Effects of Horn Ellipticity on Neutrino Flux

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Abstract

Simulations for the Deep Underground Neutrino Experiment are needed in order to optimize the muon and electron neutrino fluxes at Near and Far detector. Here, we will study the effects of varying the ellipticity of the first focusing horn and analyze the neutrino output at both detectors. Our goal is to maximize the muon neutrino, while lowering the electron neutrino flux.

1. Introduction

The three horn focusing system for the Deep Underground Neutrino Experiment (DUNE) requires an added ellipticity to the inner conductor of the horns for increased rigidness. The maximum ellipticity that can be applied to the inner conductor is 1.0mm, at this point the inner conductor and outer conductor touch and current ceases to flow in the conventional fashion. We begin our study of the ellipticity by applying ten increments ranging from 0.0 to 1.0mm in 0.1mm increments while using 0.0, a perfect circle, as our control. Nominal current is set to approximately 297kA. In studying the effect of ellipticity on neutrino flux, I will study the effects of adding an importance weight to the pions generated. Importance weight is a selection of pions and their energy, by selecting a narrow range of pion energy, valuable processing power from the grid is conserved and used more efficiently on other simulations without affecting the uncertainty in the results. Comparisons of linear fits with polynomial zero along with the calculation of the chi-squared distribution for simulations with and without importance weight will allow us to infer if further simulations will require an importance weight or not.

2. Experimental Setup

These simulations ran with the following parameters:

- 50 runs
- 100,000 Protons on target
- Graphite target
- 0.0,0.25,0.50,0.75 and 1.0mm ellipticity added to horn 1.

3. Data Set

Particle	Ellipticity	Near Detector Integrated Flux	Far Detector Integrated Flux
Muon Neutrino	0.0	0.00196136	2.76994e-10
	0.25	0.00199414	2.80859e-10
	0.50	0.00197262	2.79543e-10
	0.75	0.00196258	2.77459e-10
	1.00	0.00196879	2.79814e-10
Particle	Ellipticity	Near Detector Integrated Flux	Far Detector Integrated Flux
Electron Neutrino	0.0	7.74579e-06	9.77702e-13
	0.25	6.82056e-06	9.2293e-13
	0.50	7.8825e-06	1.05836e-12
	0.75	8.64853e-06	1.13895e-12
	1.00	7.2459e-06	9.67042e-13

Table 1. Neutrino integrated flux values for horn 1 ellipticities with importance weight.

Particle	Ellipticity	Near Detector Integrated Flux	Percent Difference	Far Detector Integrated Flux	Percent Difference
Muon neutrino	0.0	0.00196322	0.094	2.76834e-10	0.057
	0.25	0.00198875	0.271	2.80263e-10	0.212
	0.50	0.00198853	0.638	2.80208e-10	0.219
	0.75	0.00196833	1.305	2.77436e-10	0.008
	1.0	------	-----	------	-----
Particle	Ellipticity	Near Detector Integrated Flux	Percent Difference	Far Detector Integrated Flux	Percent Difference
Electron neutrino	0.0	8.27559e-06	6.837	1.0822e-12	9.656
	0.25	8.25507e-06	2.103	1.06128e-12	13.036
	0.50	8.74551e-06	1.111	1.12381e-12	5.824
	0.75	8.44684e-06	16.57	1.07648e-12	10.173
	1.0	-----	-----	-----	-----

Table 2. Neutrino integrated flux values for horn 1 ellipticity simulations without importance weight and their percent differences as compared to simulations with importance weight.

4. Analysis

Muon neutrino and Electron neutrino integrated fluxes were compared in order to measure the effects of varying the ellipticity assigned to the first focusing horn. The 0.5 – 4.0 energy range for both muon and electron neutrino fluxes were integrated (Figure 1, 2). This is the range where neutrino flux oscillates the least based on the energy given to the incident proton beam and the length between the Near and Far detectors.

$$P_{\upsilon\alpha\rightarrow\upsilon\beta}(L,E) = \frac{1}{2} sin^2 2\vartheta[1-\cos(\frac{\Delta m^2 L}{2E})] \quad (\alpha \neq \beta) \qquad (1)$$

Equation 1. Approximation expression for probability transition between two neutrinos.

The outer conductor is left at a nominal value so that it is a perfect circle surrounding the inner conductor and we compare all integrated fluxes to this value. We can observe that from the five ellipticities chosen, 0.25mm gives the highest muon neutrino flux. In addition, the electron neutrino integrated flux, which is considered background noise has been minimized for the same ellipticity.

The importance weight is associated with the simulation taking into account the pion information about its momentum, path, etc. From tables 1 and 2, we see that given the exact same parameters for the simulations, the change in both neutrino integrated fluxes do change as we increase the ellipticity. This could yield important variations for integrated flux if we kept on increasing the ellipticity, however the inner conductor of the first focusing horn as an upper limit, which is for this case 1.0mm. From this data, we conclude that continuing simulations with muon neutrino importance set to false would only take more processing time for almost no change in the simulations. However, in analyzing the electron neutrino flux, simulations without importance weight yielded data with higher percent differences as compared to data with importance weight.

5. Results

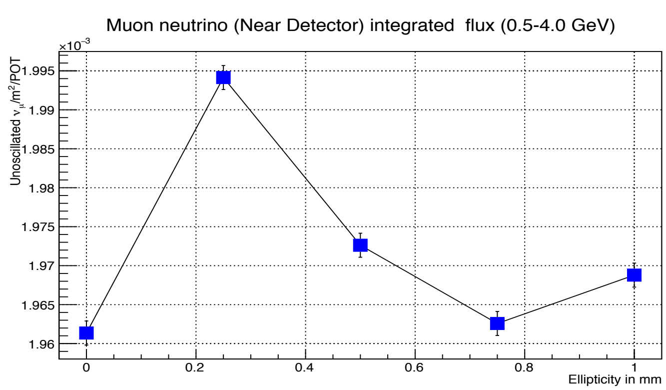

Figure 1. Integrated flux for muon and electron neutrino particles with importance weight.

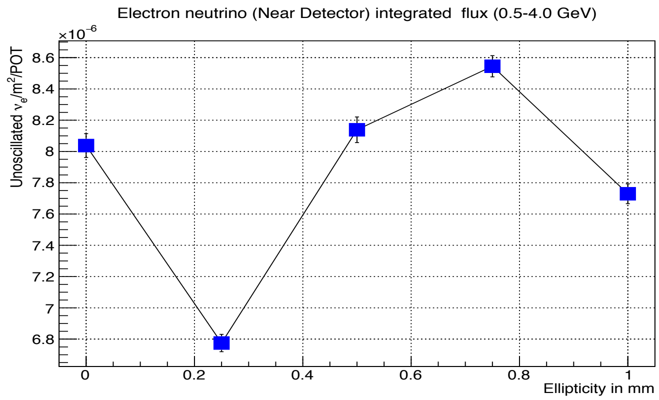

Figure 2. Integrated flux for muon and electron neutrino particles without importance weight.

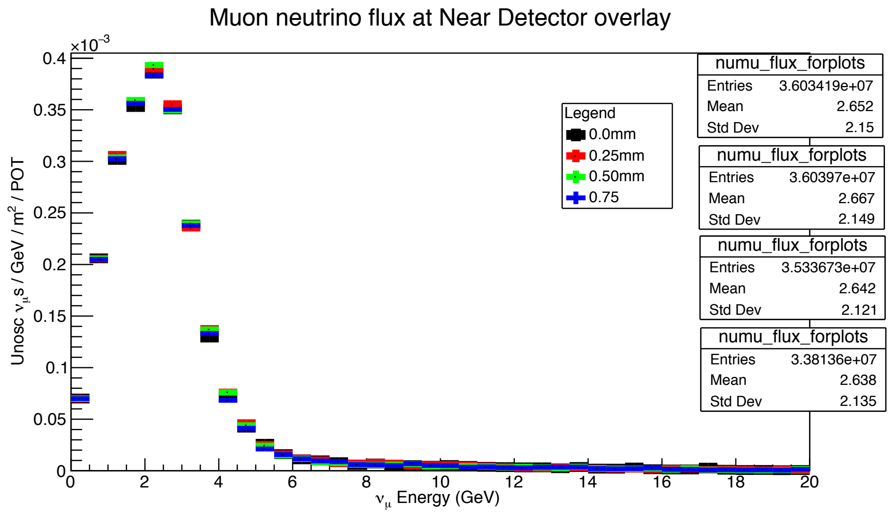

Figure 3. Muon neutrino flux overlay.

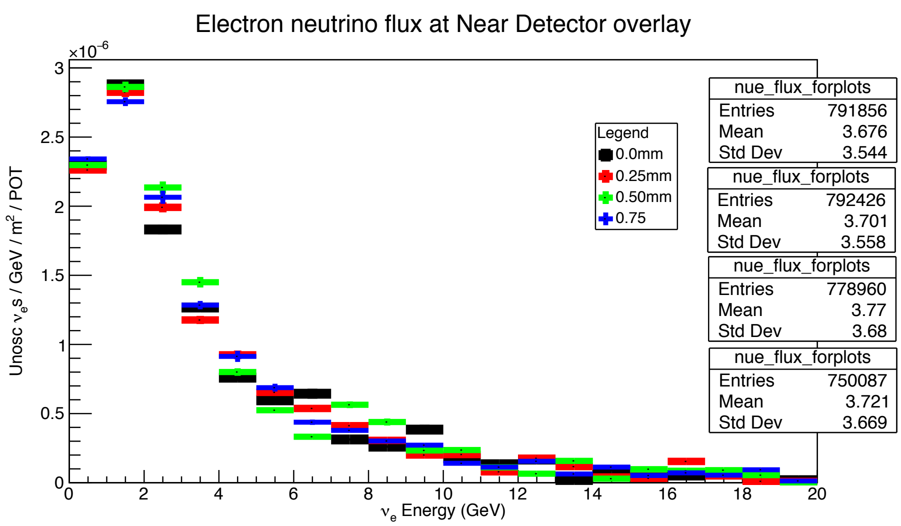

Figure 4. Electron neutrino flux overlay.

6. Conclusions and Future work

For our future work, we hope to neglect the use of importance weight for upcoming simulations in order to save processing power as well as time. The results for our ellipticity for the first focusing horn gave best results for an added 0.25mm ellipticity due to increase in muon neutrino flux as well as lowering our electron neutrino flux.

7. Bibliography

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