FNAL-DUSEL Beam Group Report

DUSEL Meeting, FNAL, 8/14/08

Mary Bishai

mbishai@bnl.gov

BROOKHAVEN NATIONAL LABORATORY

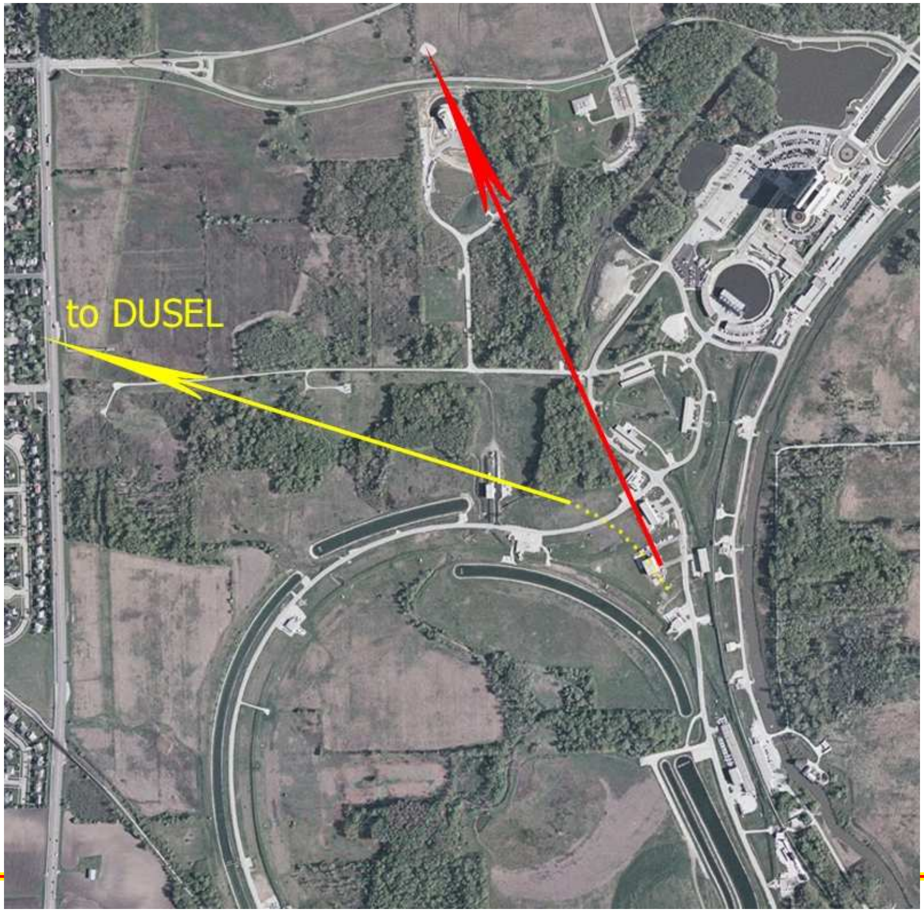
Outline

The beamline design and simulation group met on 8/13/08. The following topics were discussed:

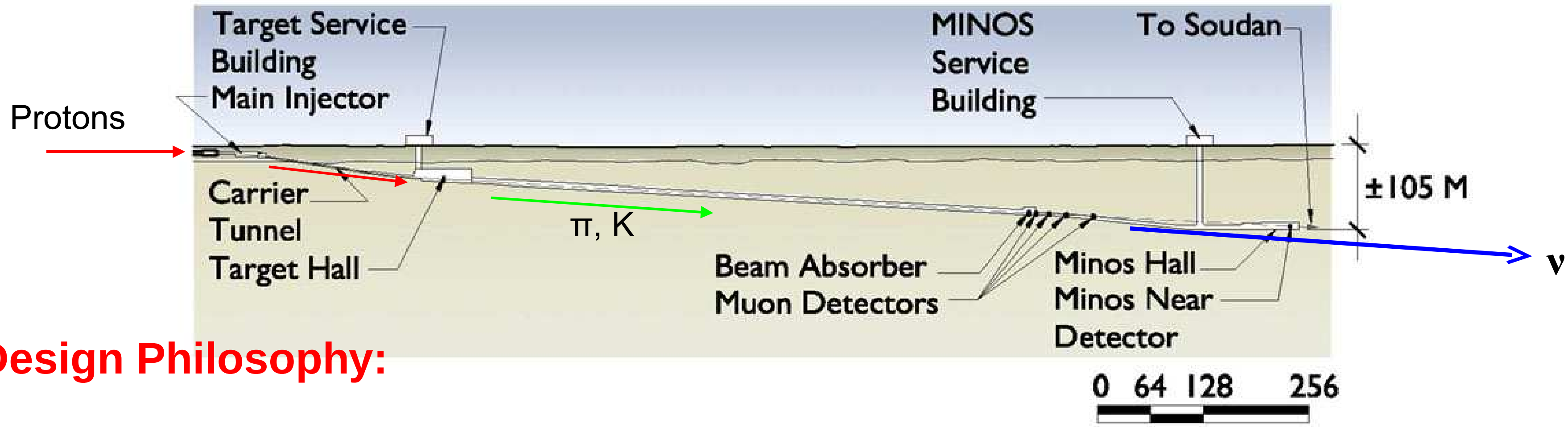
- **Design of the primary proton beam transport for FNAL-Homestake neutrino beamline: Peter Lucas, Gordon Koizumi**
- **Neutrino beam simulations and beam characteristics: Mary Bishai, Brett Viren, Mark Dierckxsens, BNL AGS design group.**
- **Developing the MARS simulation framework for energy deposition and radionuclide production: Byron Lundberg**

GOAL: Identify steps and specifications needed to produce a conceptual design of the beamline

Primary Proton Transport for FNAL-Homestake beamline



Primary Proton Line FNAL-DUSEL

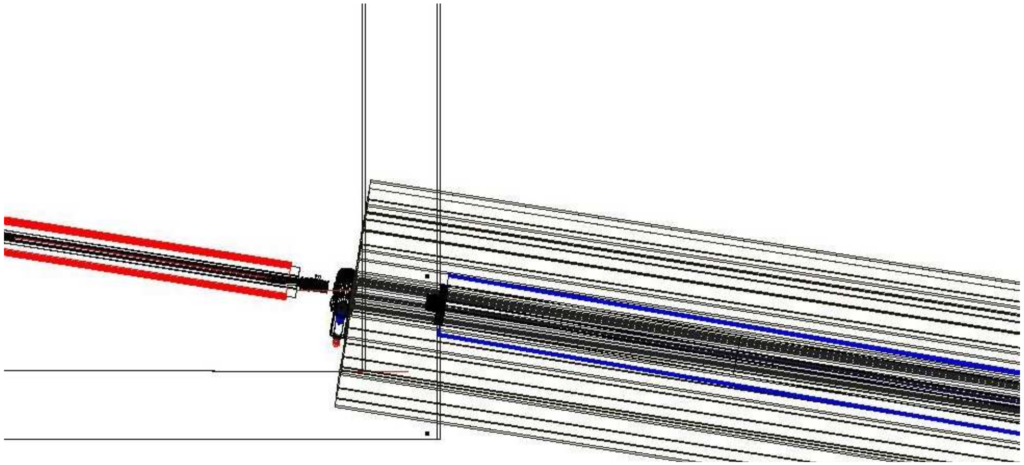


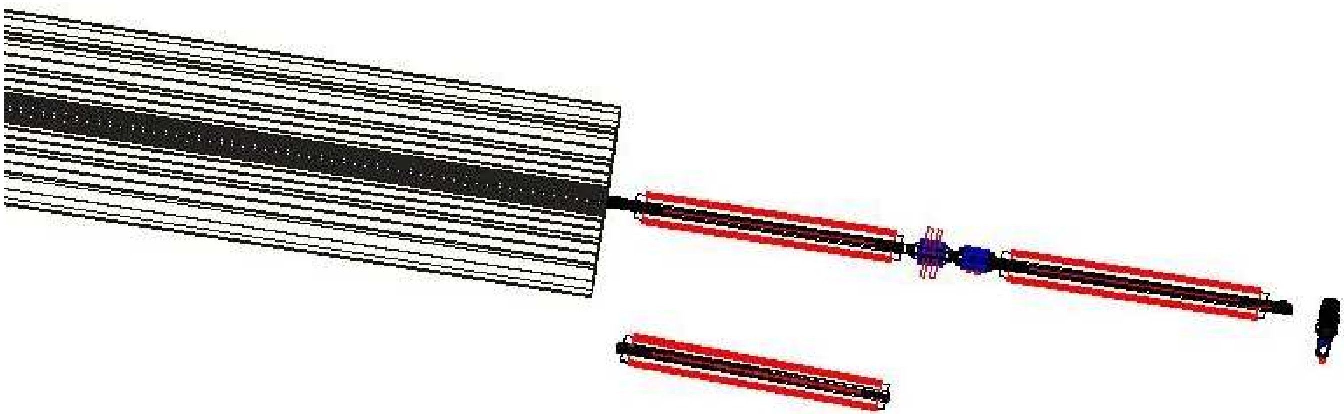
Design Philosophy:

- **Utilize the existing NuMI extraction region in the Main Injector and as much as possible of the carrier pipe (most expensive part of NuMI) that gets down into the good rock.**
- **DUSEL beamline construction should proceed** *concurrent* **with NuMI operations for MINOS/NoVA. DO NOT distrub downstream part of NuMI/MINOS line.**
- **Re-use available Main Ring components for instrumentation: 33 B2 dipole magnets + 20 ten foot quadropoles.**

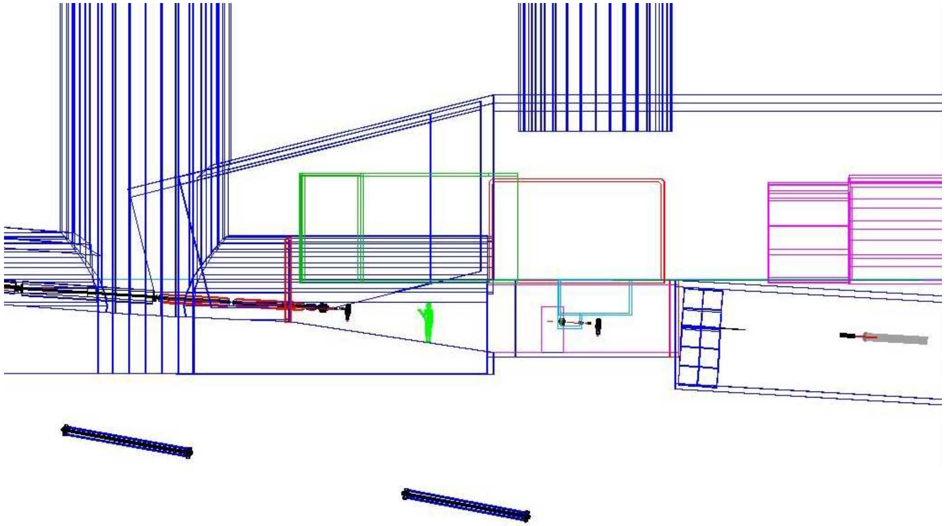
The bottle neck:

Where to branch off in the carrier tunnel?

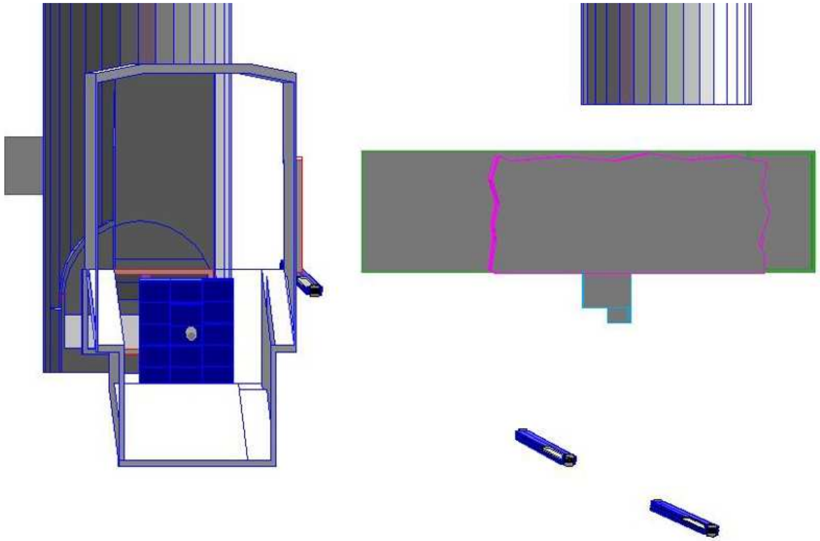




But it gets easier ...



Downstream elevation view



transverse view

Suggestions from meeting:

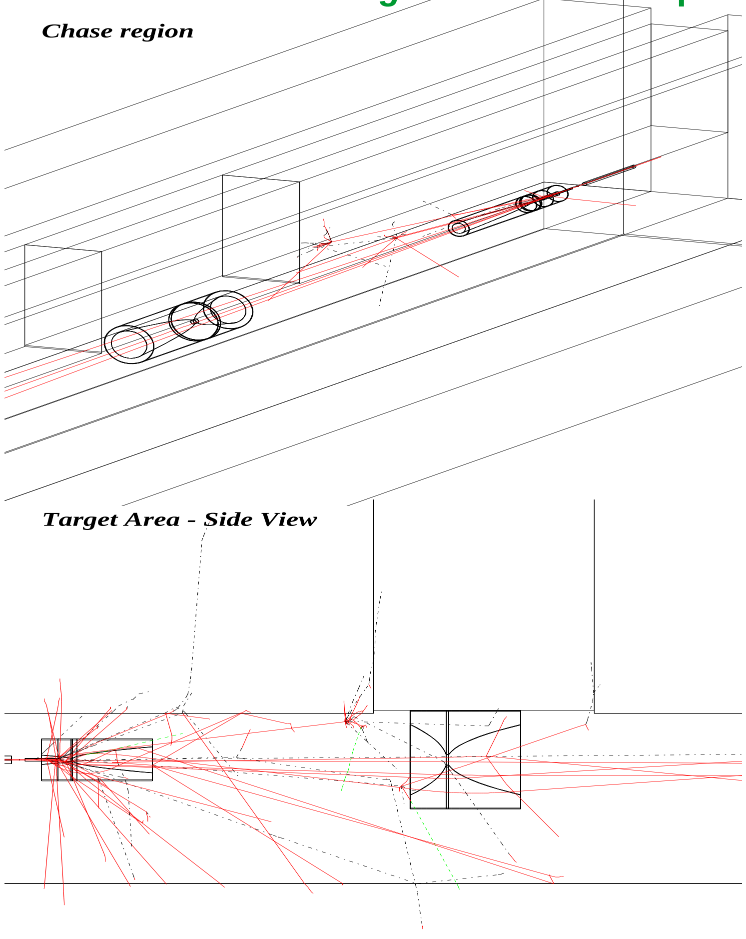
- **Convert elevator shaft at the end of the carrier tunnel to access shaft -$>$ easies bottleneck.**
- **Consult with civil engineers (Chris Laughton) to determine the optimal way (price+ minimal disruption to NuMI) to extract the Homestake primary beam from the NuMI carrier tunnel.**

Design and simulation of the secondary ν beamline

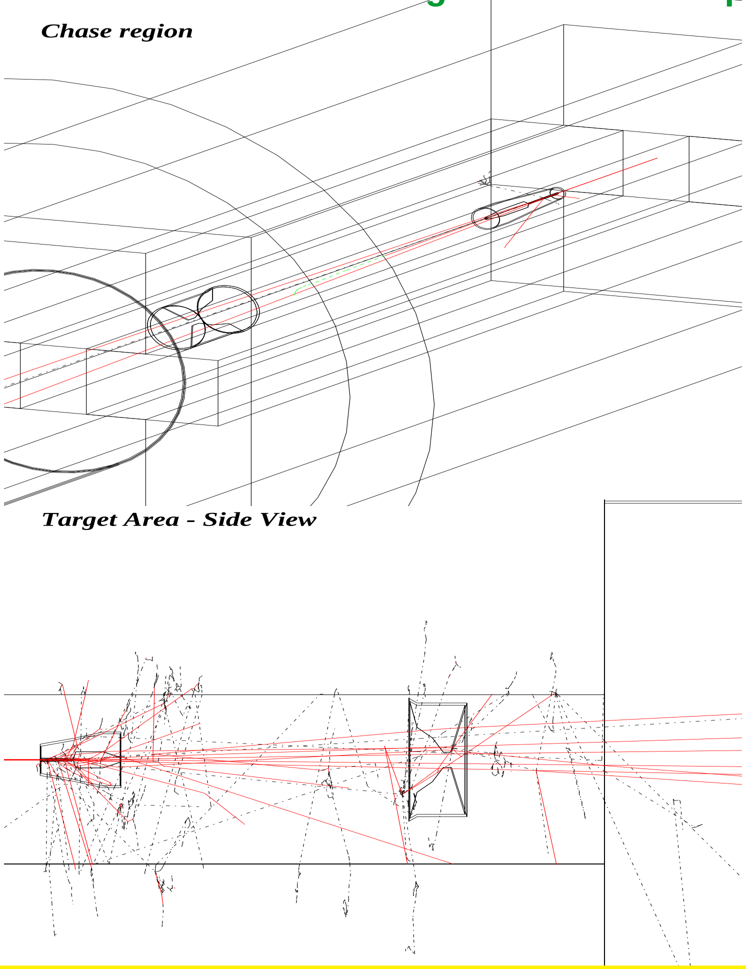
Preliminary targeting system desig

Beam to DUSEL: carbon-composite target with a density of 2.1g/cm^3 for a MW class beam + 2 wide-band horns based on BNL-AGS E734/E889:

NuMI horns/target with 120 GeV p+



Wide-band horns/target with 120 GeV p+

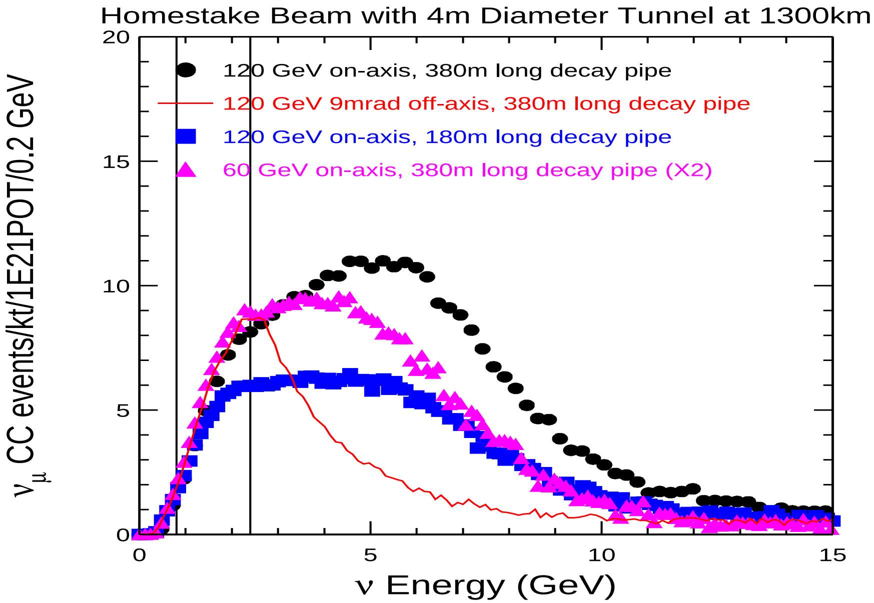


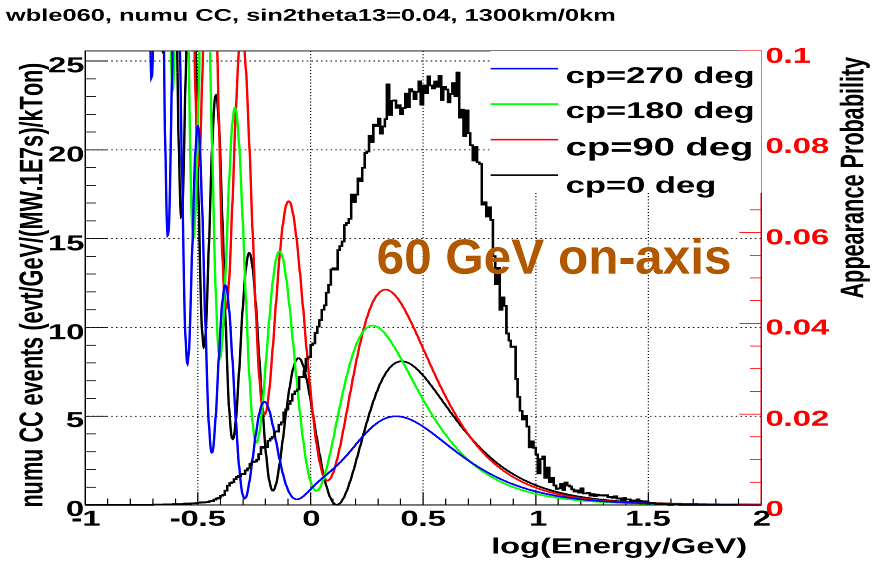
GEANT 3.21 simulation of wide-band horns+decay pipe, with FLUKA '05 for target hadro-production.

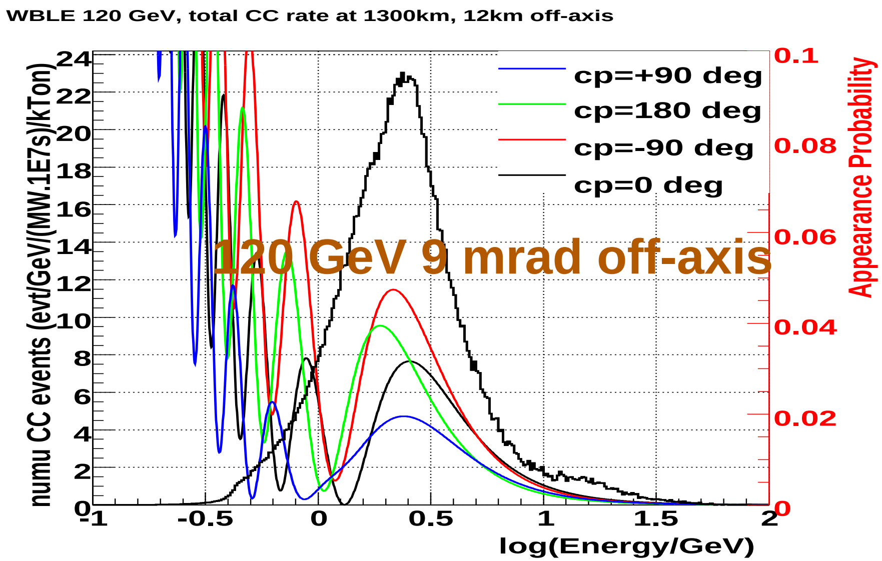
NuMI-Homestake beam options

For 120 GeV p energy of ANU/SNUMI, small off-axis angle can reduce long tails of the 120 GeV beam: $\Rightarrow$

For Project X we can run on-axis with p energy as low as 60 GeV.







A 120 GeV wide-band beam slightly off-axis is a good match to FNAL-Homestake baseline.

Pros/cons of current designs

Water Cherenkov is the more demanding detector, therefore seconday beamline design should be optimized to work for WCe.

- **NuMI/MINOS: Well focused, but too high energy! Peak rate at 3 GeV, no rate below 1 GeV (2nd oscillation maximum AND ν_e APPEARANCE from solar oscillations).**
- **NuMI/Homestake: Based on BNL AGS design for 30 GeV beam = broad band, more flux $<$ 1 GeV, but NOT OPTIMAL at 60-120 GeV - too much flux at 5-10 GeV which produces large NC backgrounds in WCe. Have to go off-axis at 120 GeV.**

Water Cerenkov Sensitivities

Mark Dierckxsens

For $\sin^2 2\theta_{13}$ and the mass hierarchy the sensitivity is given as the minimum value of $\sin^2 2\theta_{13}$ at which the experiment achieves 3σ reach for all δ_{cp}. For CPV the sensitivity is given as the minimum value of $\sin^2 2\theta_{13}$ at which the experiment achieves 3σ reach for 50% δ_{cp}.

Beam	Det size (FIDUCIAL)	Exposure $\nu + \bar{\nu}$	syst. uncert on bkgd	$\sin^2 2\theta_{13}$	sign(Δm^2_{31})	CPV
NuMI/HStake	100kT	700kW 2.6+2.6yrs	5%	0.018	0.044	> 0.1
120 GeV	100kT	1MW 3+3yrs	5%	0.014	0.031	> 0.1
9mrad off-axis	300kT	1MW 3+3yrs	5%	0.008	0.017	0.025
	300kT	1MW 3+3yrs	10%	0.009	0.018	0.036
	300kT	2MW 3+3yrs	5%	0.005	0.012	0.012
	300kT	2MW 3+3yrs	10%	0.006	0.013	0.015
NuMI/HStake	100kT	1MW 3+3yrs	5%	0.012	0.037	$>$0.1
60GeV on-axis	300kT	1MW 3+3yrs	10%	0.008	0.021	0.037
	300kT	2MW 3+3yrs	5%	0.005	0.013	0.015

For WCe 120 GeV off-axis is better than 60 GeV.

Neutrino Beam Requirements

Neutrino beam:

Property	Range of acceptable values
Peak energy (in flux)	1-2.0 GeV
Peak flux (at FD $\times$ baseline^2)	$> 3.5 \times 10^9$ ν/(m^2.GeV.MW.sec)
FWHM	$>=$ 2.5 GeV
HE flux ratio $\frac{\geq 5 \text{ GeV}}{< 5 \text{ GeV}}$	< 0.3
LE flux ratio $\frac{\leq 1 \text{ GeV}}{< 5 \text{ GeV}}$	≥ 0.1
$\nu_e + \bar{\nu}_e$ contamination	$\leq$ 1%
$\bar{\nu}$ contamination	≤ 10 %

Properties of anti-neutrino beam are similar.

Neutrino Beamline Modeling

For the sensitivity studies we used GEANT/NuMI framework to estimate neutrino flux and sensitivity. This is not adequate for designing a real beamline. Beamline model in MARS has to be developed: de facto standard for radionuclide estimation, energy deposition, beam induced heating.

Implementation Issues from Byron Lundberg:

- Begin fresh? (i.e. not with NuMI Fortran based framework)
  - C++ easier to implement and use
  - CAD drawing interface ?
- Use MARS framework as DUSEL standard or only use for beam design and 2ndary for flux? Note that the Fluka05/GEANT framework has been tuned to produce the right flux as measured in MINOS but not MARS.

On-axis/Off-axis

It is desirable to build the beamline on-axis. Design of a movable focusing system can allow a tunable off-axis beam - up to 1° with a 4m dia. decay pipe. <u>From the BNL AGS superbeam proposal:</u>

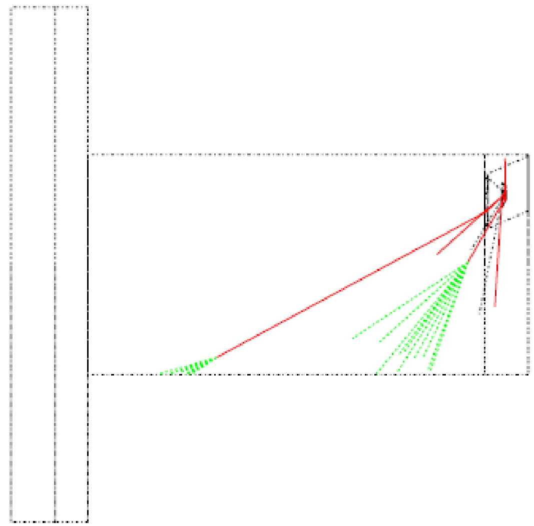


Figure 6.15: Geometry of horns and tunnel for 1 deg off-axis run. The target and horn station will be moved by 1.3 m and tilted to point into the downstream corner of the 4 m diameter tunnel to obtain approximately 1 deg off-axis spectrum.

Need MARS simulation framework to understand energy deposition of these schemes for costing shielding and beam dump design.

Summary

- Real design work on the primary proton beamline has begun. Enough main ring components are currently available to instrument the proton beamline but they need to be refurbished. Who?.
- Primary beam transport design should focus initially on the carrier tunnel extraction for DUSEL since downstream it looks doable with minimal distruption to NuMI/MINOS. Peter Lucas & Gordon Koizumi + Chris Laughton.
- Secondary beam design requirements have been identified. Current designs of targeting and focusing system need to be optimized for 60-120 GeV operation. FNAL/BNL?
- Critical effort on MARS simulation framework for DUSEL beamline have commenced. Byron Lundberg.