Solenoid Focus of Pions for Superbeams

NUFACT06

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Compare Solenoid to Horn Focusing

Solenoid

- DC operation → longer lifetime
- Charged particles diverted from coil →longer lifetime
- High Field (~20T) ; Large Aperture (~20cm) → expensive
- Pions of both signs are focused forward → Detector should be able to distinguish between positive and negatives

Horn

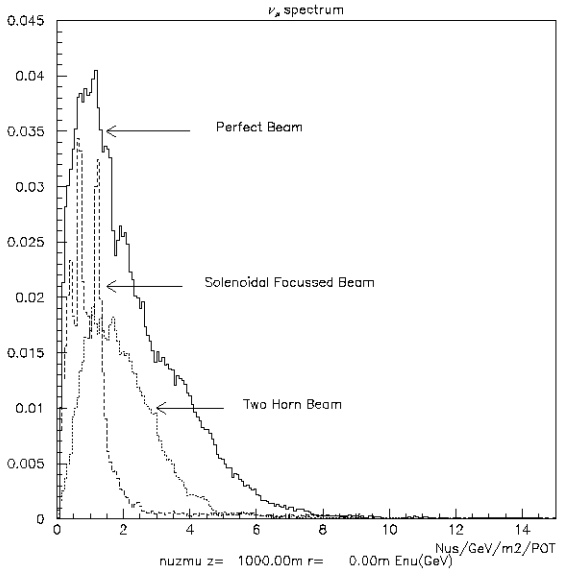
- More cost effective
- More easily replaced

First Attempts

A Solenoidal Capture System For Neutrino Production

PAC99

M. Diwan, S. Kahn, R. B. Palmer, BNL, Upton, NY



28 GeV Proton Beam

Cu Target L=22.5cm R=1cm

Solenoid Bz=20T Radius=16cm

Taper to Bz=0.2T, R=160cm at 20m

Model GEANT/Fluka

Conclusion: Solenoid Focusing does as well or better for low energy ν fluxes.

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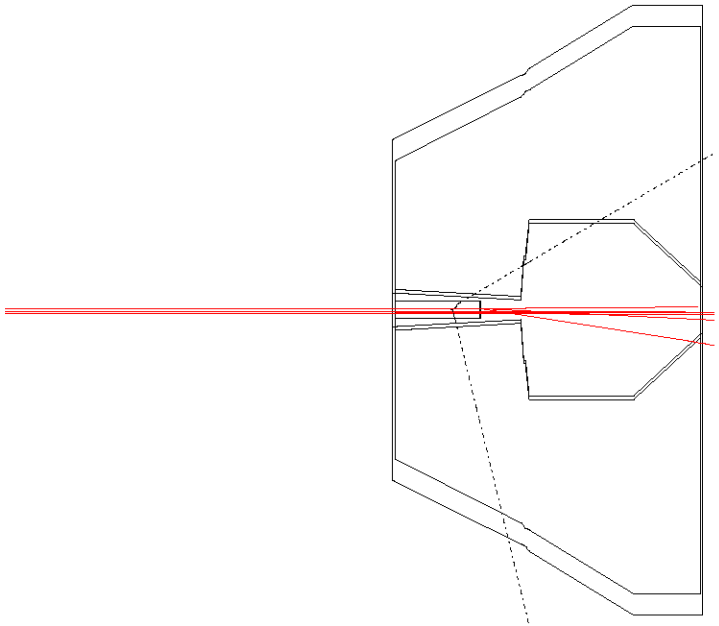
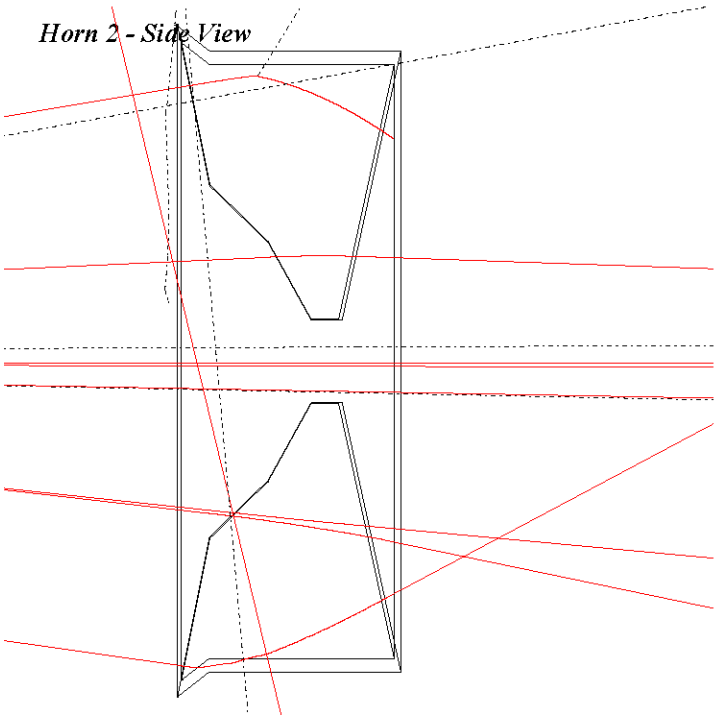
The Horn Bench Mark

J. Heim, M. Bishai, B. Viren BNL





Horn 1: Length =2.2m

Horn 2: Length =1.6m

ΔL Horn 2-Horn 1 =10m

Proton Beam/Target Input

Carbon Rod:

L = 80cm

R = 6 mm

$\rho = 2.2\ g/cm^3$

Proton Beam:

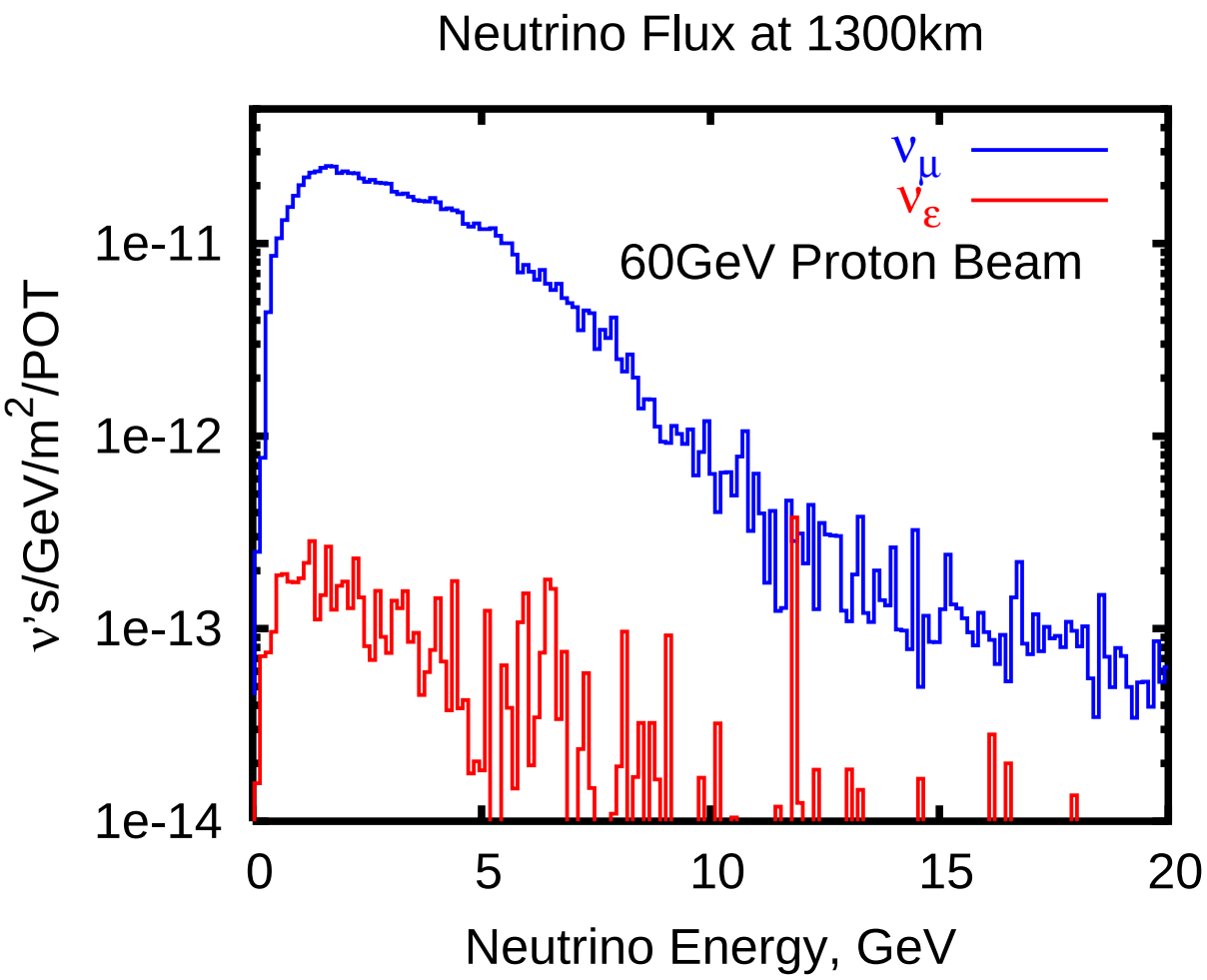
KE = 60 GeV

$\sigma_X = \sigma_Y = 2mm\ rms$

Model:

MARS 14

The Neutrino Flux at 1300km



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

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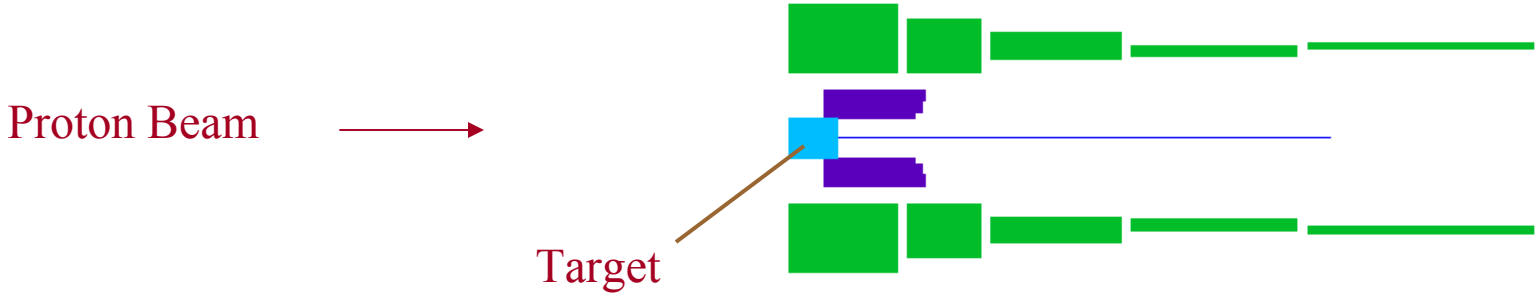
Solenoid Capture Concept



- Surround target with high-field, large aperture solenoid
- Adjust field taper for desired focusing
- Both signs of ν `s will be simultaneously collected

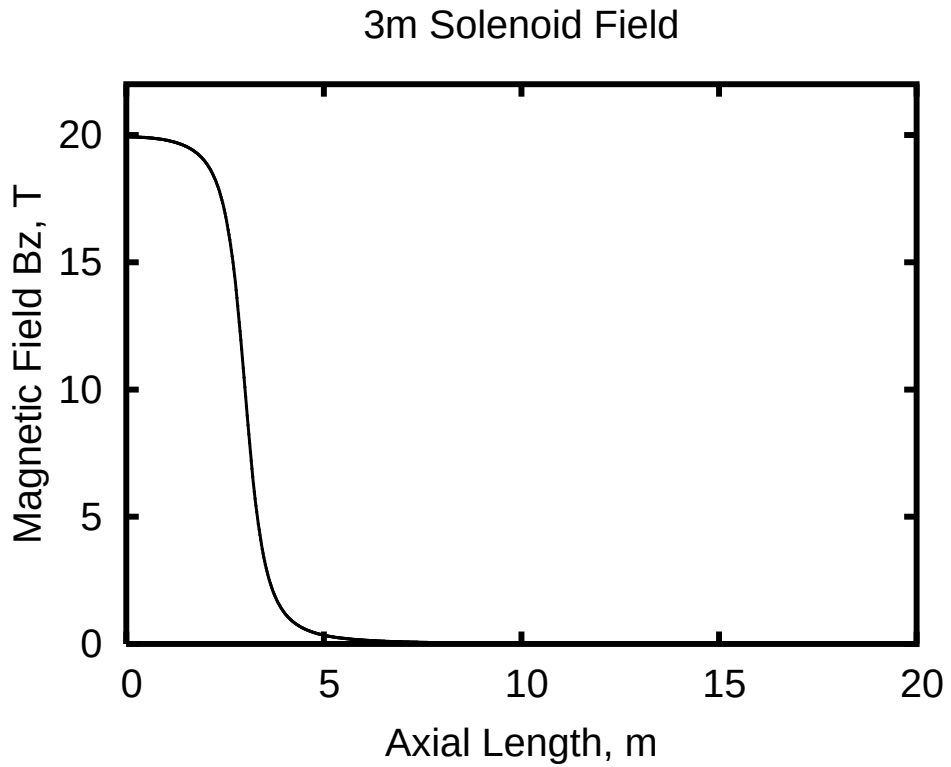
Solenoid as a Point to Parallel Lens

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

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

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

$$P_n = \frac{P_0}{2n+1}, \quad (n = 0, 1, 2, ...) \qquad \text{where} \qquad P_0 = \frac{eBL}{\pi c}. \tag{50}$$



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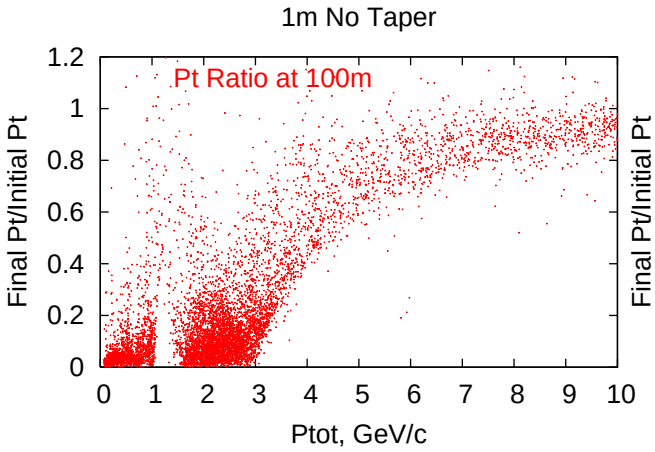
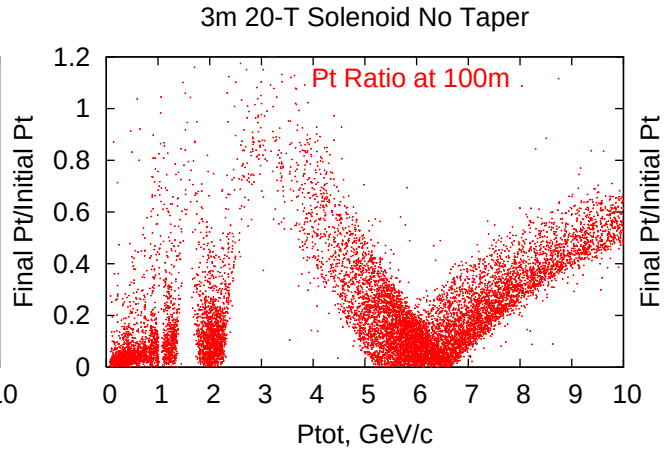
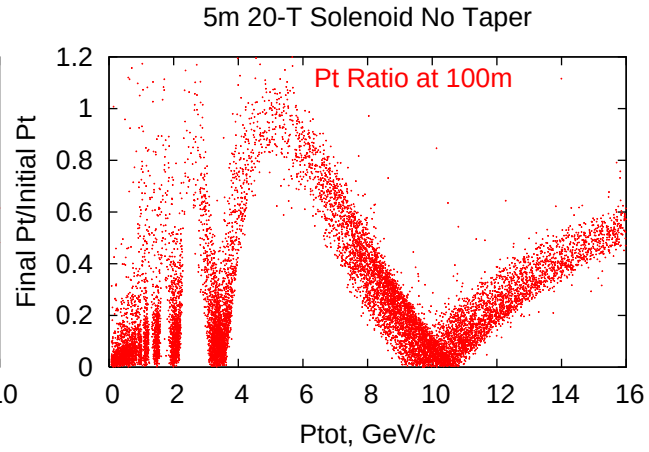
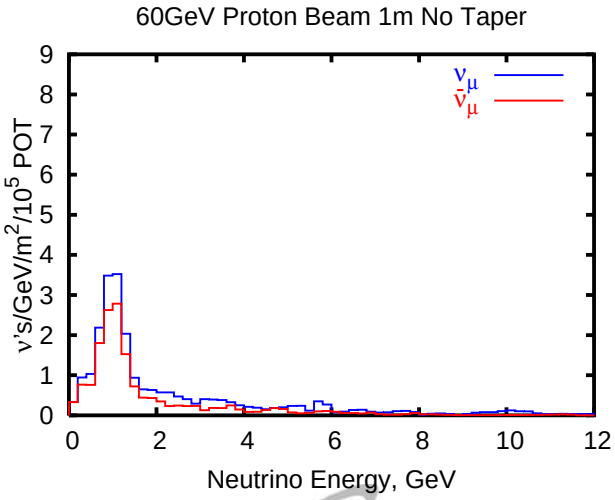
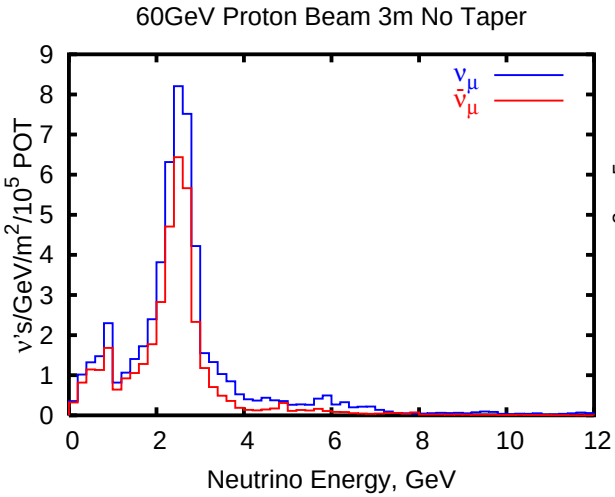
Varying the Length of the Solenoid

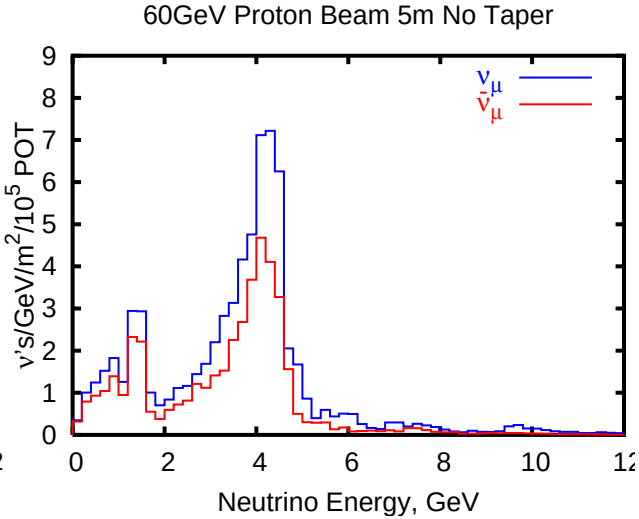












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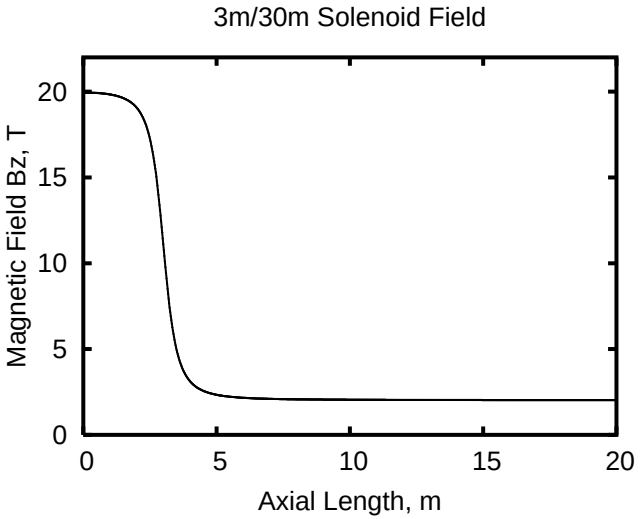
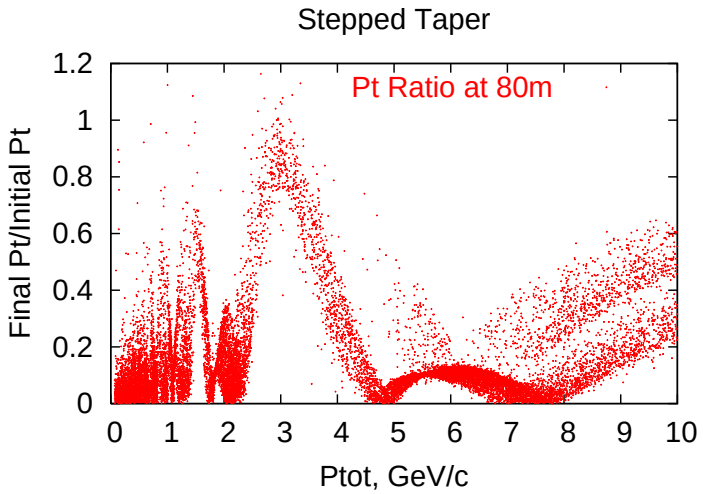
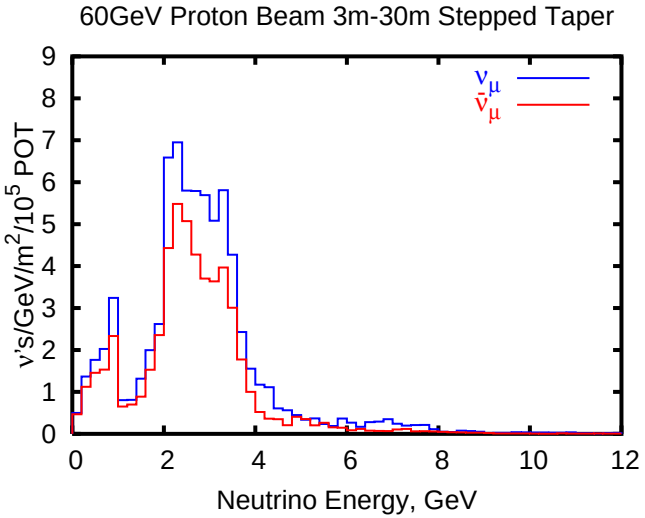
Broaden the Focal Momenta







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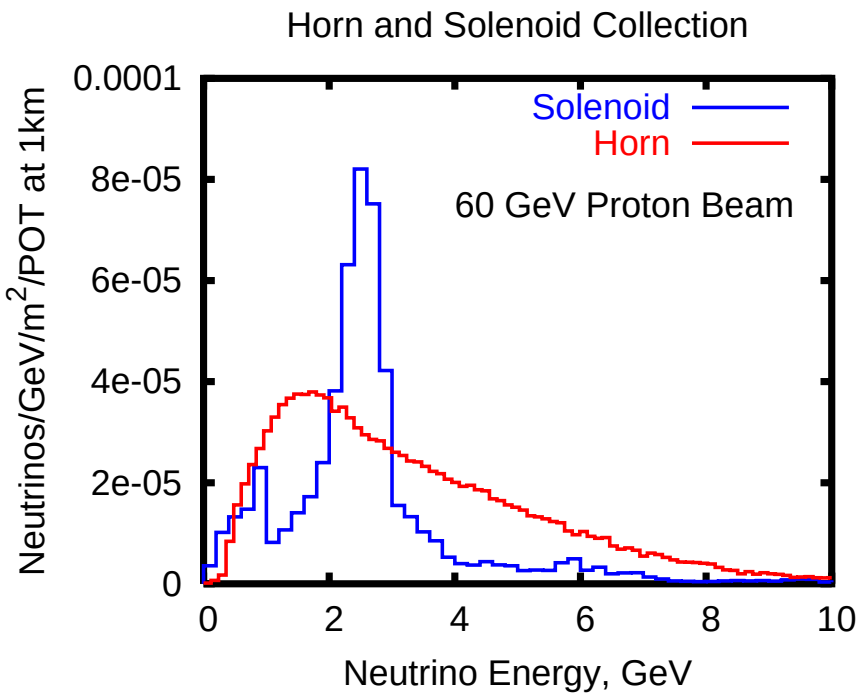
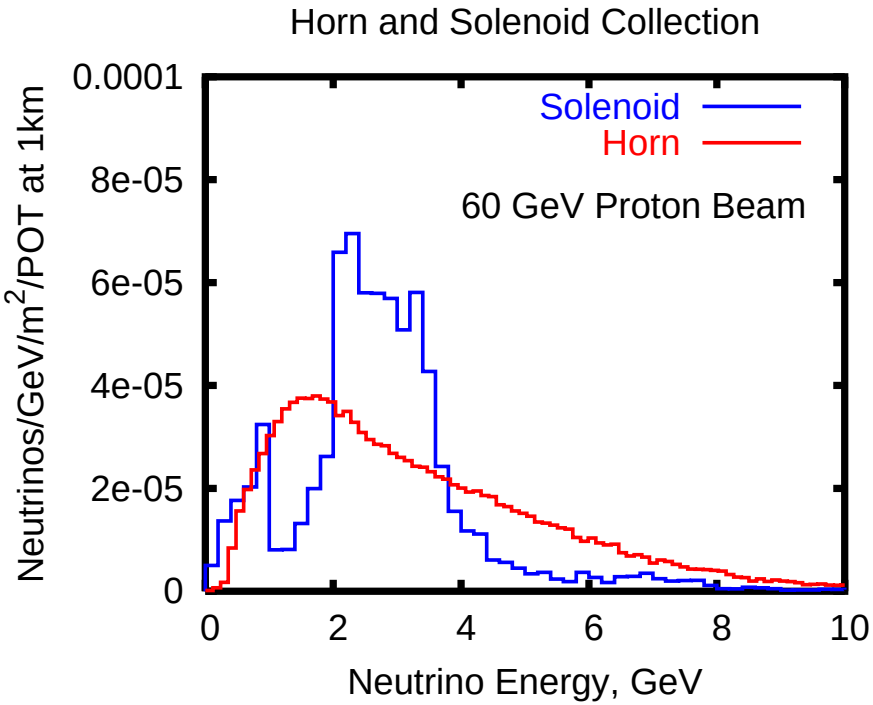
Compare Horn and Solenoid



3m Solenoid



3m-30m Solenoid

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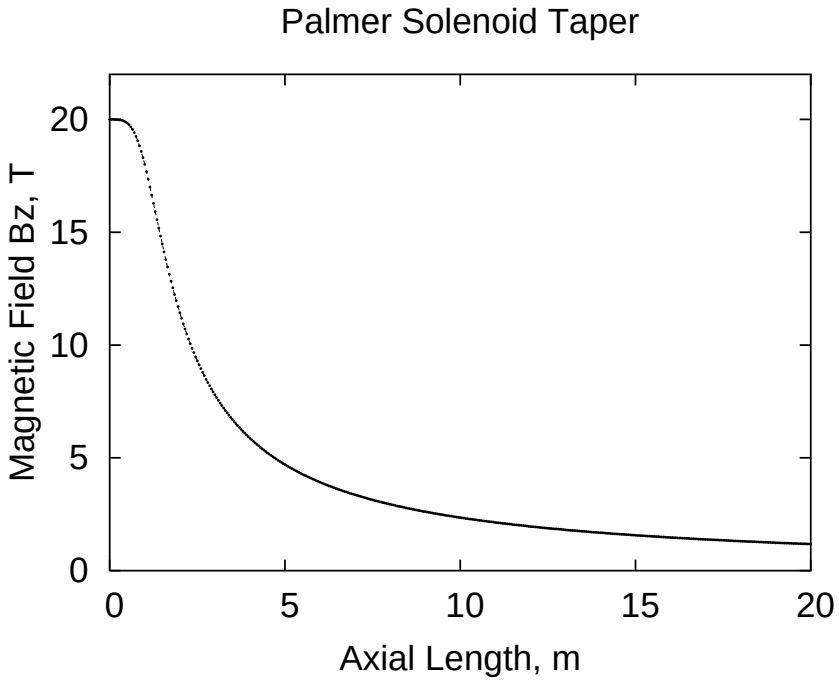
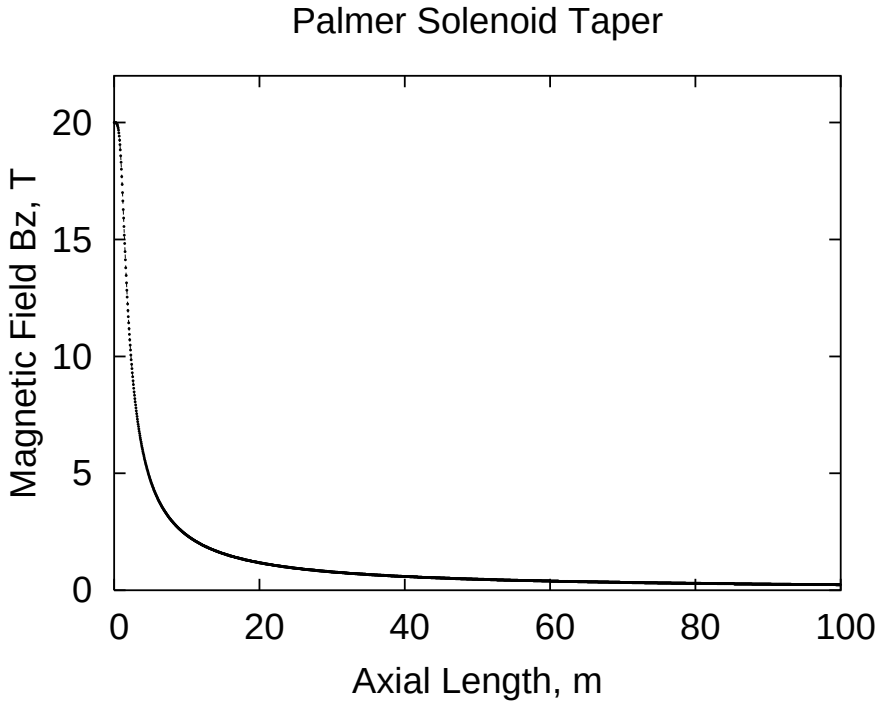
Taper for Wide Band Collection





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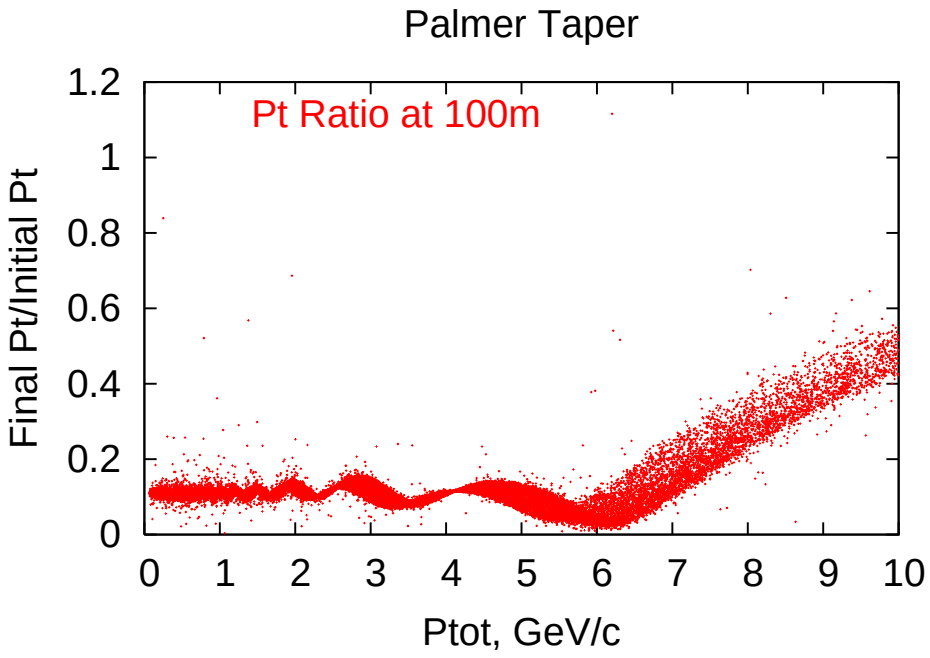
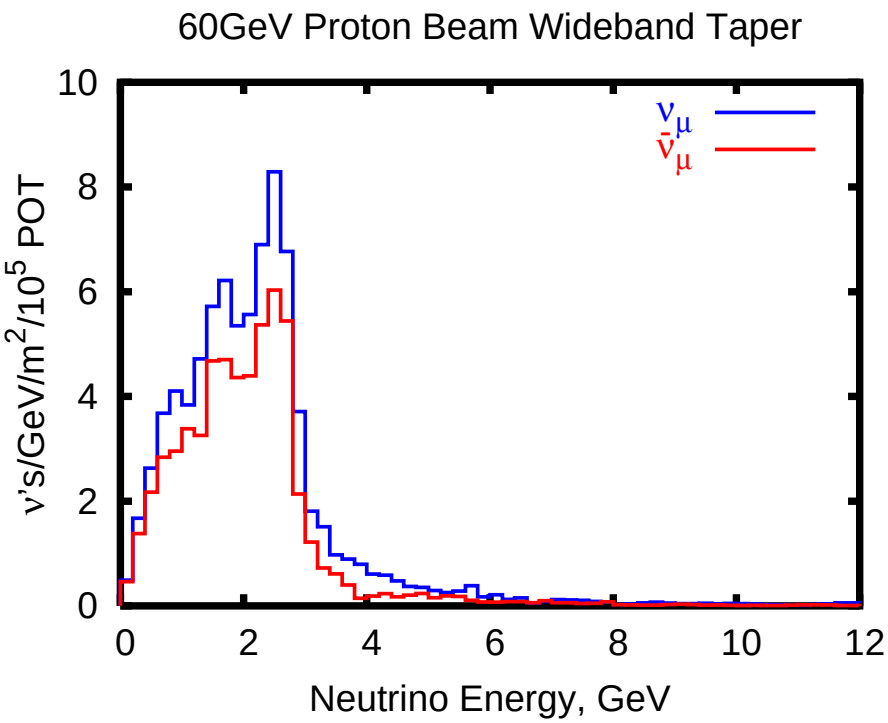
Broadband Low Energy Capture





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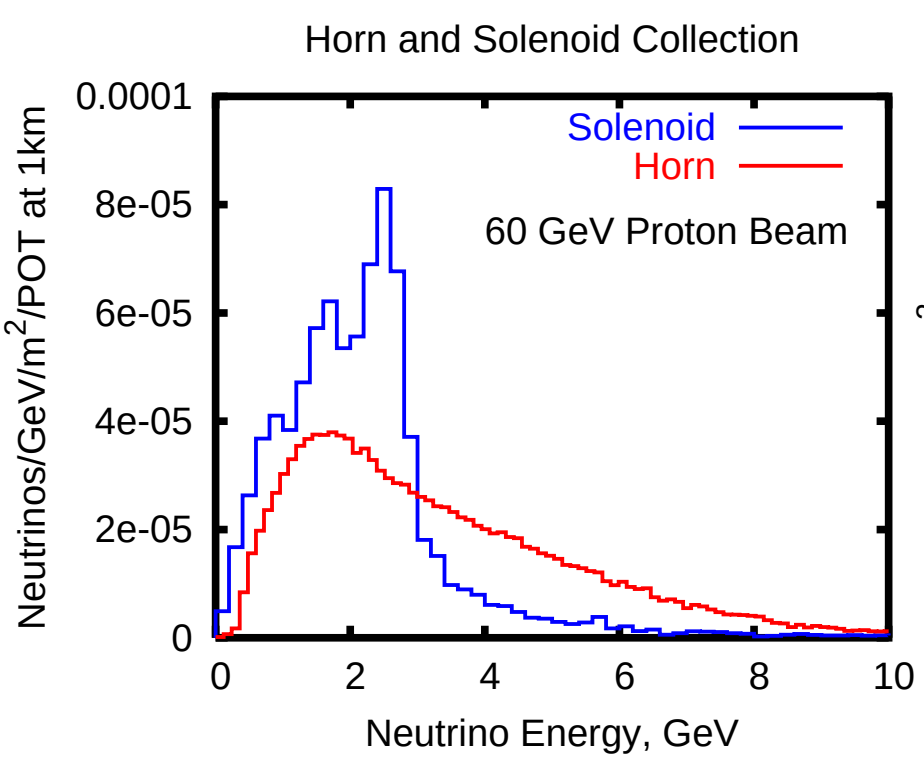
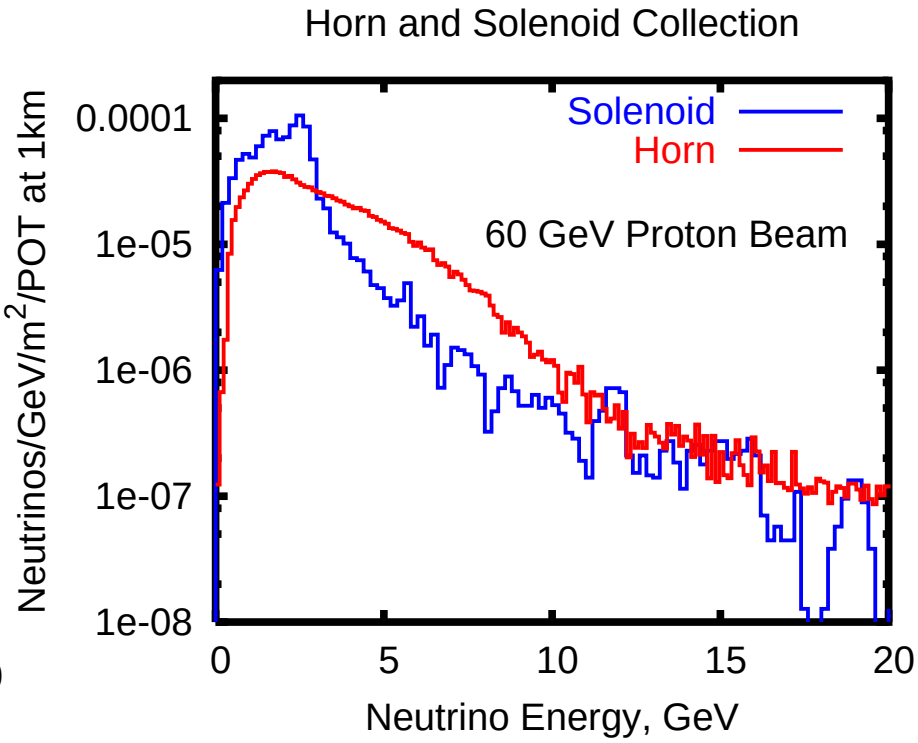
Compare Horn/Solenoid Neutrino Fluxes





Neutrino "Pointlike" Fluxes scaled to 1km

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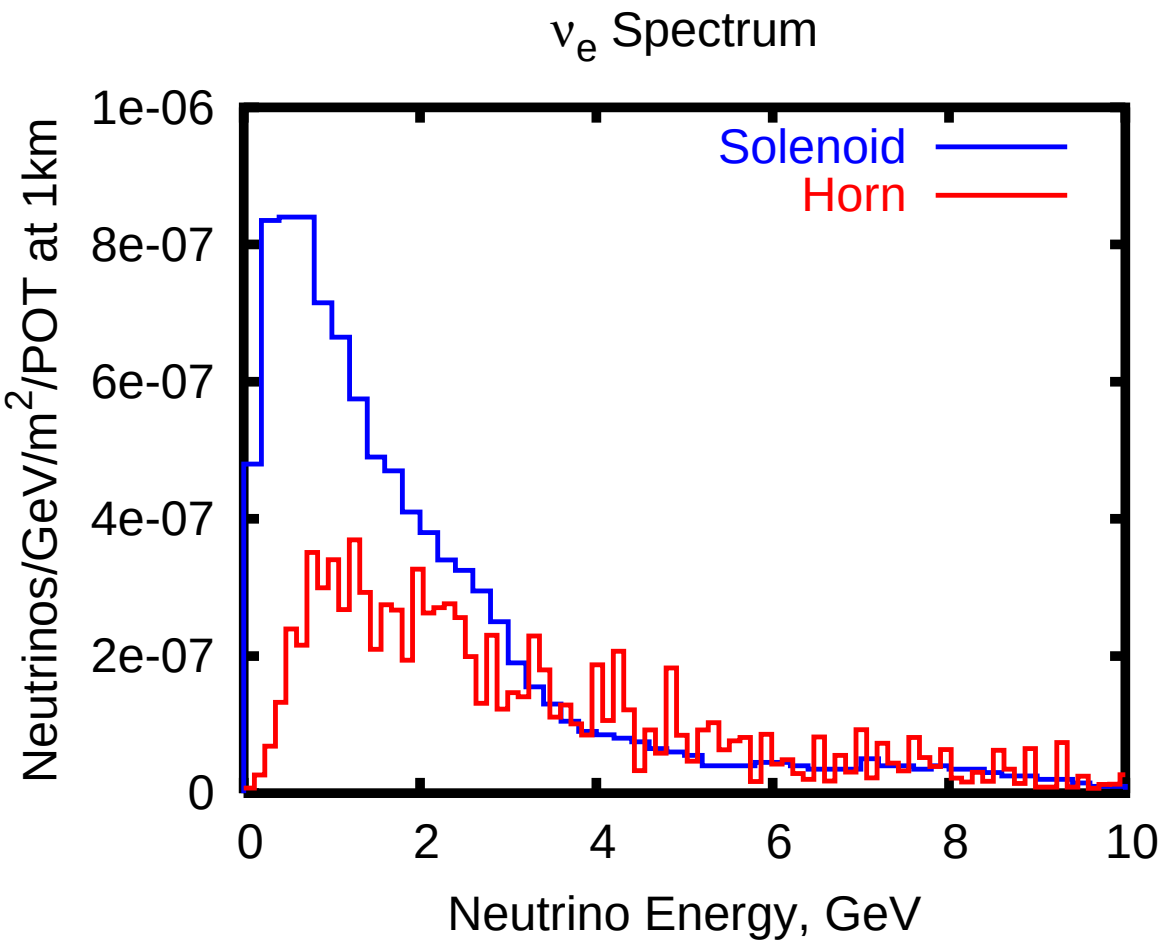
Compare Horn/Solenoid ν_e Fluxes



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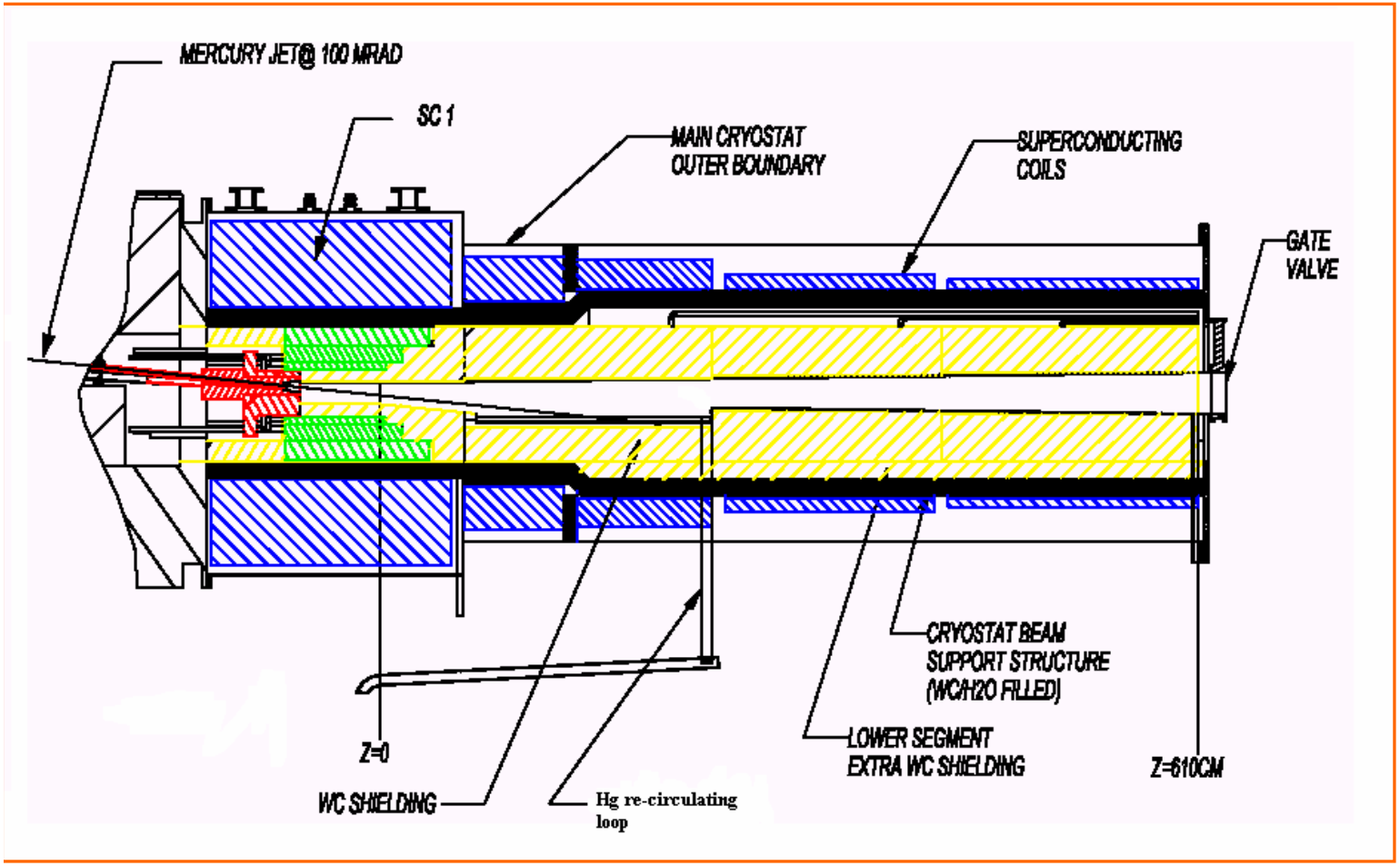
Neutrino Factory Study2a Target



The Field Taper

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

At Z=20m
Bz =1.75T
Bore =60cm

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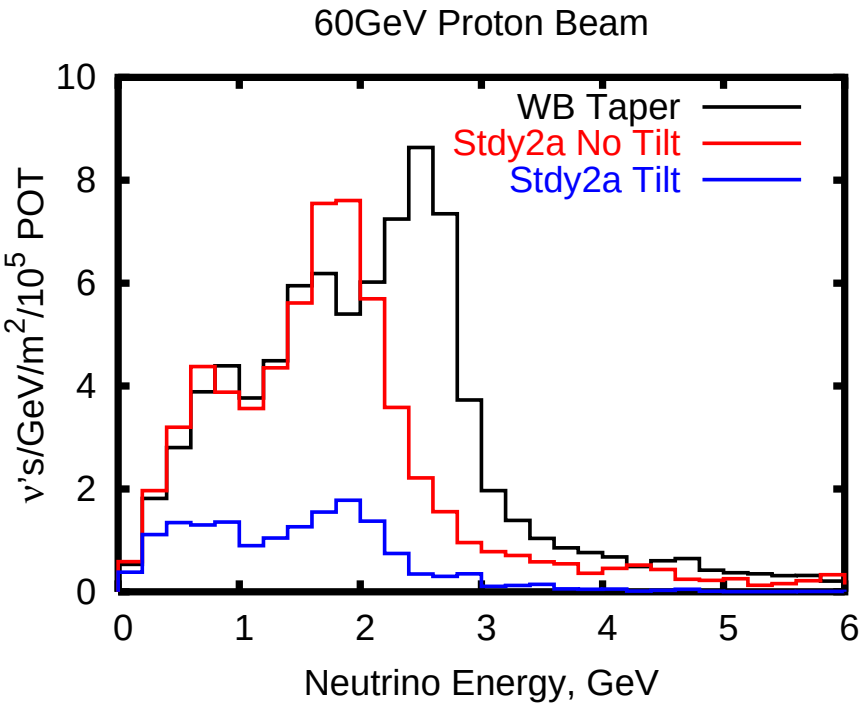
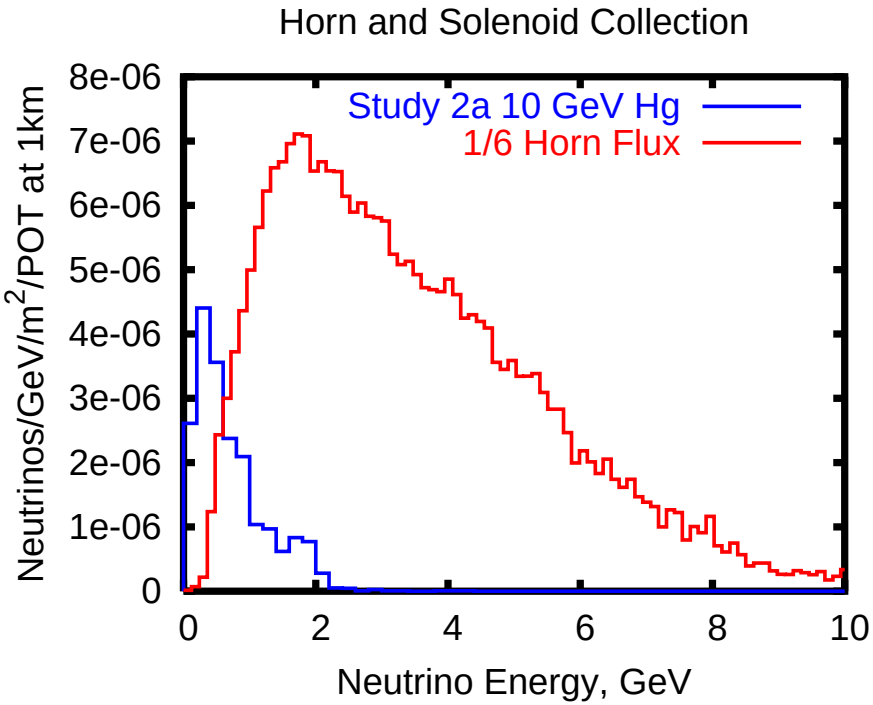
Study 2a Solenoid Horn





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Conclusions

- **A Solenoid Focusing System is competive (superior) to a horn focusing system for the capture of the lower energy portion of the neutrino spectrum**
- **Solenoid focusing is particulary attractive for the production of narrow-band, low-energy ν's**
- **Backgrounds from high-energy ν's are reduced for solenoid focusing**
- **Solenoid focusing results in larger number of soft ν_e `s (< 1GeV)**

Backup Slides

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Transverse Momentum Considerations

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

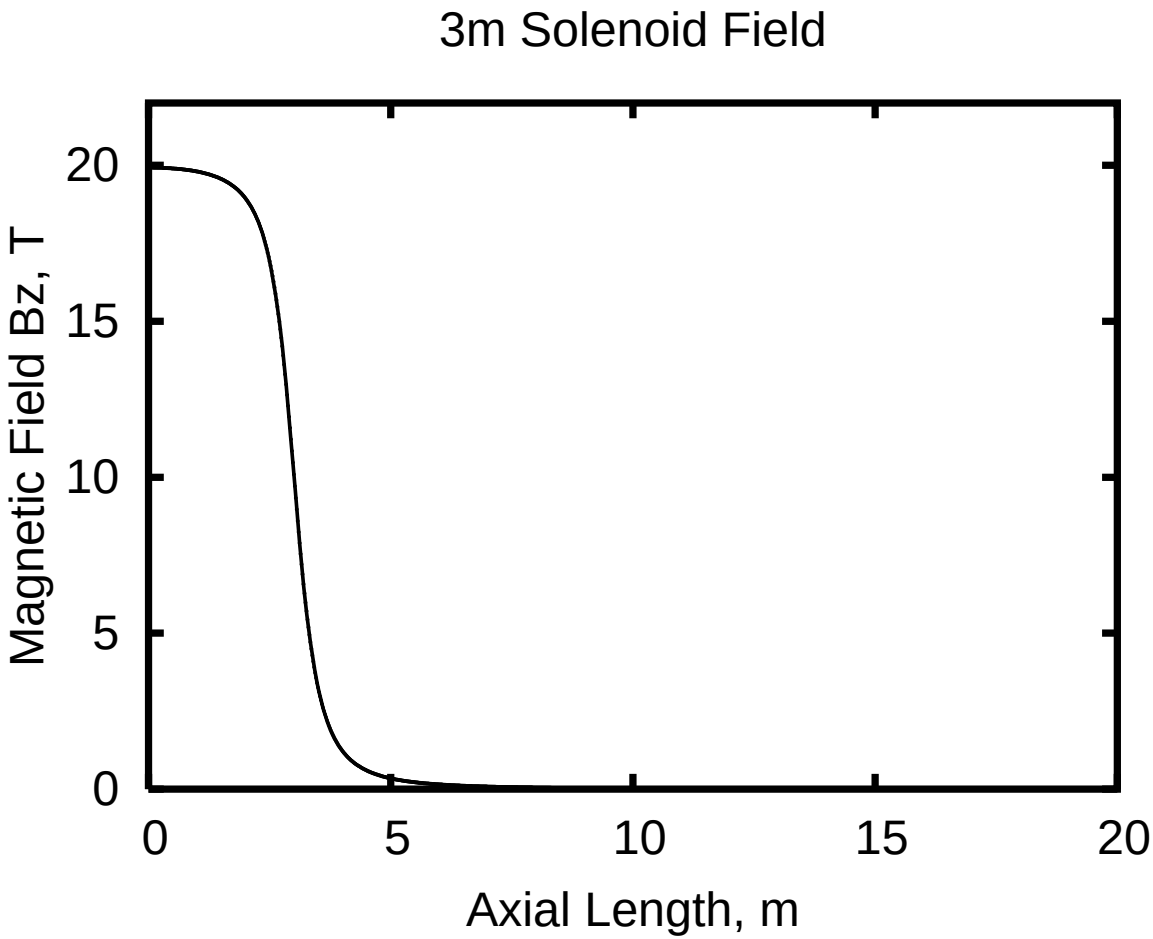
For $B_Z = 20T$ and $R_{Max} = 7.5cm$ $P_{T\,Max} = 225$ MeV and $\langle P_T \rangle$ is ~ 200 MeV

For $B_Z = 1.25T$ and $R_{Max} = 30cm$ $\langle P_T \rangle$ is ~ 50 MeV

Need to reduce field and increase Bore diameter further,

For $B_Z = 0.078T$ and $R_{Max} = 120cm$ $\langle P_T \rangle$ is ~ 12.5 MeV

Solenoid without Taper



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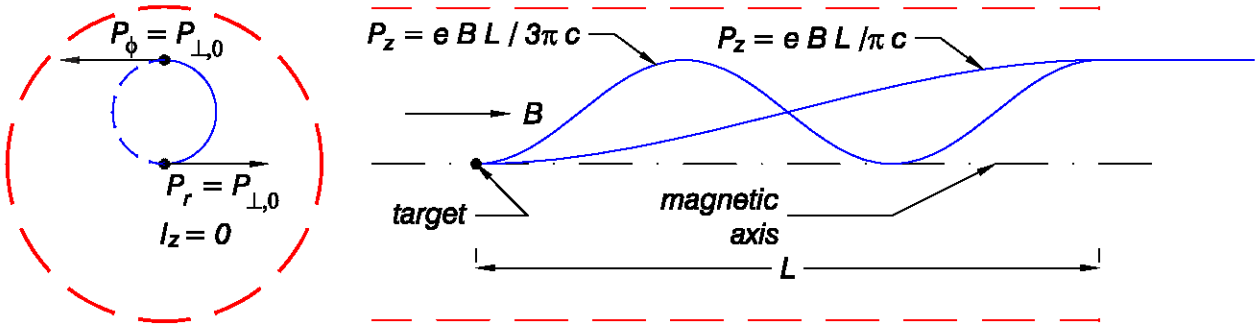

Figure 2: Concept of a neutrino horn based on solenoid focusing. The pion production target is inside the uniform field region of the solenoid. The focusing effects of the fringe field at the exit of the magnet (at distance L from the target) act as ideal thin lens of focal length L for a discrete set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