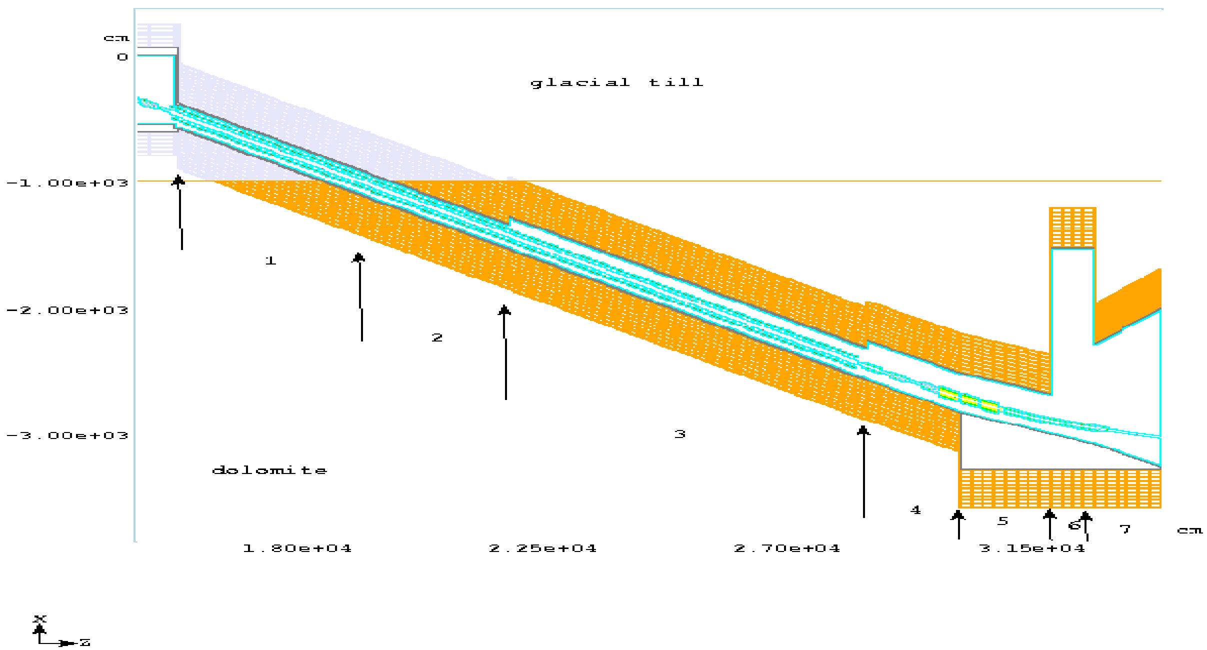
Overview: NuMI Primary Beamline Sensitivities

- NuMI requirements are for a very large fraction of the available Main Injector intensity over a period of several years.
  - Planned operation in parallel with the Collider program is that for each MI cycle the first of 6 batches is utilized for PBAR production, with the remaining 5 batches sent to NuMI.
  - Beam power sent to NuMI each year will be comparable to the integrated total beam power for previous FNAL fixed target running. (Since 1972)
- Additionally, NuMI primary transport is in an unshielded tunnel passing directly thru the protected groundwater resource.
  - Leads to significant restrictions on allowed NuMI beam transport loss upstream of the shielded target area.

Primary Beam Loss Restrictions – Sensitive Region



Primary Beam Loss Restrictions

- Detailed MARS modeling to determine beam loss limits
- Allowable beam loss along transport:
  - For ~ central half of transport line, limited to DC average (for high intensity operation – 4E13 ppp) fractional loss at any point of $< 10^{-4}$.
  - Driven by ground water protection, but residual activation considerations lead to similar numbers. A sustained loss of 10^{-4} on a magnet produces ~ 150 mR/hr for tunnel access conditions.

Primary Beam Design

- Major design improvement [extraction, beam optics and matching to magnet apertures] in 2002, to produce beam design appropriate for NuMI intensities and beam loss restrictions.
- Severe specification standard for beam transport acceptance
  - Transport design which is without beam loss for maximum beam envelope of 500 π and dp/p = 3E-3.
  - Parameter choices are to enable loss free transport for maximum emittance and momentum spread which Main Injector can reasonably accelerate to 120 GeV.

Criteria for Beam Stability Specifications

- Requirement levels set are significantly tighter than those imposed by matching apertures to losses for groundwater control
  - Very important to maintain beam control and tuning capabilities enabling reliable operation for intense NuMI beams , as well as minimizing beam control effects on physics sensitivity
  - Specifications set are also well matched to previous operational experience, where similar to NuMI

Beam Stability Specifications

*Timing requirements are **not** included here*

Targeting Parameters:

- Position Stability
  - Maintain beam centered within 0.5 mm (absolute value)
- Targeting Angle
  - Maintain angle control within 60 microradians

For these specifications, minimizing potential physics backgrounds has significant impact. Target half width size is 3.2 mm.

Beam Stability Specifications (cont)

Beam Position Monitor Functional Accuracy:

– Transport - 200 microns (rms)
– Targeting - 100 microns (rms)

Review June '02

Component Alignment Accuracy:

– 250 microns transverse (rms). 2.5 mm longitudinal

Requires comprehensive laser tracker network.

Specs similar to results achieved for KTeV

Constraints Determining Power Supply Regulation Specs

- Several types of constraints have a role in determining specifications for NuMI power supply regulation:
  - Rigorous beam loss limits
  - Requirements on primary targeting angle (aiming the beam toward Soudan,MN)
  - Requirements on targeting position precision
    - How well must we center beam on target; optics stability
  - Matching corrector strength to major bend power supply specifications & stability
  - Constraints from Autotune position control
- A goal is to also look toward solutions for improved power supply regulation which match those chosen for other Beams Division systems.

Beam Stability Specifications (cont)

Power supply stability:

For all power supplies summed:

- Short term: (< 30 minutes): 100 microns (rms) beam excursion along transport and 50 microns for targeting.
- Long term: (hours to days): 1.0 mm (rms) along transport and 0.5 mm for targeting.

For individual power supplies:

- Long term: 0.4 mm (rms) beam excursion along transport and 0.2 mm for targeting.

Beam Stability Specifications (cont)

Corrector range capability:

- Each corrector (Hor. & Ver.) capable of compensating for sum of misalignments, plus errors in regulation, and extracted beam stability.

'Autotune' position constraints:

- Activate for transport (targeting) errors of 0.5 (0.25 mm). Correct to 0.25 (0.125mm).

These numbers are preliminary until detailed matrix Autotune algorithms are developed. In two previous usages corresponding numbers were:

- *Switchyard – activate for 0.4 mm (0.2 mm septa lineup); correct to 0.2mm (0.1 mm)*
- *KteV (Large targeting optics magnification) – activate for 1.0 mm (0.05 mm)*

A Caveat re. Specifications

Specifications given should be considered as limits:

- No real safety factors have been included, for a complex multi-faceted problem. Not at all good practice, but presented this way as some specs approach practical resource driven limits; others are easy to meet.
- Where challenging to meet, such as for kicker power supply, is impractical to consider a safety factor.
- Where current technology readily offers affordable solutions to go x 2-3 beyond these specified limits, such as for several conventional power supplies, should plan to do this

Presentation Agenda

- *Overview/ beam stability specifications* *S. Childress*
- Beam Transport & Sensitivity to Error Sources P. Lucas
- Meeting Power Supply Regulation Needs S. Hays
- Summary S. Childress