Nominal and Optimized Beam Study at Near and Far Detectors from DUNE Experiment

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Kim Truc Nguyen
High Energy Physics Group
Department of Physics
The University of Texas at Arlington

Abstract

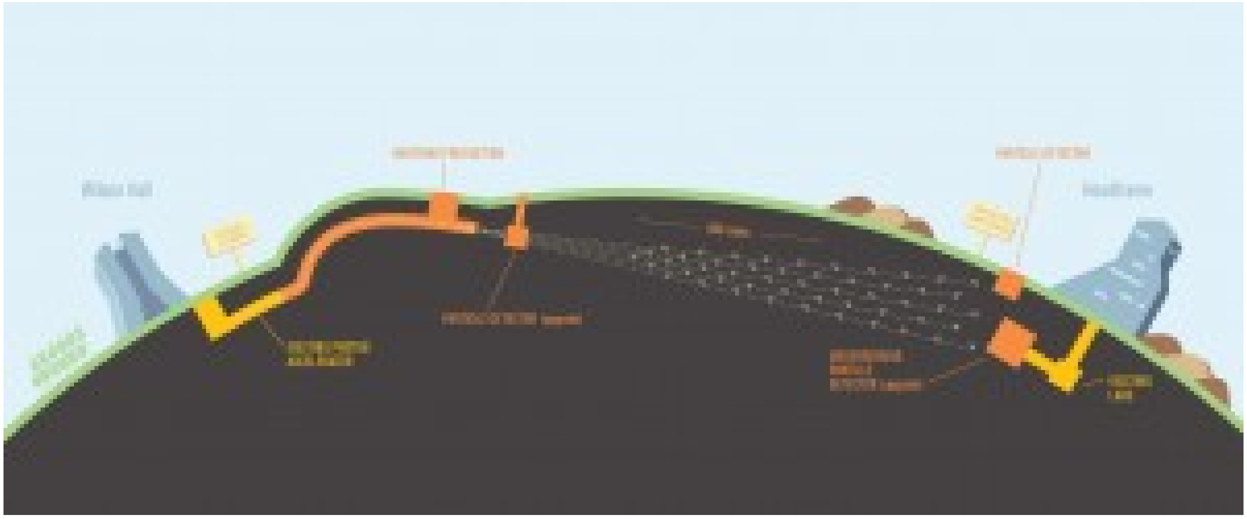
The main objective of the study was about generating the nominal neutrino flux then apply different methods such as making overlay and ratio graphs to compare with the flux generated from other students. The research also focused on detecting the neutrino flux from the detector with different optimization methods to determine how each changes can affect the virtual machine and how different their results would be from the original machine. Besides generating different fluxes from the nominal, the main objective of the optimization study was to maximize the amount of neutrino flux detected at each detector by minimizing the amount of anti-particles detected through the machine. There are many contributing factors to the detected neutrino flux, yet the main focus for now was to determine the current that could generate the most particles, also the least anti-particles running from the background.

1. Introduction

This note would focus about optimizing the original neutrino beam in order to attain the optimal neutrino results from the DUNE experiment. There would be many features involved in order to alter the beam in certain ways that would yield the best neutrino flux with most of the background particles minimized.

The neutrino flux beam-line would consist of the beam source, first and second horns, the near and far detectors, and a decay-pipe. When proper current was applied, a flux would be generated in which a particle would be shoot from the source, then went through the decay-pipe and would be subsequently detected at the first and second detectors. The beam machine also contained the first and second horn. Neutrino flux would be the main concern of the machine, yet other particles would also be detected at each horn then would soon be refracted by the decay pipe, leaving only neutrino flux went through the near and far detectors.

Figure 1 General Structure for Deep Underground Neutrino Experiment (DUNE)



2. Experimental Setup

The first half of the research focused on generating another flux files and compare it with the original one. The main concern from both original and newly generated flux files would be around the position of the horn one, horn two, the near and far detectors, the decay-pipe, and finally the target. One of the best way to compare both flux files was to overlay one histogram from one file onto a corresponding histogram from the other file. Then a ratio plot would be taken between both histograms in which the plot shall yield a straight line around one to indicate the similarity between both histograms.

The main purpose of the remaining portion of the experiment would focus on the optimization study of the nominal beam in order to detect the most optimal conditions in neutrino flux generation. There are many variables that would be useful to generate the optimization of beam, such as changing current, the lengths of horn one and horn two, or rescaling the whole nominal flux files, etc. For now, the study would only focus on detecting the optimal current for beam simulation.

3. Data Set

3.1 Nominal flux beam data set

As the new flux file was generated based on the original nominal flux, the parameters used were 100,000 protons on target, the current applied was 298 kA, 50 jobs were submitted, and the flux was observed at the first and second horns, the near and far detectors, and the decay-pipe.

3.2 Optimized beam data set

Applied the same parameter as nominal neutrino flux beam, the optimized beam would have the parameter of 100,000 protons on target with different current applied, then compared with the nominal current of 298 kA. The optimized beam study only focused on comparing the flux at different currents for now, yet it would soon be expanded out for further analysis. However, the optimized beam study would still be focused at the same position of nominal flux study, in which the first and second horns, the near and far detector, and the decay-pipe would be the main concern.

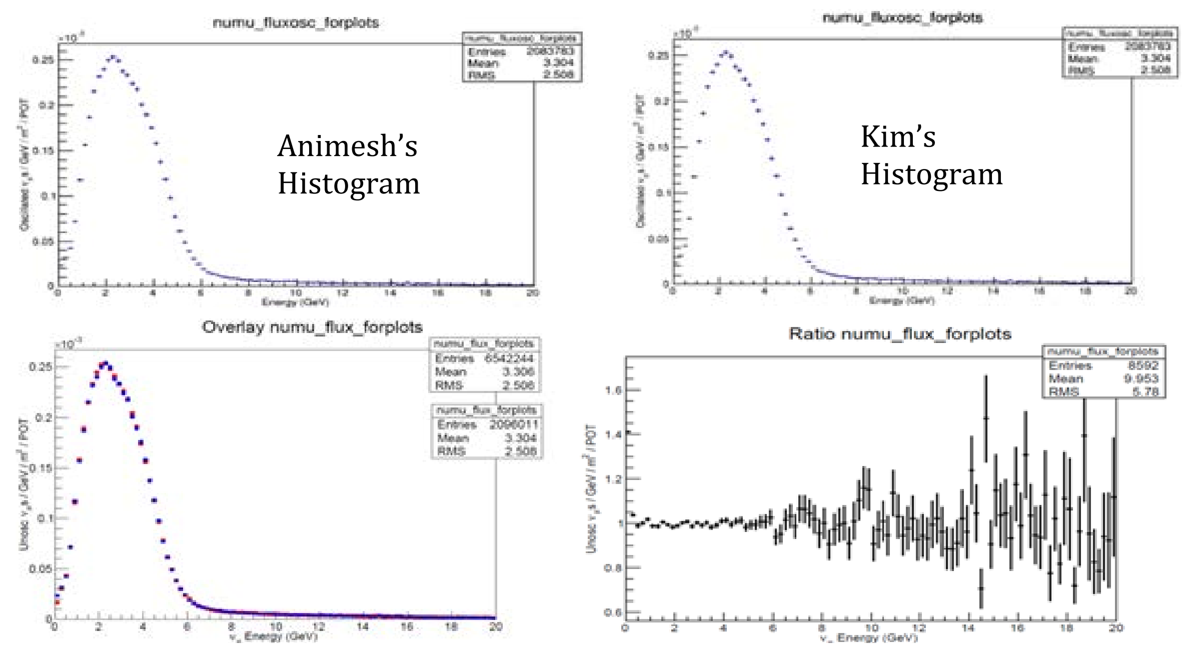
4. Analysis

4.1 Nominal flux beam data analysis

In order to analyze the data, the generated flux would be plotted using the software Root in order to show how the data fluctuated at different energy levels. The best method to make a comparison between the original and the newly-generated nominal flux would be to overlay them on the same graph, then take a ratio between them.

As the new nominal flux represented the same data set as the original data set, the overlay plots of these histogram were almost identical to each other. Each histogram was color coded as blue and red for the ease of identification, yet the result indicated a merging of these histograms that was difficult to identify one plot from another. For the ratio plots, although the result did not yield a straight line at one, the plot indeed fluctuated around this line with higher error bars when more energy was applied.

4.2



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Unlike nominal flux, the overlay graphs of these optimized beam show a significant differences between each changes from the original histograms. From the results taken at the current of 230 kA, 288 kA, and 298 kA, the highest current was capable of generating more particles (figure 3). Although there was less anti-particles detected from all the applied currents, the amount of anti-particles detected was still considered significantly high and other methods need to be applied to minimize the amount of anti-particles. These histograms also had small error bars at low energy, then they slowly increased at higher energy thus indicated more fluctuation.

In order to minimize the amount of anti-particle generated, a shield was then installed in the machine. Then generate the plot of all the particles distribution and the neutrino flux detection for comparison purpose (figure 4). Taken from the generated flux of near detector at 288 kA, the particle's location plot showed a wider range of distribution, yet there were less anti-particle detected at higher energy. The neutrino flux distribution also had similar pattern in which less anti-particles detected than particle, although both graphs had peaks around 2 GeV, there was still significantly smaller amount of anti-particles detected.

Figure 3 Optimized Neutrino Beam at 230 kA, 268 kA, and 288 kA

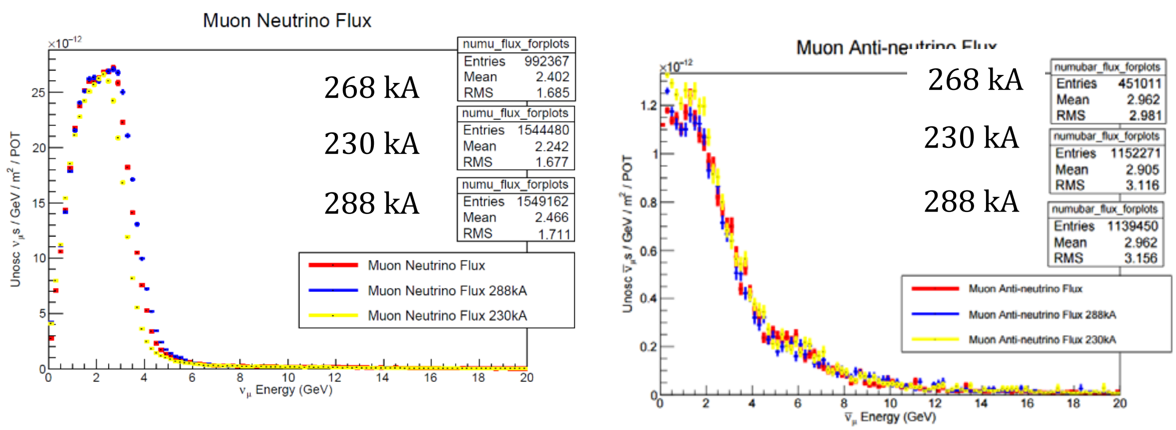
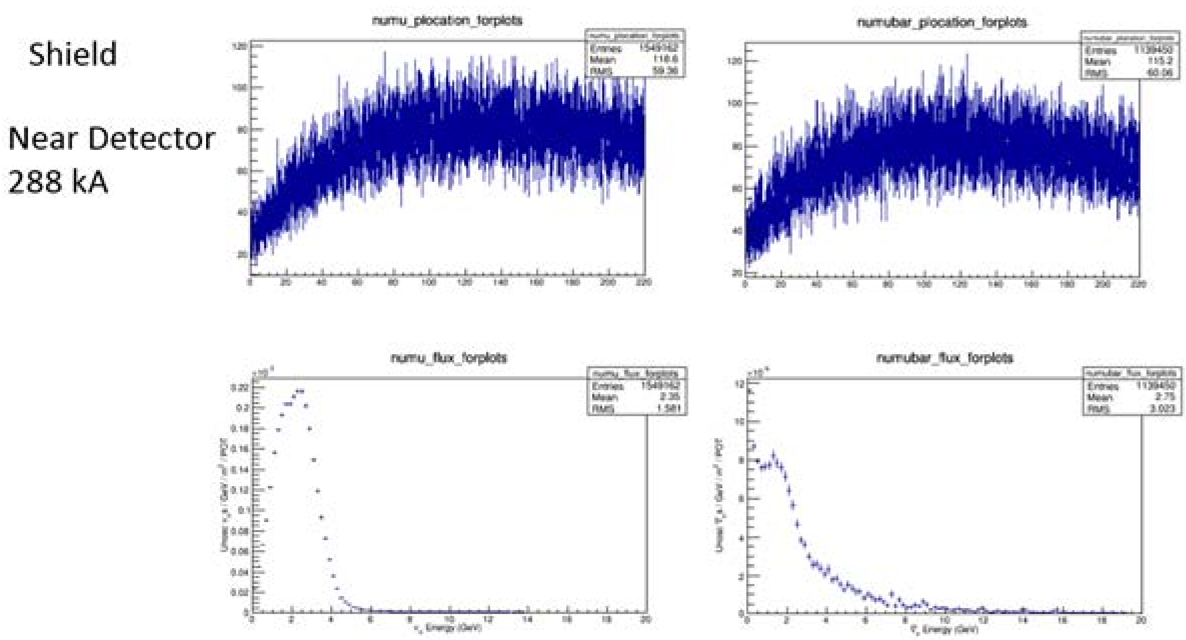


Figure 4 Particle Location and Neutrino Distribution at Near Detector, with shield on at 288 kA



5. Results and interpretations

In order to show the genuine relationship between the new-generated flux files with the original one, the histograms between each files were plotted overlay on top one another. The result of these overlay histograms indicated that the new flux files had a high similarity rate with the original one as their histograms were perfectly fit on top each other. Another method which could also detect the similarities between both flux files would be making the ratio plot. As the histogram of the new flux files was divided with the original flux files, an indicator of the genuine characteristics of both histograms would the ratio graph would fluctuate around the line at one indicated on the y-axis.

The optimization study was also applied with the same method in which the optimized beam was generated then plotted overlay on top with the nominal beam, then a ratio plot was taken to exhibit the relationship between two beams. The first optimized study with changes in applied current at 288 kA compared with the nominal flux at 298 kA with the parameters of 100,000 protons on target, there were fifty jobs submitted, and both were taken at the near detector. The study focused on different particles observed at the near detector, but the same method could be applied at different beam locations. Unlike the flux generated from the same nominal flux, the optimized beam had some distinct differences. As at least one alteration was applied for each optimized beam study, thus the overlay plots between this beam and the nominal beam would not be genuine, also the differences were indicated in the ratio plot with some fluctuation around the line at one on y-axis. As the ratio plots for each flux beam always fluctuated around one, an observation can be detected that at higher energy applied, the plots would be more statistically different with higher error bars.

6. Conclusions and future work

The main concern of this experiment was to compare the newly-generated histograms with the reference ones from the near and far detector, the first and second horn, the target and the decay-pipe. Although both files were generated from the same source and parameter, the result still indicated some deviations from one another. One of the main concern that might explain for this incidence was due to background noise and other particles that somehow defected the neutrino flux from being detected. The experiment also focused on beam optimization in which different changes were applied to the nominal beam to determine the optimal conditions for neutrino detecting. For future references, more alterations at the beam would be applied to detect the optimal conditions for beam simulation on top with beam current.

7. Bibliography

1. J. Huber and K. Jepsen, “The dawn of DUNE,” Quantum Diaries. Fermilab, 2015. Web. 22 Aug.2015