NuMI Primary BEAM Instrumentation

Basis for Technical Requirements

Sam Childress

Presentation Overview

- Primary Beam Design Parameters
- Beam Transport Design
- Basis for Instrumentation Specifications
- Instrumentation Requirements
- Other Significant Constraints

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 500 π mm-mr maximum envelope
Momentum spread	2×10^{-4} δp/p 2σ expected 23×10^{-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

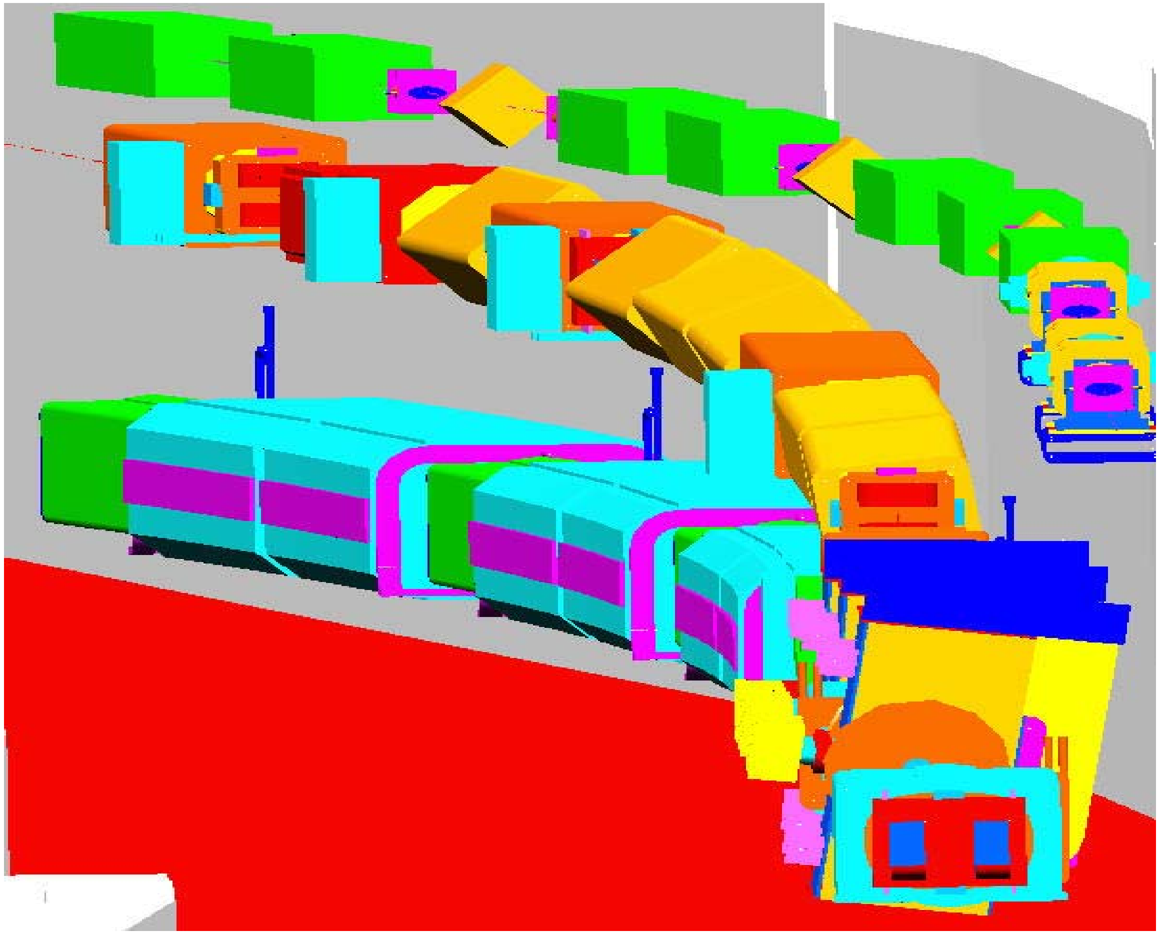
Primary Design Parameters (cont)

- Parameters are summarized in NuMI Technical Design Handbook – Ch 3.
- Specifications given for instrumentation sensitivities use these parameters
- However – NuMI is very actively pursuing options for significantly higher beam intensities / shorter cycle times than given here. These require major accelerator system upgrades.
- A key is to design with the thought of future upgrade

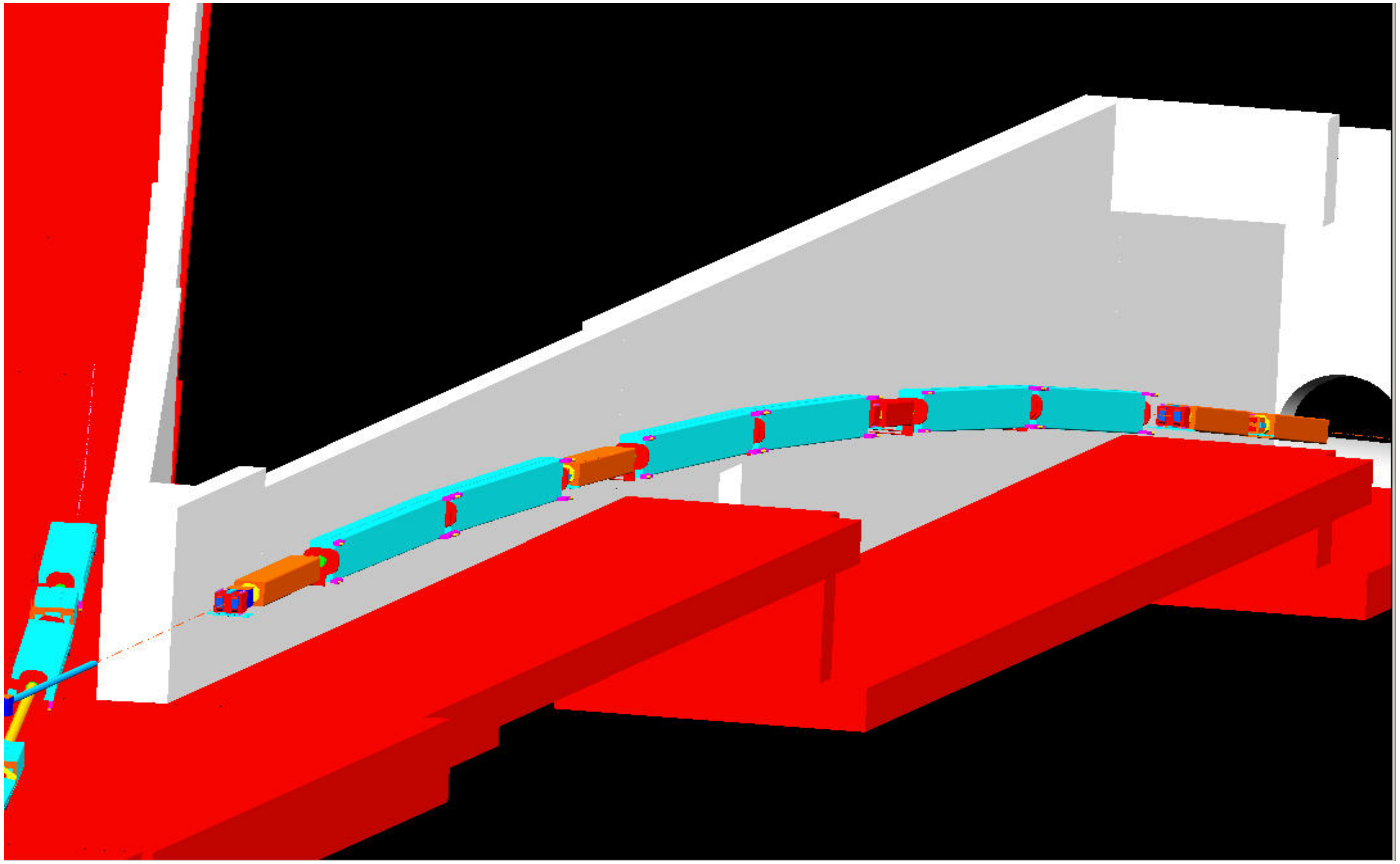
Beam Transport Design

- Presented in Ch. 4.1 of Technical Design Handbook and in NuMI Primary Beam Design Report (P. Lucas,et.al)
- Two unique features drive much of the extraction and transport design:
  - Very high beam intensity (5/6 of Main Injector)
  - Unshielded transport thru protected underground aquifer

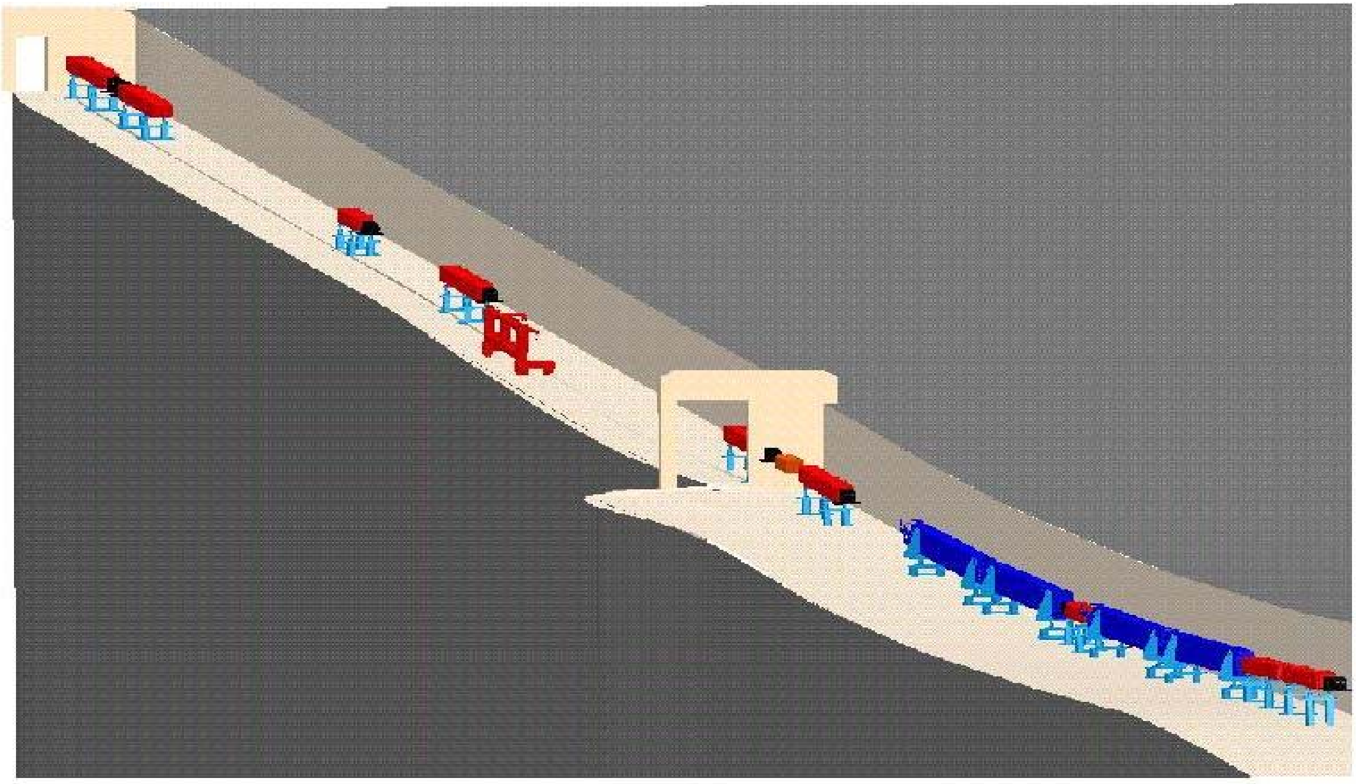
MI-60 Region (MI, NuMI, RR)



Extraction Enclosure
(MI to carrier tunnel)

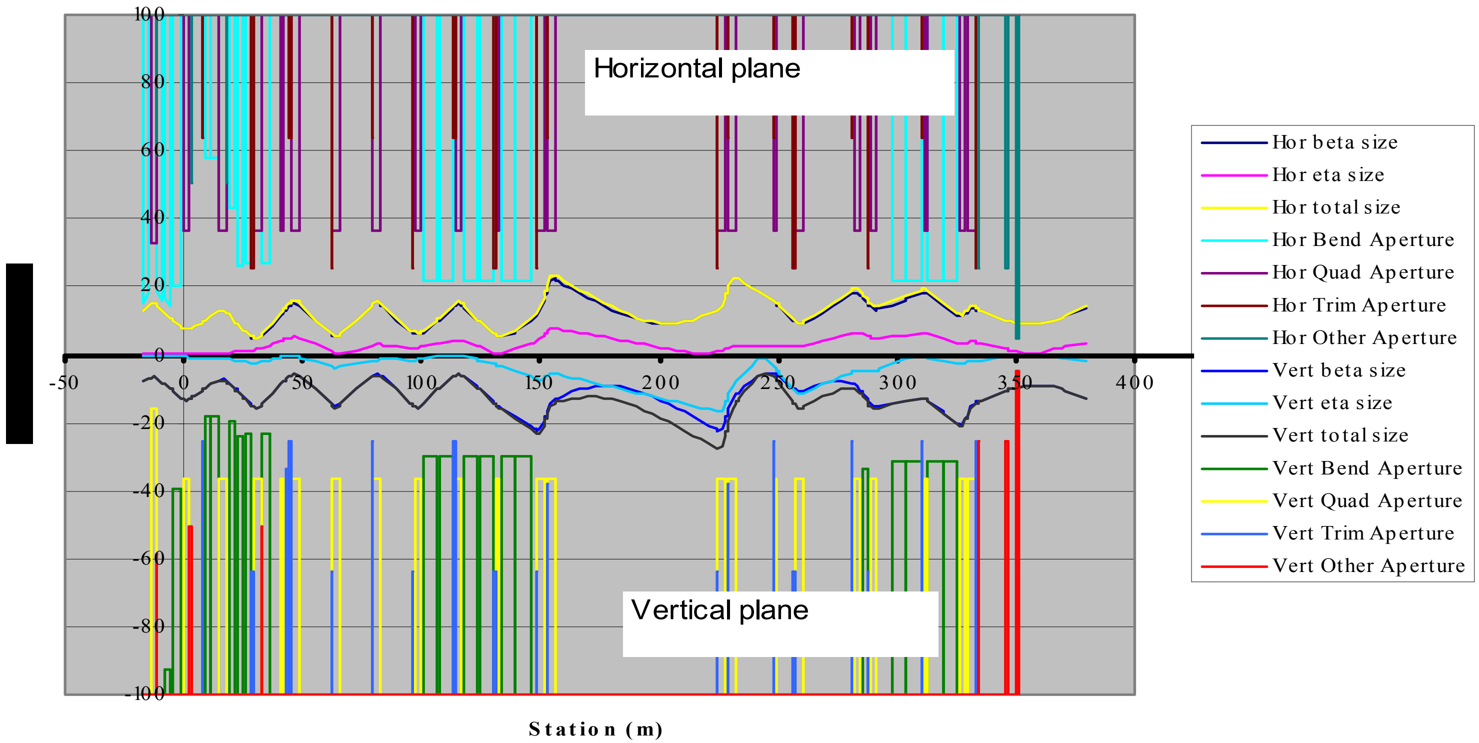


Pretarget Enclosure (rock tunnel)

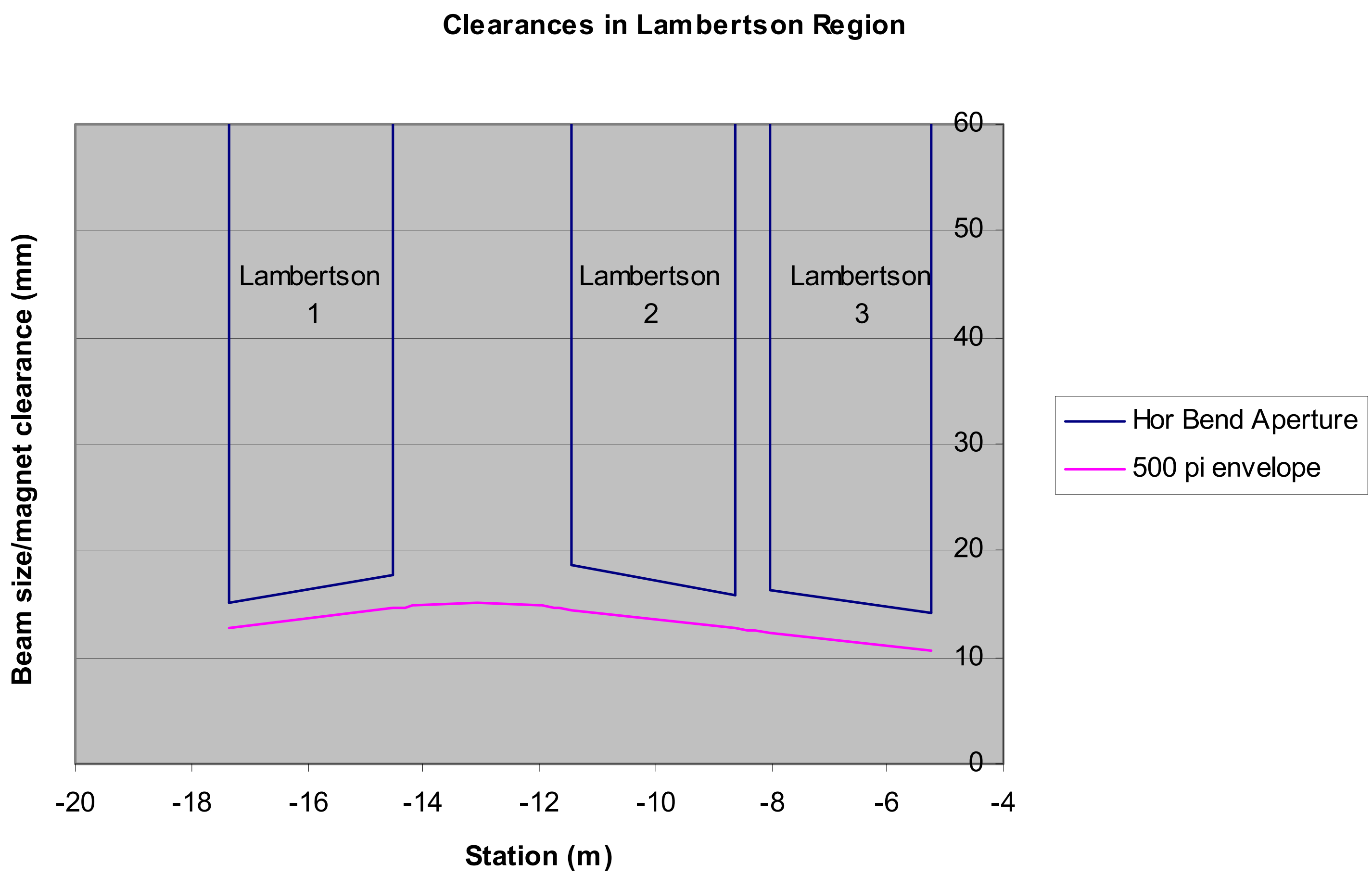


Beam Transport & Aperture Clearance

Maximal Beam Sizes, 500pi & 3E-3, vs Clearances 09/27/02



Extraction Lambertson Aperture Clearance



Basis for Instrumentation Specifications

- MARS beam loss studies
- Targeting requirements
- Optics lattice
- Beam control requirements

MARS Beam Loss Studies

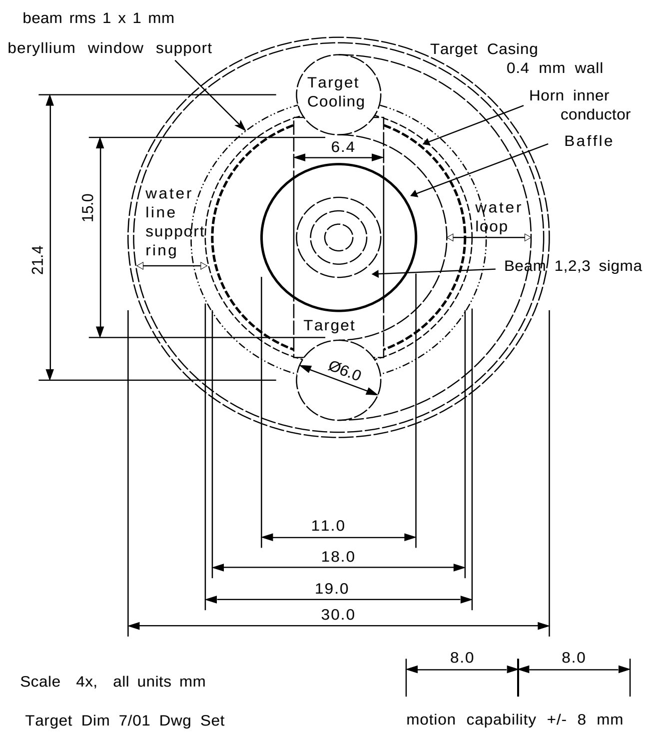
- **Extensive MARS beam loss study by S. Striginov, I. Tropin, M. Kostin, N. Mokhov. Combined with study of groundwater flow near NuMI transport tunnel (N. Grossman,et.al), results set limits on allowed beam loss along NuMI primary beam**
  - For design intensity, 4E13/pulse, average fractional beam loss limit allowed is few x 10-4 along much of transport. This becomes few x 10-6 in part of carrier tunnel region. Here, we use a large diameter transport pipe, with walls shadowed by upstream components, plus magnet current limits.
- **Tunnel residual activity limits provide comparable limit on average beam loss allowed. Fractional loss of 10-4 on one component produces residual activity ~ 100 mR/hr.**

MARS Beam Loss Studies (cont)

- **MARS studies also provide confirming results for beam transport sensitivity to error sources, such as extraction beam offsets and power supply instability**

- **Results of beam loss studies directly influence a number of instrumentation specifications**
  - **Use of non-interacting BPM's for continuous beam position monitoring**
  - **Maximum profile monitor mass exposed to beam**
  - **Use of precision always active beam control measures (Autotune, Beam Permit System)**

Targeting Requirements



- Beam's eye view of target and baffle (TDH Ch. 4.2)
- 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

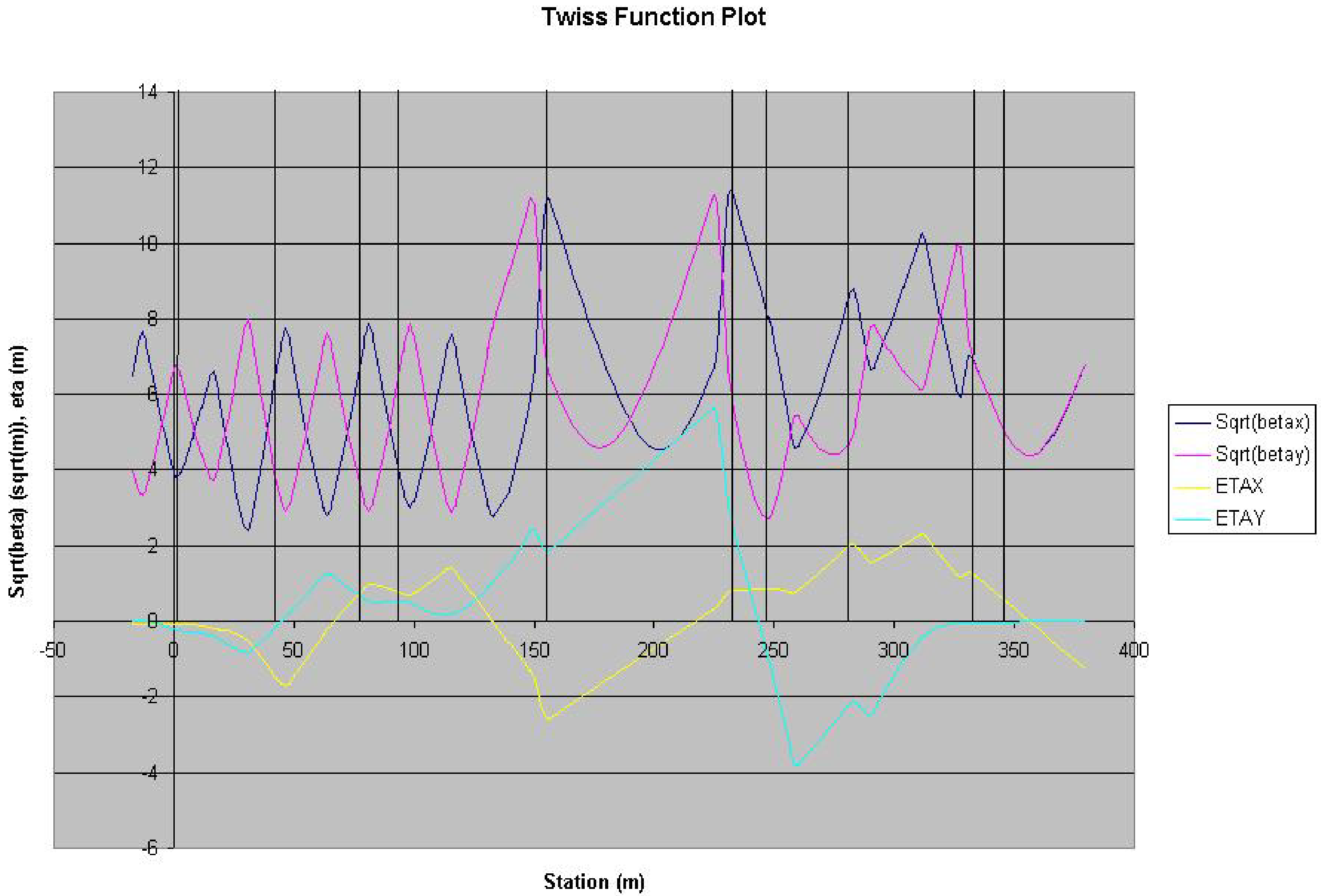
- **Beam size at targeting leads to smaller profile monitor SEM grid pitch (0.5 mm) at targeting [compared to 1 mm along transport].**
- **To maintain position accuracy at target requires functional instrumentation accuracy of a factor of 3-4 smaller than required beam control accuracy.**
  - Experience 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

NuMI SPLIT PIPE BPMs

Target BPM

Transport BPM

Optics Lattice & Profile Monitors



Impact of Transport Lattice

- Determination of profile monitor placement
- Lattice matched to that of Main Injector; also use Main Injector corrector dipoles
  - Leads to similar BPM accuracy specifications
    150 microns along transport
- Determination of beam sensitivity to error sources
  - As example, 1 mm offset at extraction leads to a similar position error at the target

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]

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.

Instrumentation Requirements

- Detailed presentation of NuMI Primary instrumentation requirements and quantities is given in following talks [as well as in the TDR design parameters]
  - Jim Crisp – Intensity monitors, discrete loss monitors, BPM's and resistive wall monitor
  - Bob Webber (for Gianni Tassotto) – Profile monitors, and total loss monitors.

Other Significant Constraints

- The near time schedule for NuMI beam commissioning (< January ’05) leads to the need for focused production efforts for all instrumentation
- However, the real schedule is much more severe still. We must accomplish ALL primary beam system installation for the upstream half of NuMI in the next accelerator shutdown (Summer ’04). Also, severe restrictions on access into the MI tunnel require very robust instrumentation performance.

- Status & schedule are covered in following talks. These now become easily as important as technical issues.