Plugging NuMI On and Off Axis

Brett Viren

bv@bnl.gov

Physics Department

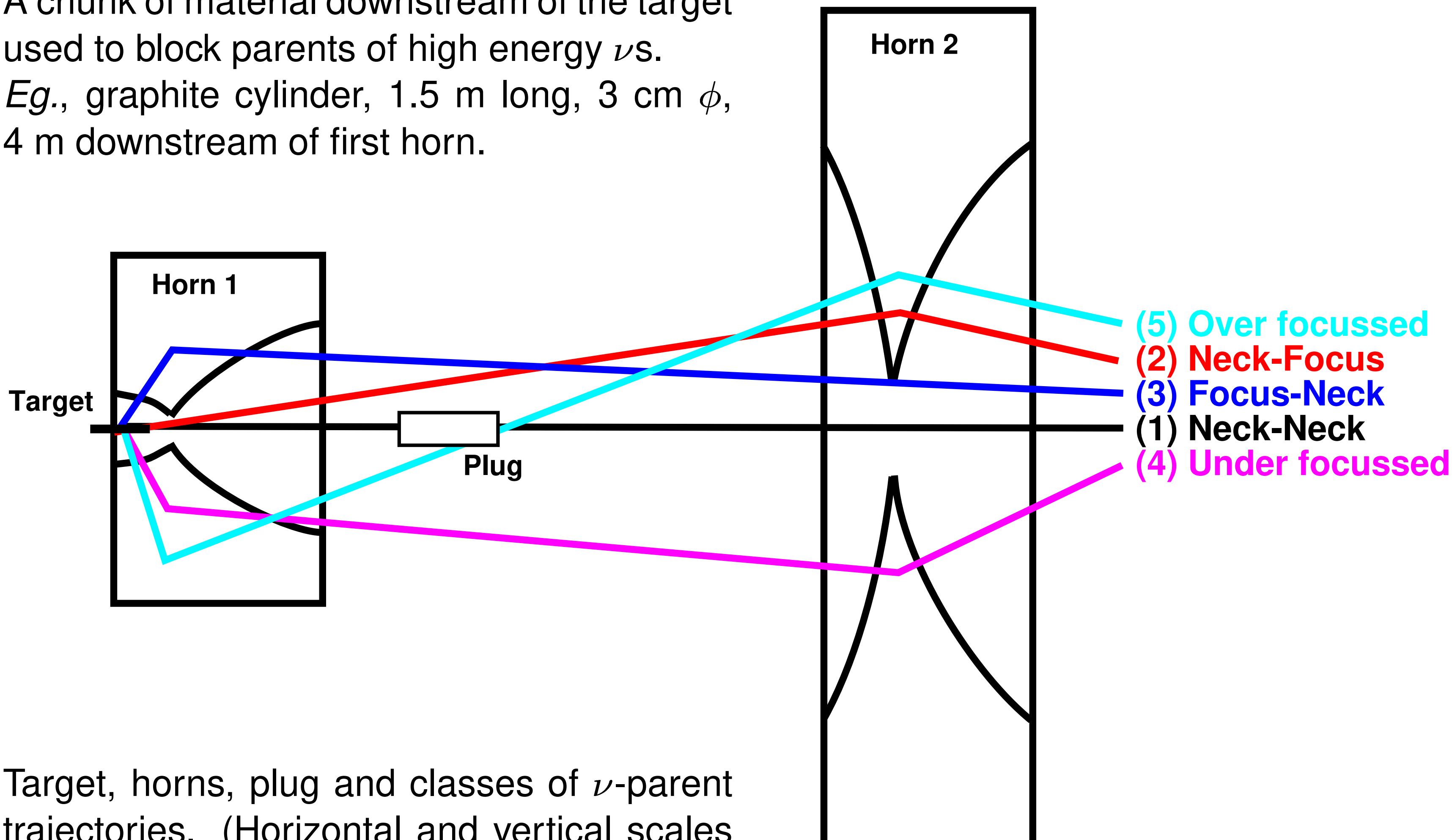
Brookhaven National Lab

Outline

- Orientation: plugs as seen on-axis.
- What happens when seen off-axis?
- Plugs in π^- focused beams.
- Beam ν_e.
- Conclusions.

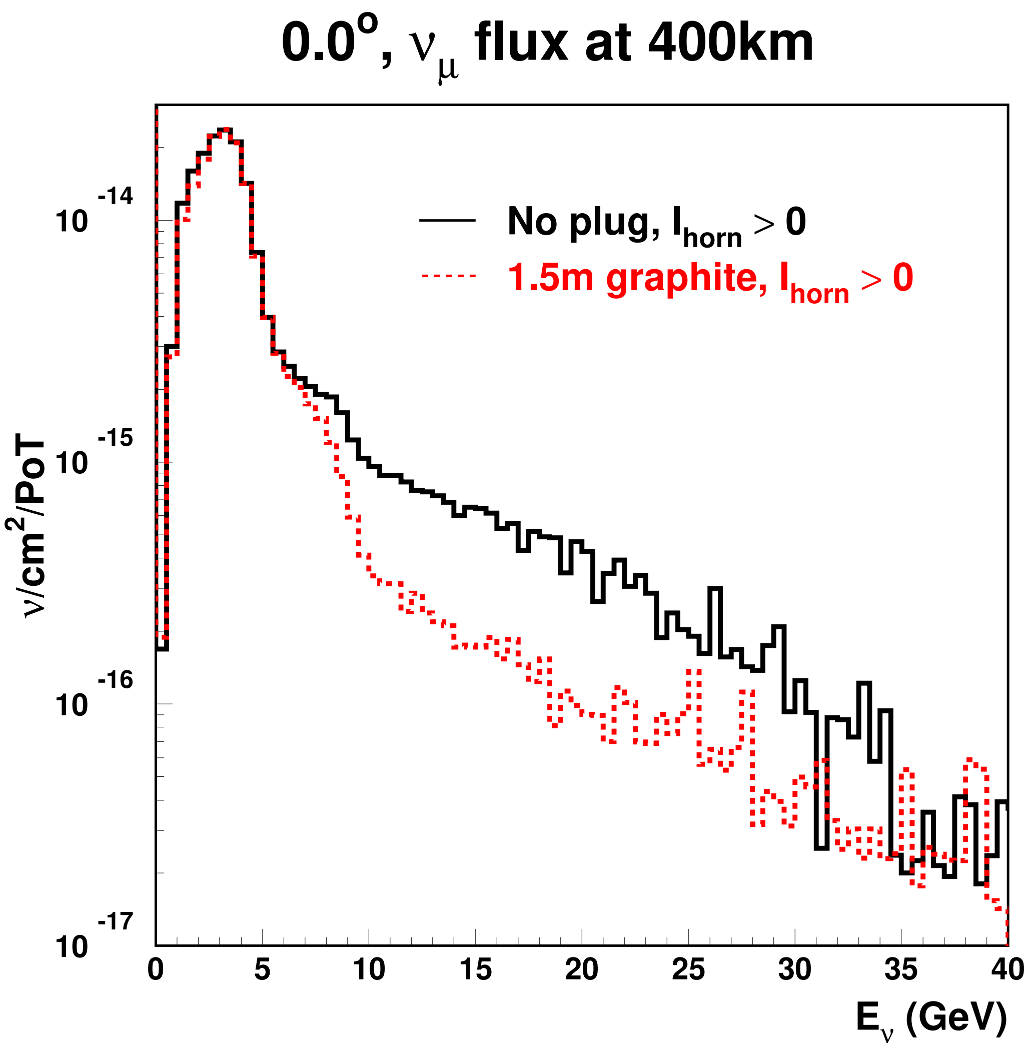
What is a plug?

A chunk of material downstream of the target used to block parents of high energy νs. *Eg.*, graphite cylinder, 1.5 m long, 3 cm ϕ, 4 m downstream of first horn.



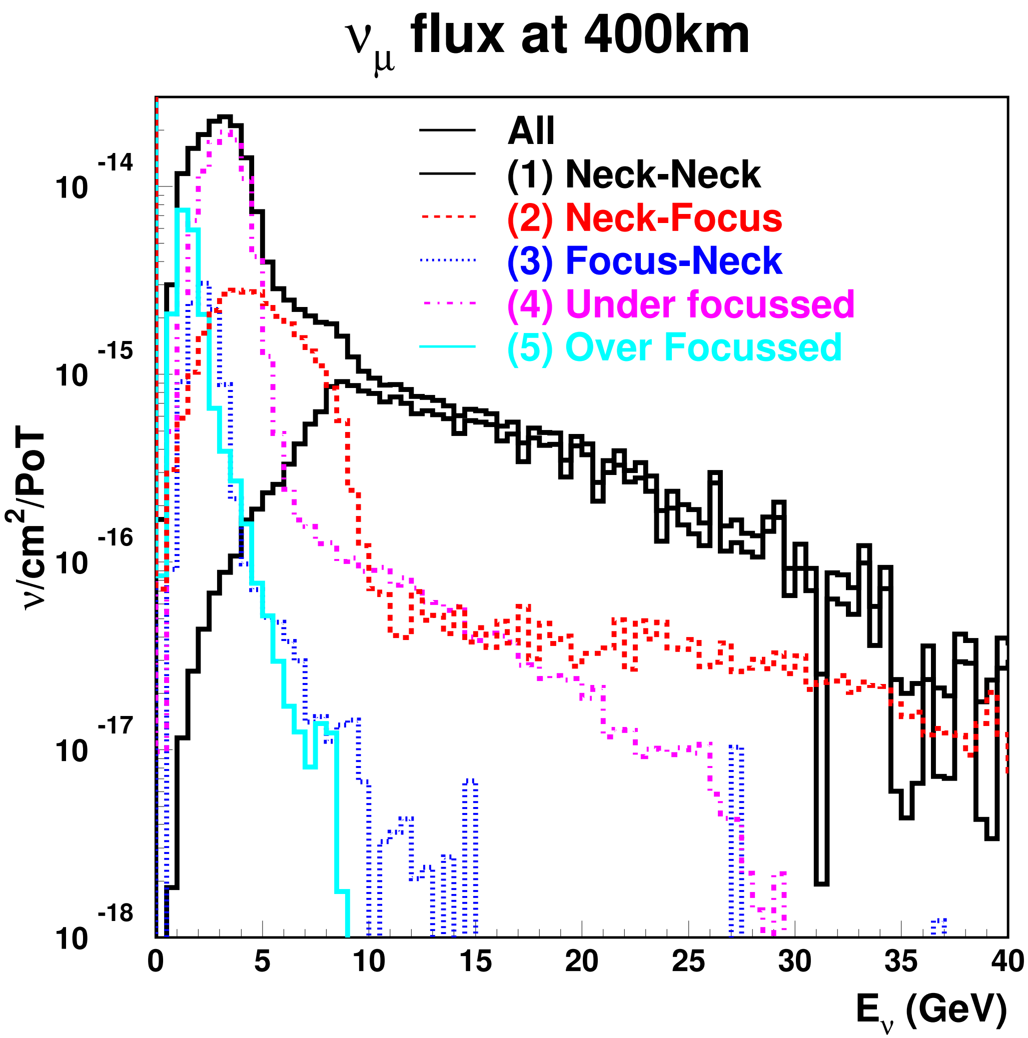
Target, horns, plug and classes of ν-parent trajectories. (Horizontal and vertical scales differ.)

ν_μ Spectra @ 400km



- On axis, ν_μ flux, 400 km from target
- $\times 3$ reduction for $E_\nu > 10$ GeV
- 5% loss for $E_\nu < 3$ GeV
- 7% loss for $3 < E_\nu < 10$ GeV

Spectra by parent tracks, no plug, on-axis



- Neck-Neck responsible for bulk of tail
- Neck-Focus next contributor
- Over focussed and Focus-Neck give low-E_ν
- Under focussed give medium-E_ν

Spectra by parent tracks, plugged, on-axis

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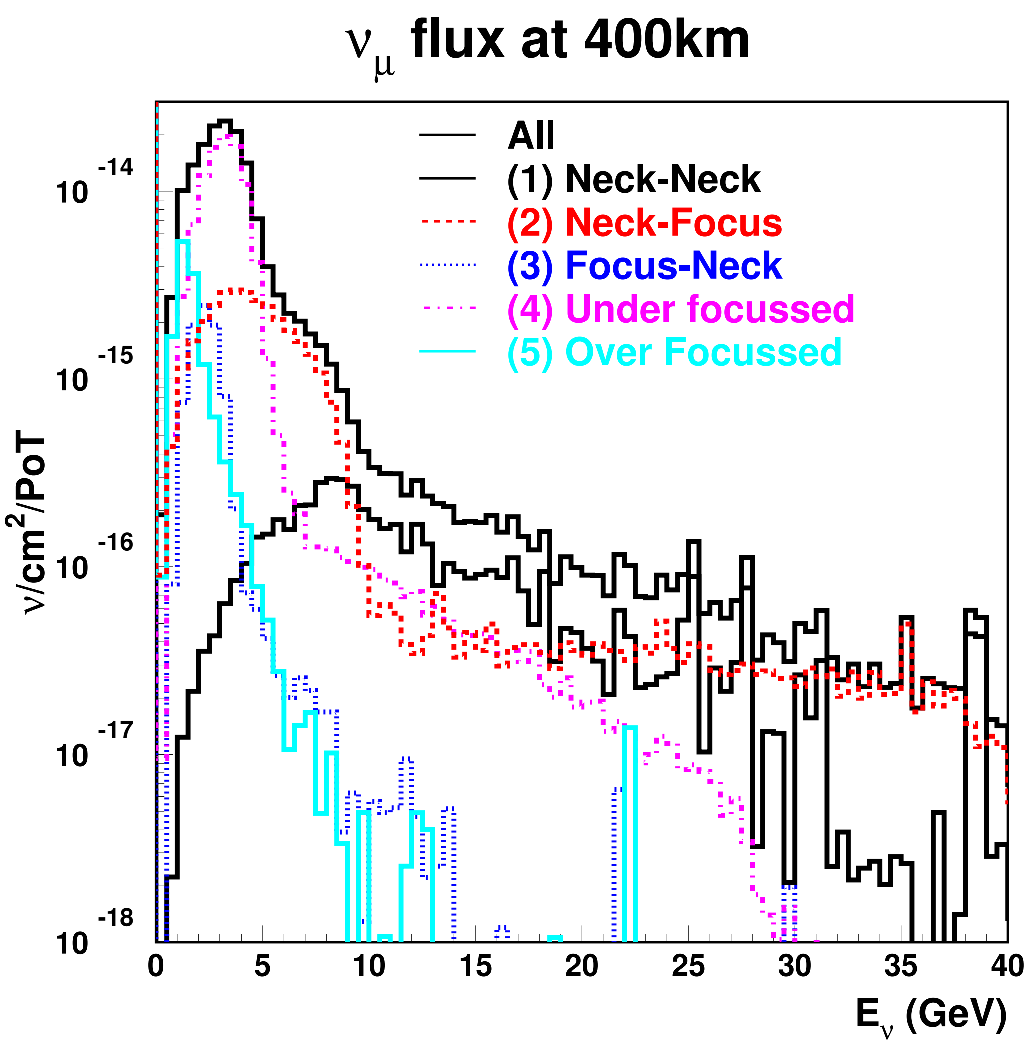
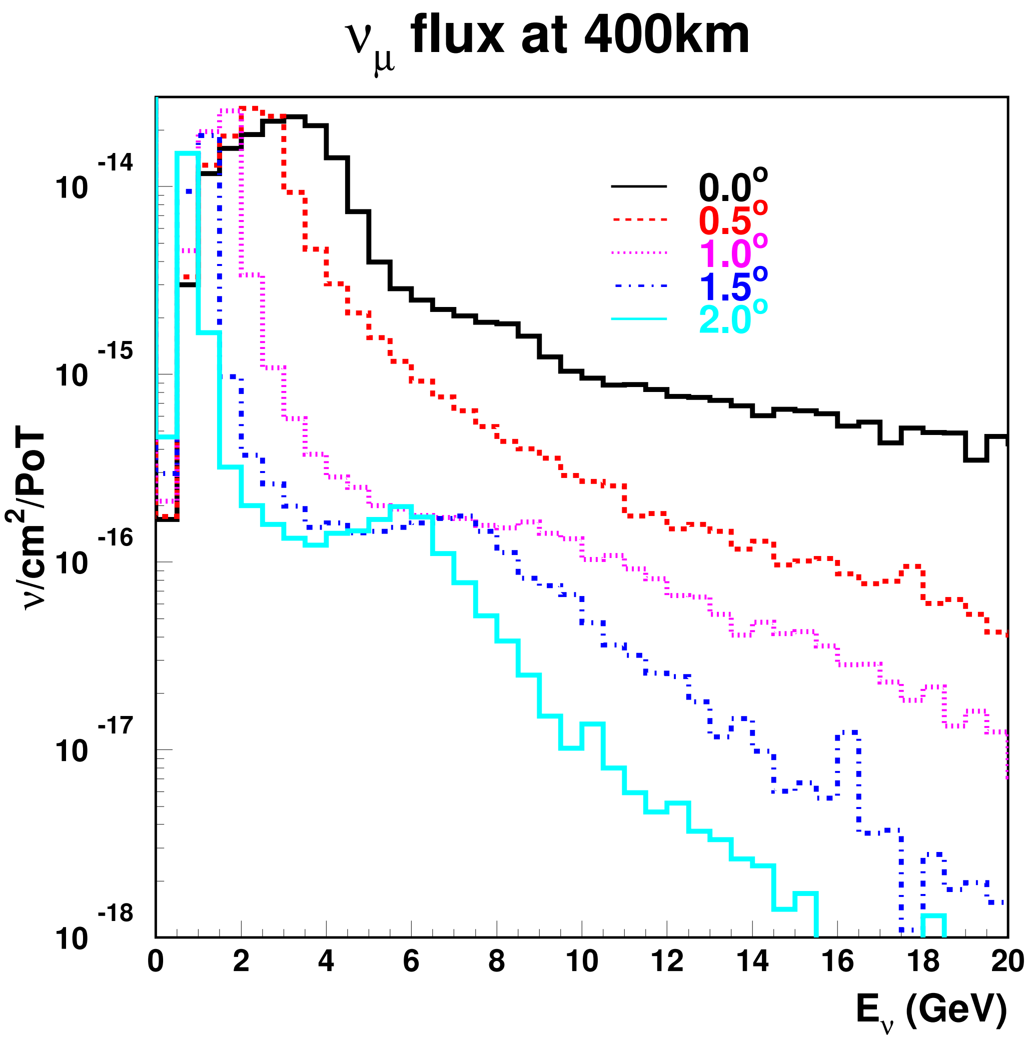


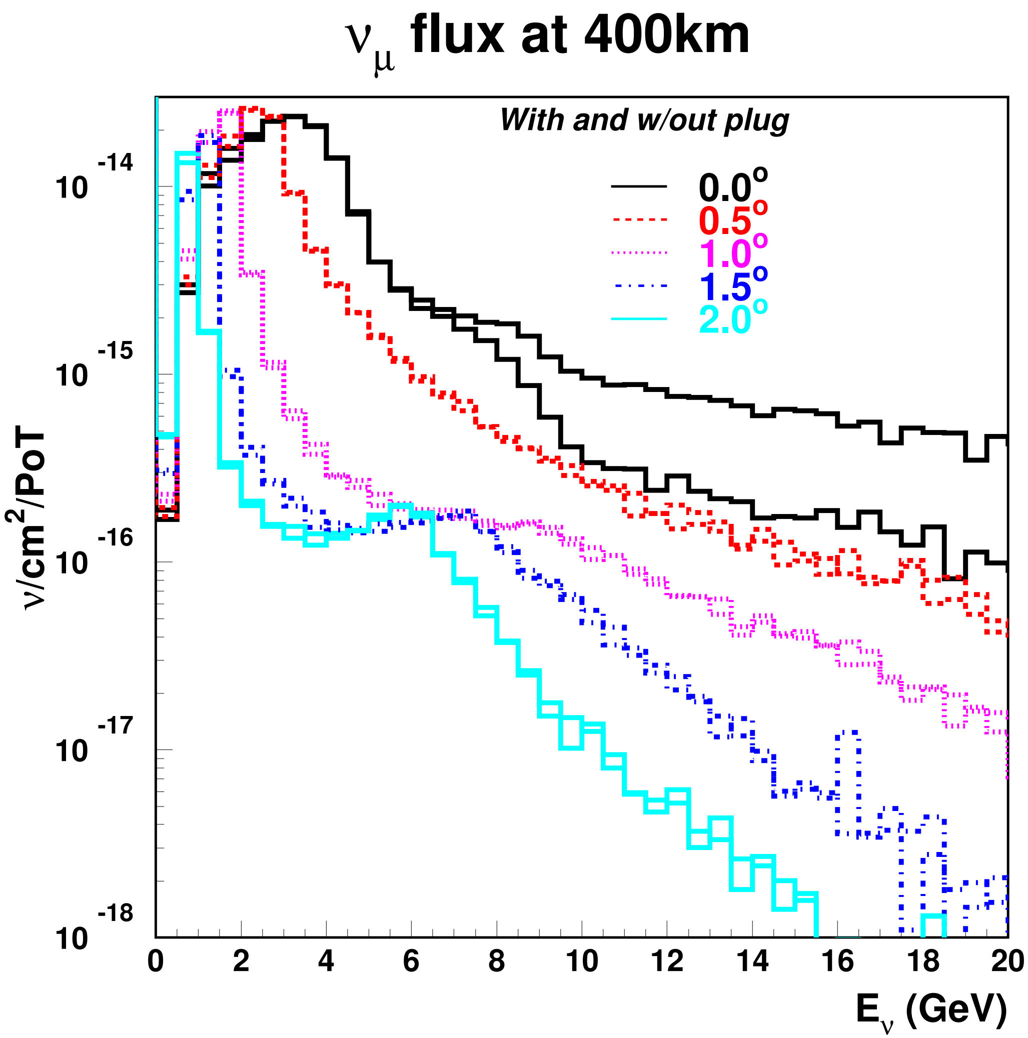
- Cylindrical graphite plug
- L=1.5m $\times$ ϕ=1.5cm
- Starts 4m from horn 1 face

Going off-axis



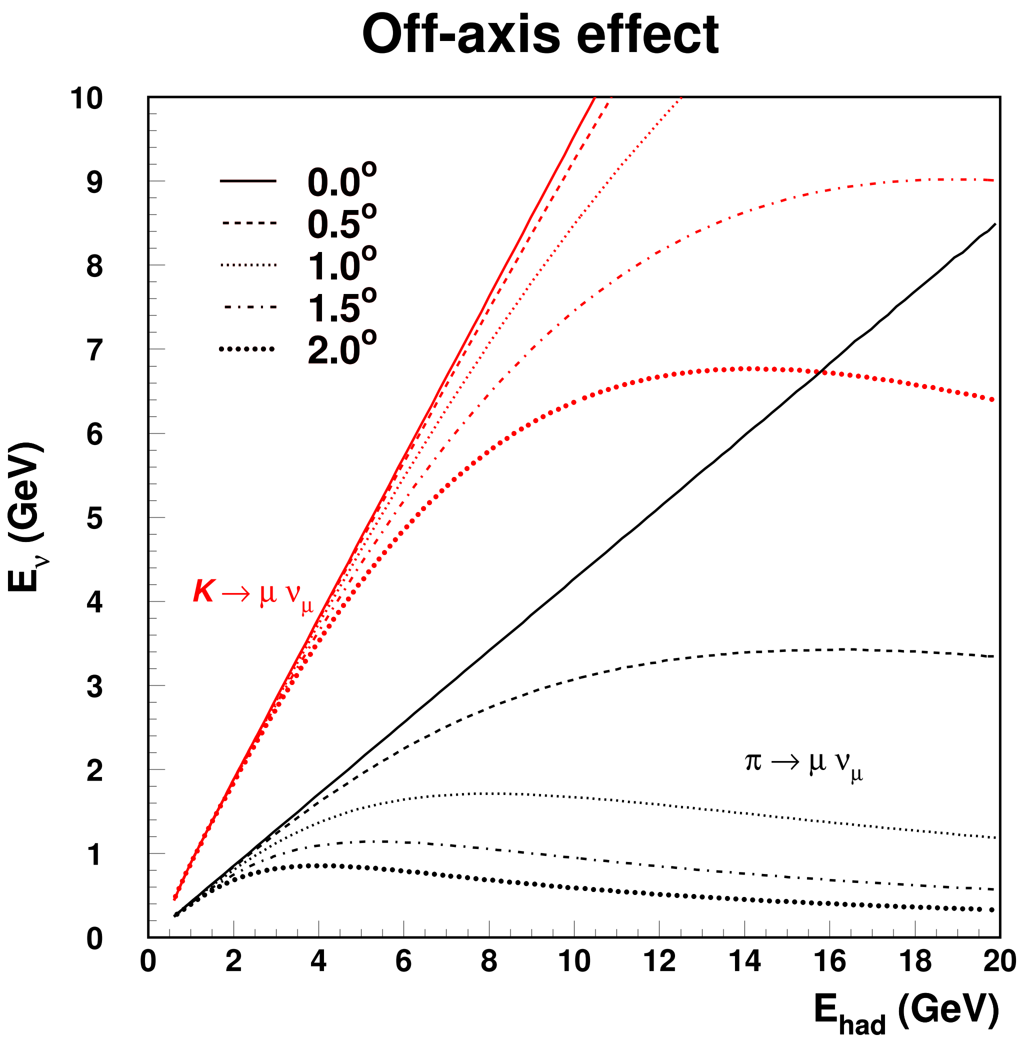
- Idea from BNL P889
- Reduces high energy tail
- Reduces mean energy
- Reduces spectrum width
- Doesn't reduce peak much

Off-axis plug



- Off-axis tail sees no decrease.
- Low-E_ν peak still suffers decrease.
- No benefit !!
- Why? 3 Reasons $\longrightarrow$

Off-axis effect

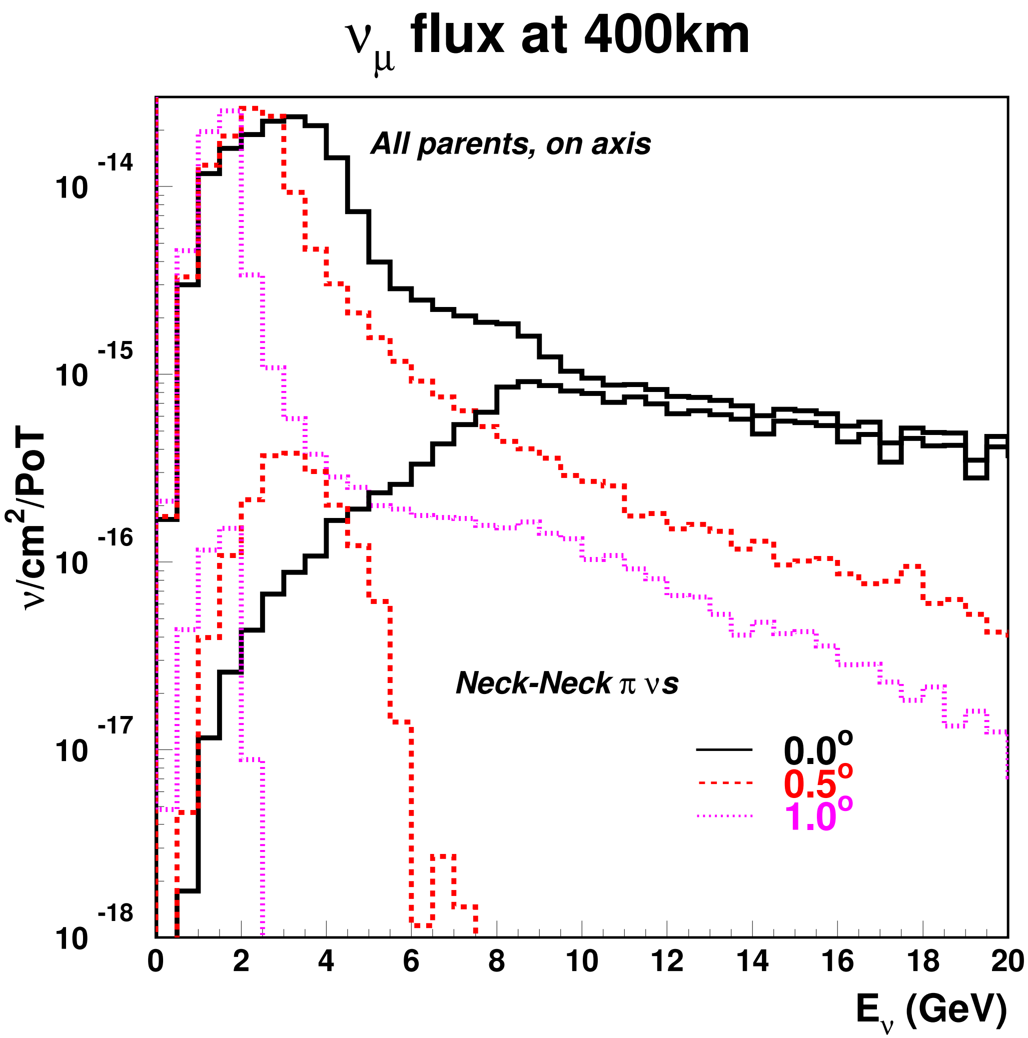


- $had \rightarrow \mu\nu_\mu$
- $E_\nu = \frac{0.5(m_{had}^2 - m_\mu^2)}{E_{had} - P_{had}\cos\theta}$
- Off-axis νs insensitve to π energy, (and for far off-axis or high energy νs, K energy)

  $\Downarrow$

  Cutting out high energy hadron tail doesn't effect off-axis E_ν spectral shape
- In general, $E_\nu \downarrow$, including νs responsible for the on-axis tail. $\Rightarrow$

Neck-Neck-π νs shift down



Just look at 0°, $\frac{1}{2}^\circ$, 1° beams:

- High energy ν tail from non-focussed pions shifts down in energy, along with peak.

$\Downarrow$

- Small contribution to a large peak.

Neck-Neck-K νs don't contribute much

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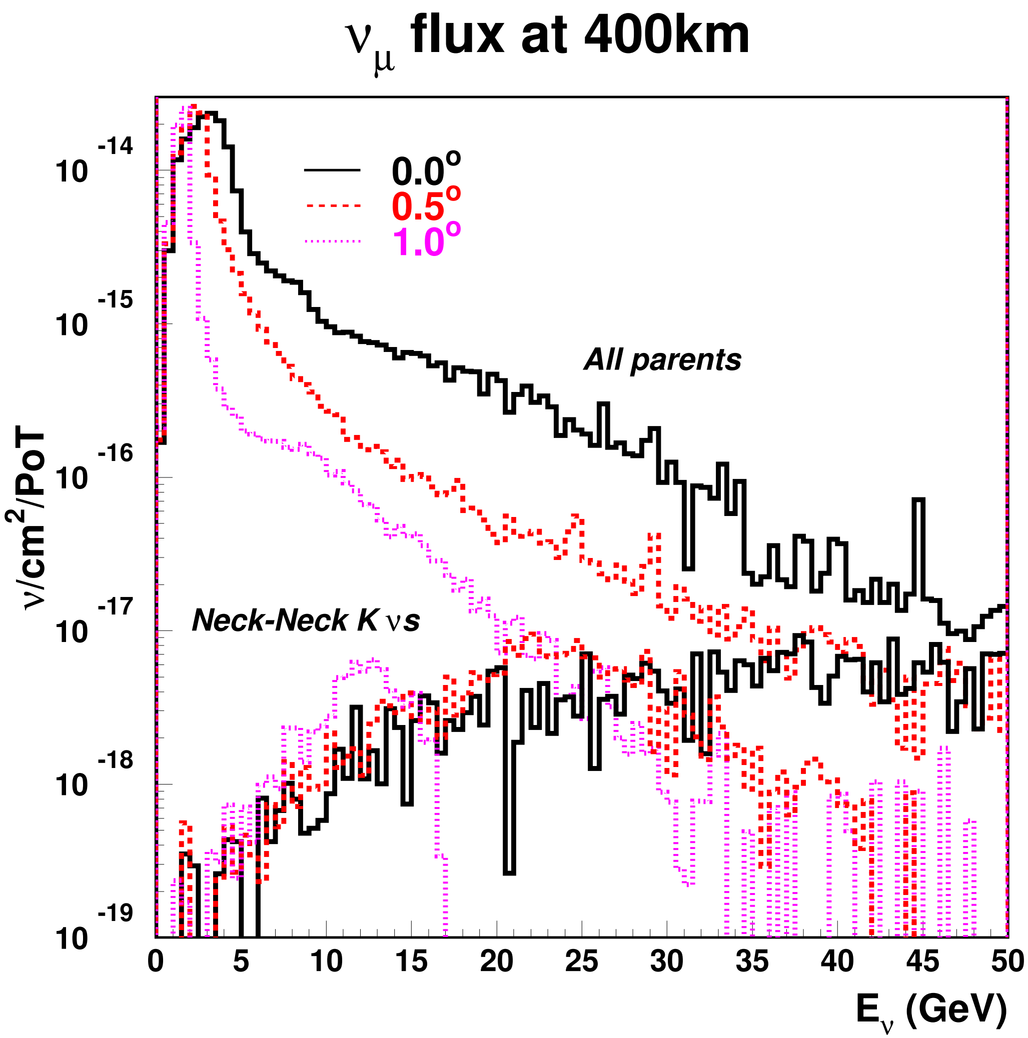


Neck-Neck Kaons provide less and less neutrinos relative to focused kaons as one goes off-axis.

$\Downarrow$

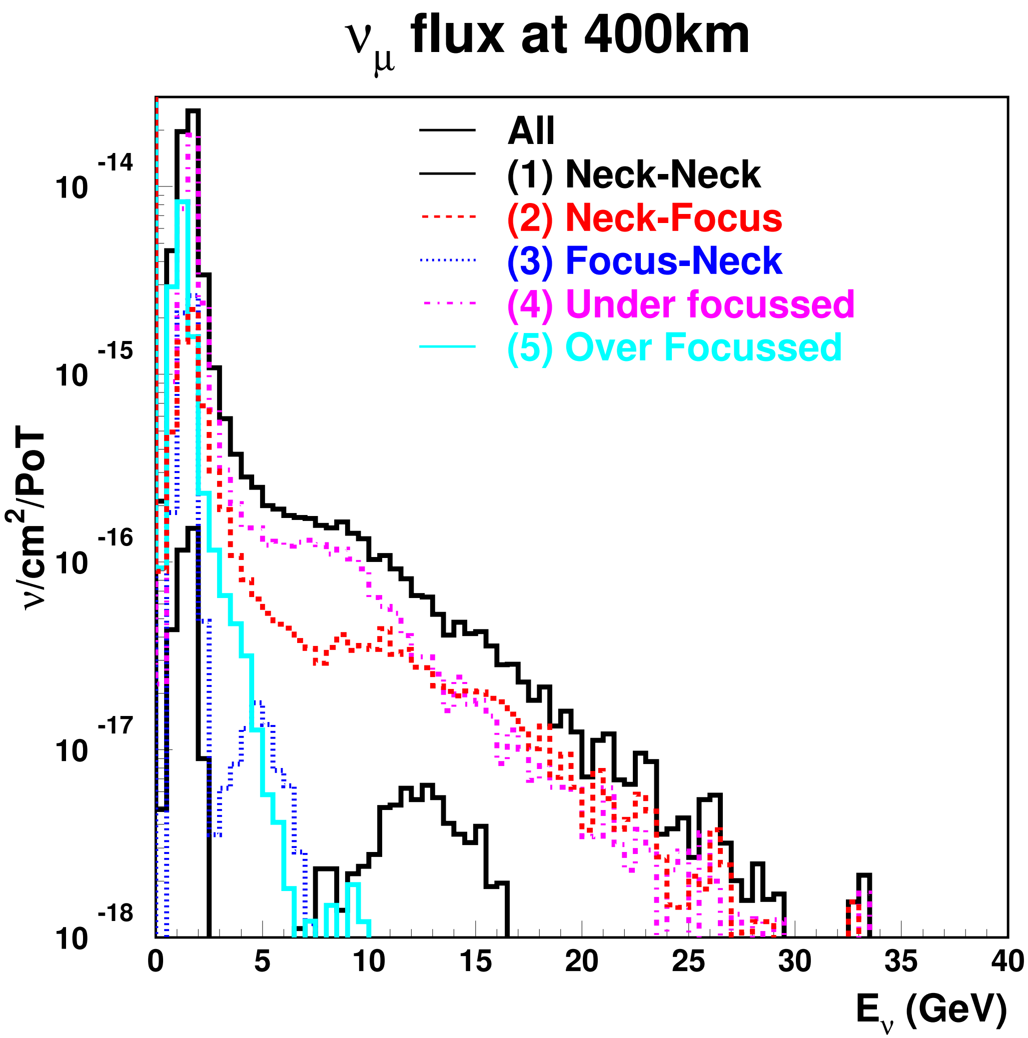
The dominant contribution are the Neck-Focus Ks

$\Downarrow$

Improvement by moving plug closer to target?

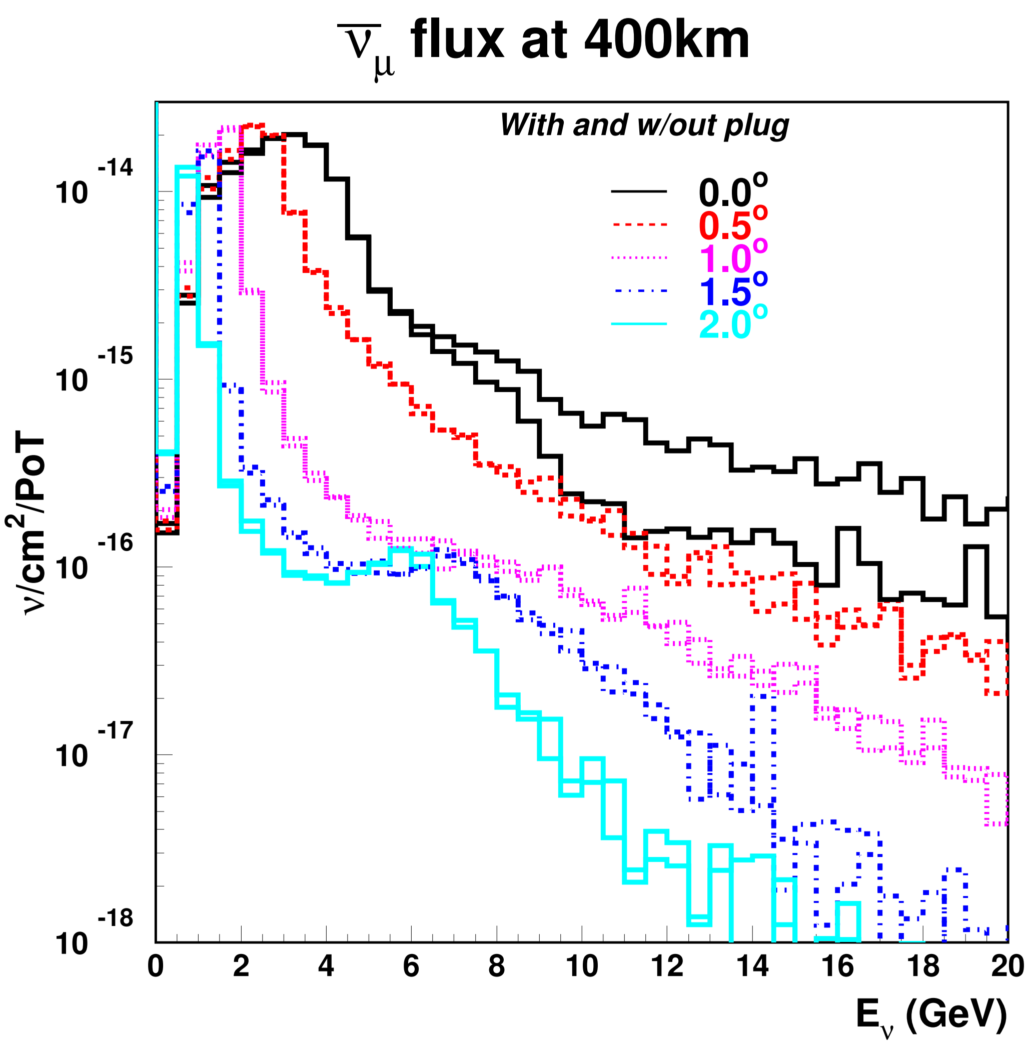
$\Downarrow$

Off-axis Spectra by Parent Trajectory



- $1°$ off axis.
- Remaining tail due to Under Focussed and Neck-Focus parents
- A close-in plug may be able to kill Neck-Focus parents
- But, Under Focussed?

Negative beam



No qualitative difference to the positive beam case.

Beam ν_e

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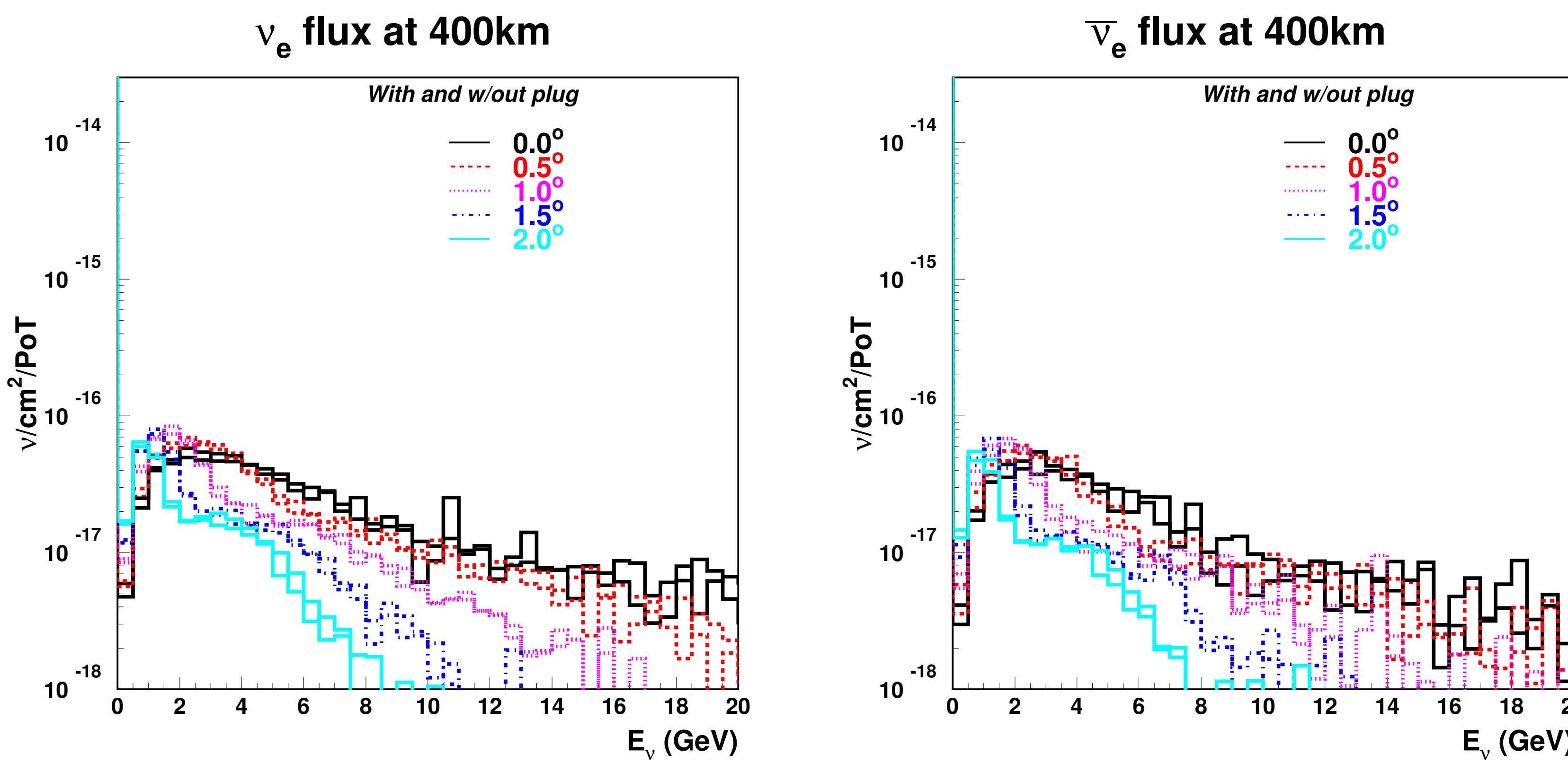
ν_e and $\bar{\nu}_e$ flux for positive and negative beam, respectively.



Conclusions

- The usual plug design $\sim$4 meters downstream of the first horn is useless for off-axis beams.
- There may be some hope of removal of Neck-Focus Kaons by moving the plug closer to or even inside the first horn.
- But, in general, I am not hopeful for a plug helping an off-axis beam.