Solenoid Focus of Pions for Superbeams

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The Horn Bench Mark

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Horn 1: Length = 2.2m

Horn 2: Length = 1.6m

ΔL Horn 2-Horn 1 = 10m
Proton Beam/Target Input

Carbon Rod:
   \( L = 80\,\text{cm} \)
   \( R = 6\,\text{mm} \)
   \( \rho = 2.2\,\text{g/cm}^3 \)

Proton Beam:
   \( KE = 60\,\text{GeV} \)
   \( \sigma_x = \sigma_y = 2\,\text{mm rms} \)

Model:
   MARS 14
The Neutrino Flux at 1300km

Neutrino Flux at 1300km

Neutrino Energy, GeV

Neutrinos/GeV/m²/POT

60GeV Proton Beam

250kA each horn; 380m, r=2m decay pipe

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Neutrino Factory Target Concept

The Field Taper

At Z=0m
Bz = 20T
Bore = 15cm

At Z=20m
Bz = 1.75T
Bore = 60cm
Solenoid without Taper

3m Solenoid Field

Magnetic Field Bz, T

Axial Length, m
Solenoid as a Point to Parallel Lens

K.T. McDonald, *A Neutrino Horn Based on a Solenoidal Lens*, MUCOOL Tech Note 282

2.5.1 Neutrino Horn: Point-to-Parallel Focus, \( L = (2n + 1)\pi c P/eB \)

A solenoid magnet provides point-to-parallel focusing for particles produced inside the magnet, on its axis, with a discrete set of momenta \( P_n \) given by

\[
P_n = \frac{P_0}{2n + 1}, \quad (n = 0, 1, 2, \ldots) \quad \text{where} \quad P_0 = \frac{eBL}{\pi c}.
\]

(50)

Figure 2: Concept of a neutrino horn based on solenoid focusing. The pion production target is inside the uniform field region of the solenoid. The focusing effects of the fringe field at the exit of the magnet (at distance \( L \) from the target) act as ideal thin lens of focal length \( L \) for a discrete set of particle momenta, given in eq. (50).
Varying the Length of the Solenoid
Broden the Focal Momenta

3m/30m Solenoid Field

Magnetic Field Bz, T

Axial Length, m

Stepped Taper

Pt Ratio at 80m

Final Pt/Initial Pt

Ptot, GeV/c

60GeV Proton Beam Stepped Taper

Neutrinos/200MeV

Neutrino Energy, GeV

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Taper for Wide Band Collection

Palmer Solenoid Taper

Magnetic Field $B_z$, T

Axial Length, m

Palmer Solenoid Taper

Magnetic Field $B_z$, T

Axial Length, m
Transverse Momentum Considerations

For \( \pi \rightarrow \mu \nu \) \( \langle P_T \rangle \) is 23.4 MeV

For \( B_Z = 20T \) and \( R_{\text{Max}} = 7.5cm \) \( P_T_{\text{Max}} = 225 \) MeV and \( \langle P_T \rangle \) is \( \sim 200 \) MeV

For \( B_Z = 1.25T \) and \( R_{\text{Max}} = 30cm \) \( \langle P_T \rangle \) is \( \sim 50 \) MeV

Need to reduce field and increase Bore diameter further,

For \( B_Z = 0.078T \) and \( R_{\text{Max}} = 120cm \) \( \langle P_T \rangle \) is \( \sim 12.5 \) MeV
Broadband Low Energy Capture

Palmer Taper

Pt Ratio at 100m

60GeV Proton Beam with Solenoid Capture

Neutrino Energy, GeV

Neutrinos/200MeV

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Compare Horn/Solenoid Neutrino Fluxes

Neutrino “Pointlike” Fluxes scaled to 1km

Horn and Solenoid Collection

60 GeV Proton Beam

Neutrino Energy, GeV

Neutrinos/GeV/m**2/POT at 1km