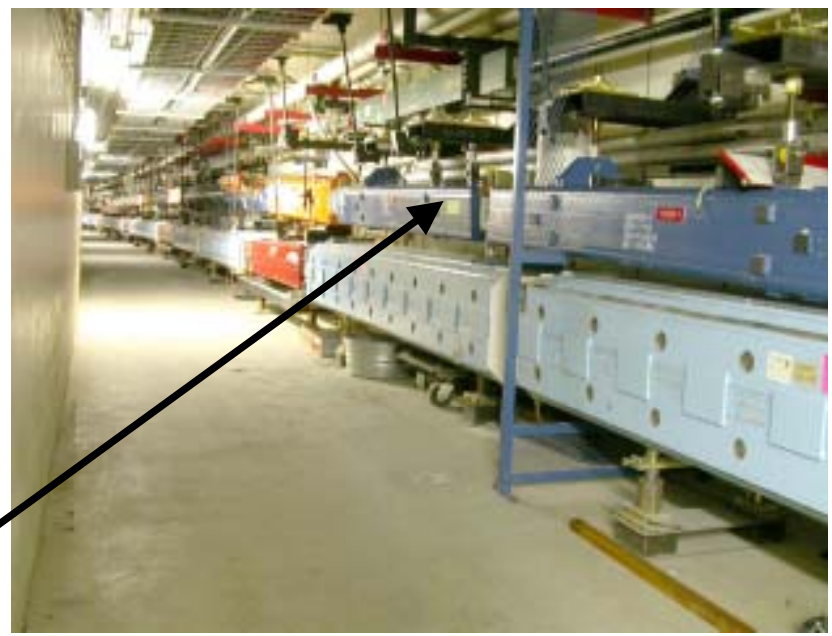
NuMI Installation
MI-608 Region

NBI03
Nov. 7-11, 2003
NuMI Primary Beam
S. Childress (FNAL)

Extraction Lambertsons



Upstream NuMI Transport

Installation NuMI Extraction Enclosure

V108 down-bend dipoles

Quads before carrier tunnel drift

Lined 70 m. carrier tunnel

2003-2004 Shutdown Efforts

- **For the upstream half of the NuMI primary beam: MI-60 and Extraction Enclosures, the only work access is through the Main Injector / Recycler tunnel – with severe restrictions on access options.**
  - **All large magnets in these areas (except kickers) are now installed**
  - **For 2004 shutdown (Summer) must install correctors, all instrumentation, vacuum system, LCW hookup, remaining cabling, and extensive testing.**

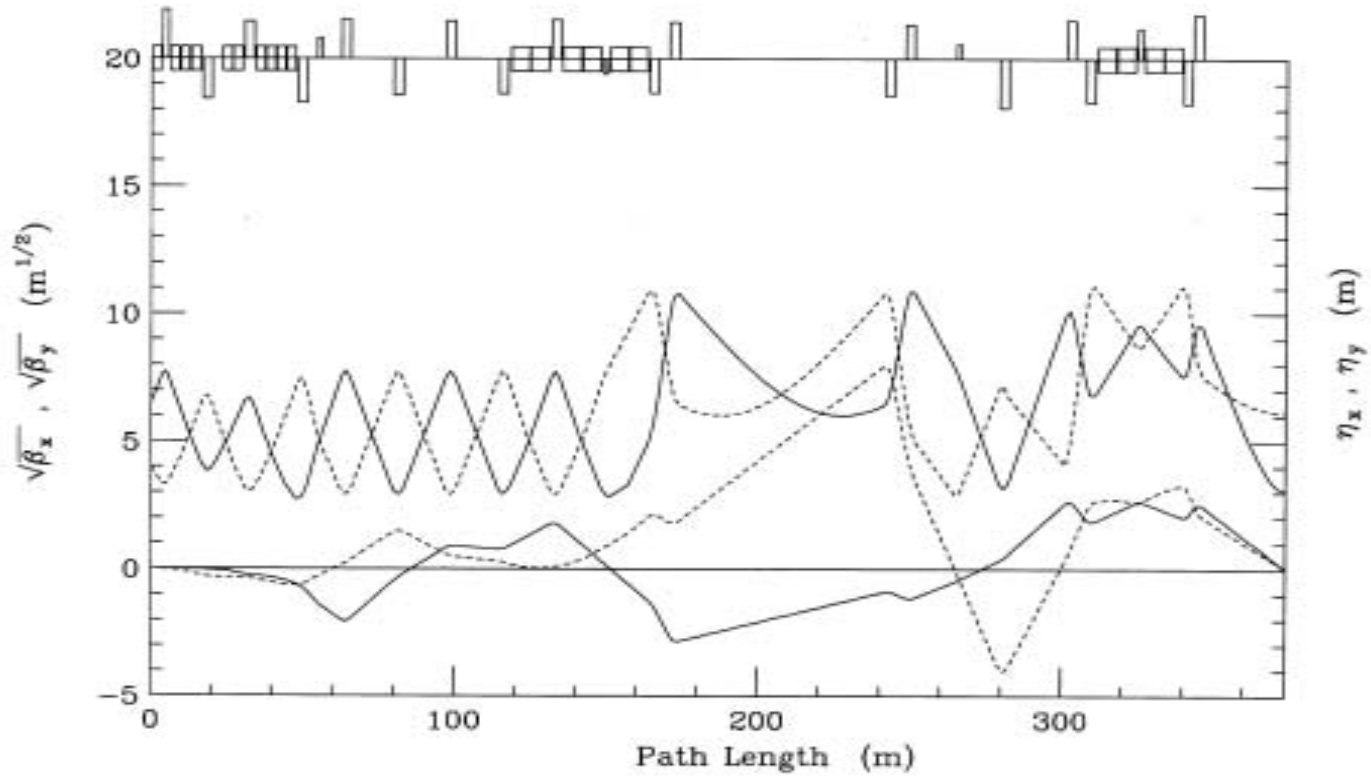
Preparing for Installation: Pretarget Tunnel

Beneficial occupancy October ‘03

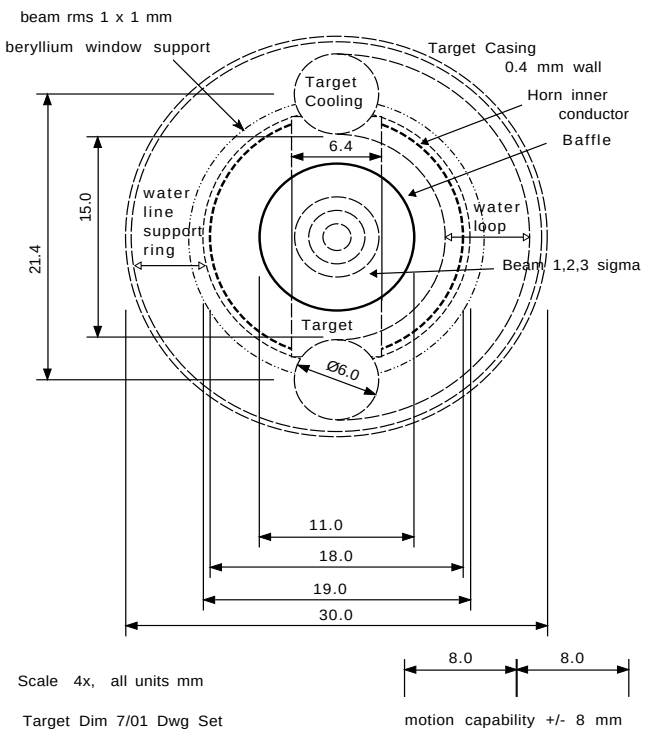
Tunnel still ‘a bit’ damp

Here primary installation is not critical path. Access not tied to Main Injector shutdown

Beta & Eta Functions: Primary Beam Design



Targeting Requirements



- Beam's eye view of target and baffle.
- Beam size on target:(σ) 1mm
- Position stability on target (σ) +/- 0.25 mm.
  - « Minimize physics backgrounds
- Angle stability on target 60 μrad
  - « Modest requirement for low energy beam

Instrumentation Design Impact: Targeting Requirements

- **Beam size at targeting leads to smaller profile monitor SEM grid pitch (0.5 mm) at targeting** [compared to 1 mm along transport].
- **To maintain position accuracy at target requires functional instrumentation accuracy of a factor of 3-4 smaller than required beam control accuracy.**
  - Experience from many applications
  - Requirement for < 75 microns instrumentation accuracy
- **For targeting BPM's use smaller diameter detector plate separation (allowed by smaller beam) than along transport**
  - Enhances detector accuracy proportionally

Profile Monitor Usage

- Profile monitors have a dual use application in the NuMI primary line
  - Determination of beam size and shape along the transport and for targeting. This provides the primary diagnostic for emittance or optics problems, as well as fraction of beam targeted
  - Precision calibration for the BPM's. This imposes additional requirements for profile monitor position reproducibility < BPM accuracy.

NuMI Beam Position Monitors

Target BPM's

Transport BPM's

Building new BPM electronics based on digital receiver technology.

Recently commissioned for Recycler Ring with excellent performance

NuMI Beam Control

- **Beam position and profile monitor accuracy requirements needed to respond to error source sensitivity are well matched to those for targeting, within a factor of 2, with targeting being the more severe.**
- **One disadvantage with NuMI beam control compared to the Main Injector is the additive presence of error sources from individual magnet string power supplies.**
- **NuMI beam control requirements for beam loss and targeting control are met by the combination of enhanced power supply stability <100 ppm for major bends and always active position control [Developed for TeV Switchard; used in several applications]**

NuMI Primary Priorities: 2004

- Upstream enclosures beam ready by September 2004
- Fully beam ready by December 2004
- Major focus for:
  - Pretarget installation
  - Beam instrumentation construction
  - Main Injector full ring beam tests
  - Beam control implementation
  - EVERYTHING not yet done