

Near Detector Neutrino Flux with Horn/Current Configurations

9th January 2019 / University of Warwick / DUNE ND Meeting

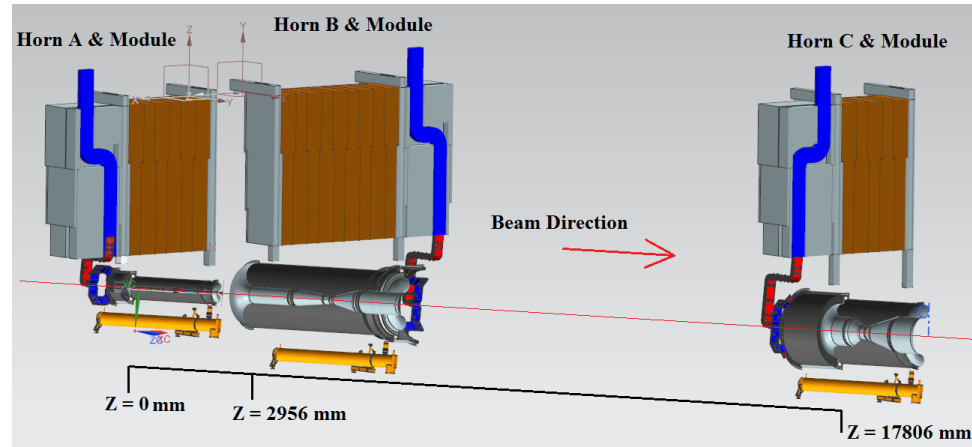
Motivation



Cross-section Calibration

- Accurate reconstruction of true neutrino energy is difficult due to uncertainties from missing energy due to low energy hadrons and unseen neutrals.
- Without a well-defined incoming neutrino beam energy, extrapolation to Far Detector without good calibration / well-known ν cross-sections is limited.
- Near Detector cross-section and flux measurements would benefit from some restriction of the wide-band neutrino beam to a more well-defined neutrino energy.

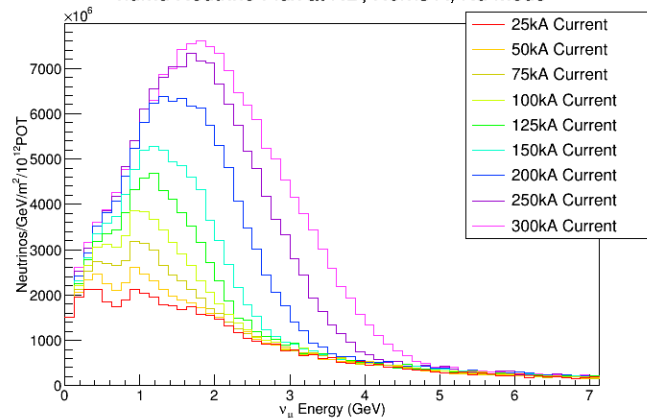
Concept



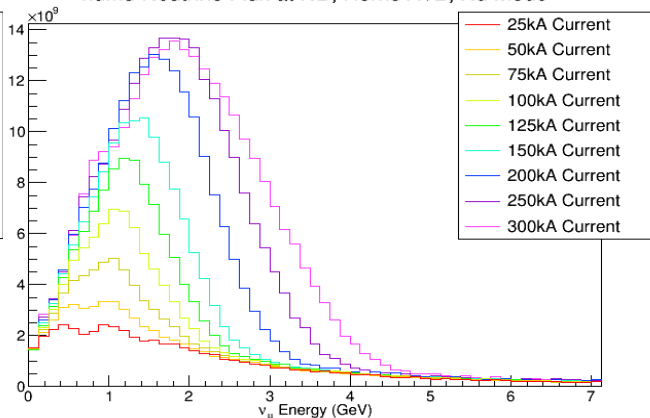
- Horn currents and configurations can be varied, with caveat all powered horns need operate on the same current value as horns are connected in series.
- Consider 5 options in configuration: A only, A+B, A+C, B+C, and A+B+C
- Tune-ability of numu flux over range of current and configuration settings is shown in the following slides

NuMu Fluxes On-Axis

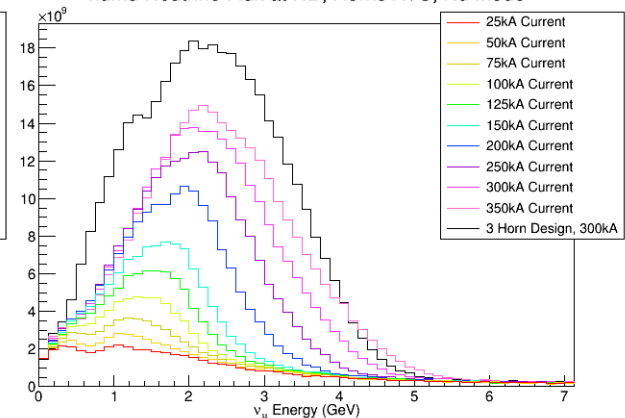
numu Neutrino Flux at ND, Horns A, Nu Mode



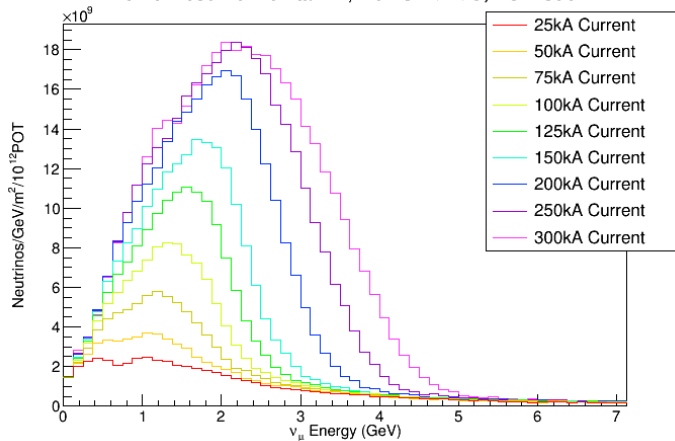
numu Neutrino Flux at ND, Horns A+B, Nu Mode



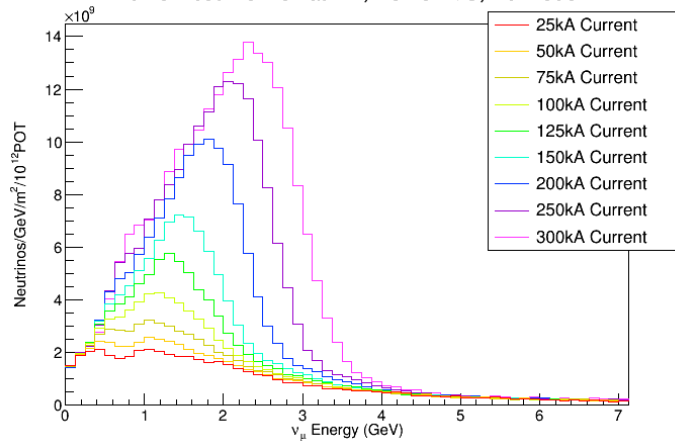
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode

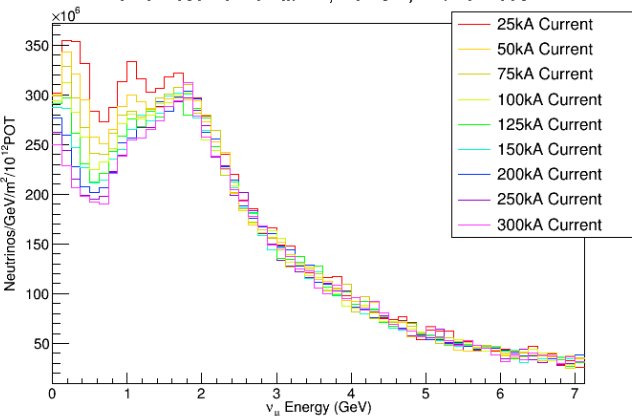


numu Neutrino Flux at ND, Horns B+C, Nu Mode

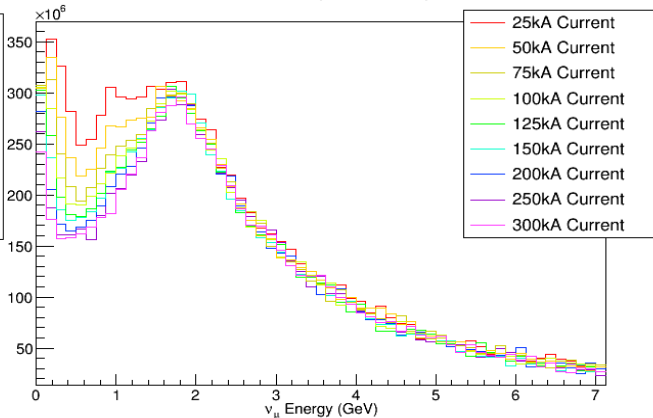


NuMu Fluxes On-Axis

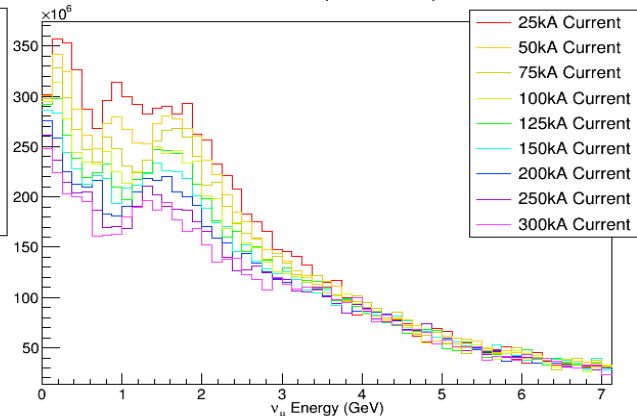
numu Neutrino Flux at ND, Horns A, AntiNu Mode



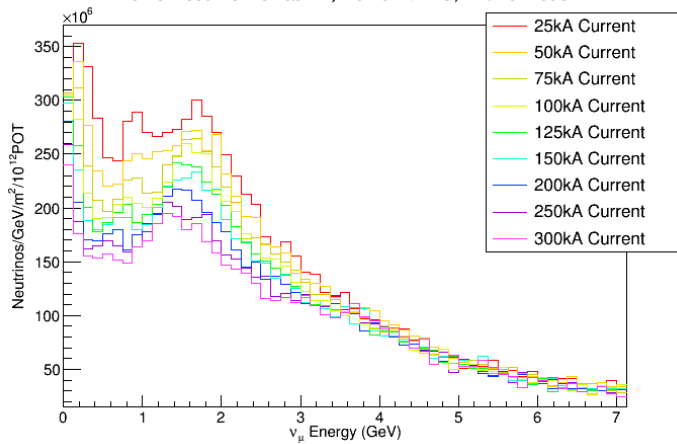
numu Neutrino Flux at ND, Horns A+B, AntiNu Mode



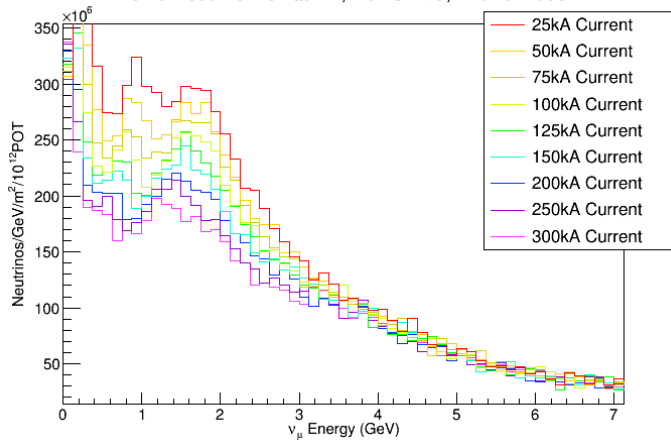
numu Neutrino Flux at ND, Horns A+C, AntiNu Mode



numu Neutrino Flux at ND, Horns A+B+C, AntiNu Mode



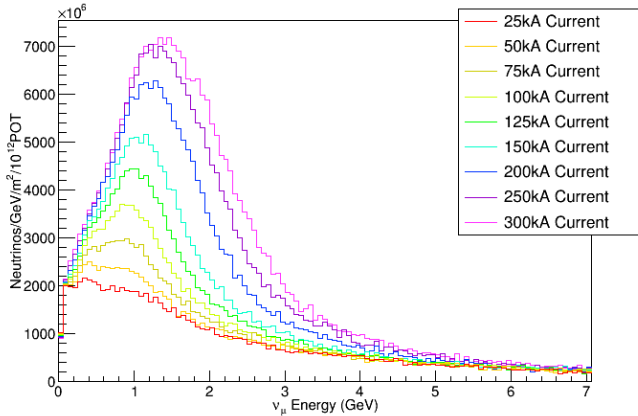
numu Neutrino Flux at ND, Horns B+C, AntiNu Mode



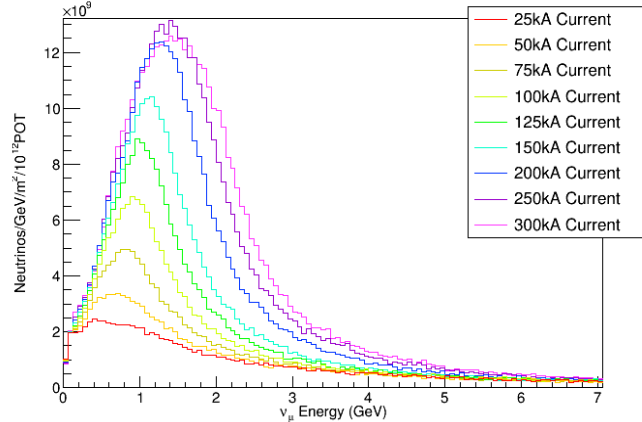
Off-Axis Fluxes

NuMu Fluxes 6m

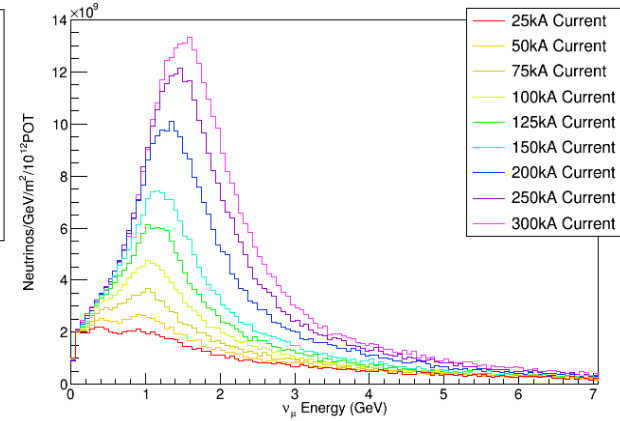
numu Neutrino Flux at ND, Horns A, Nu Mode



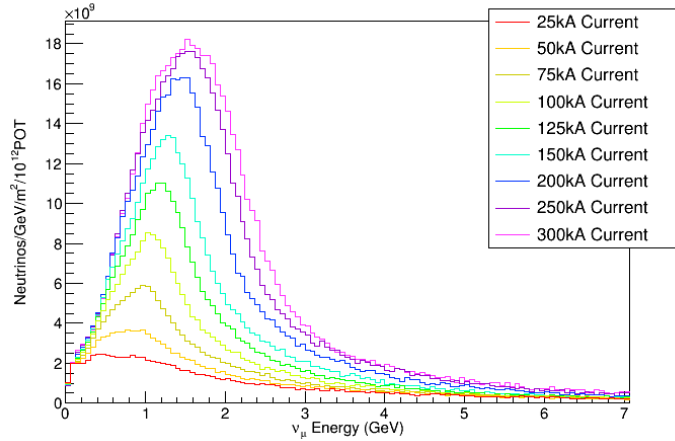
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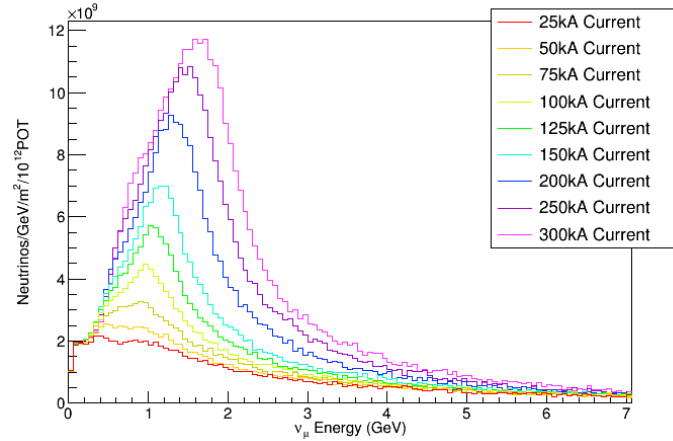
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode

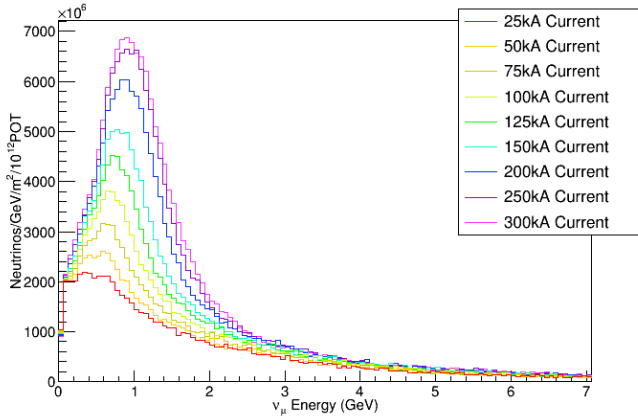


numu Neutrino Flux at ND, Horns B+C, Nu Mode

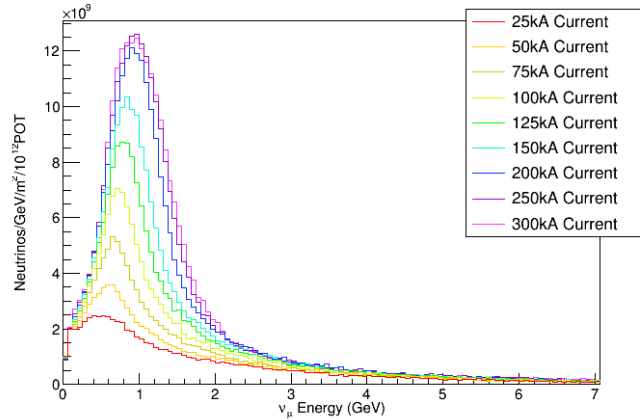


NuMu Fluxes 12m

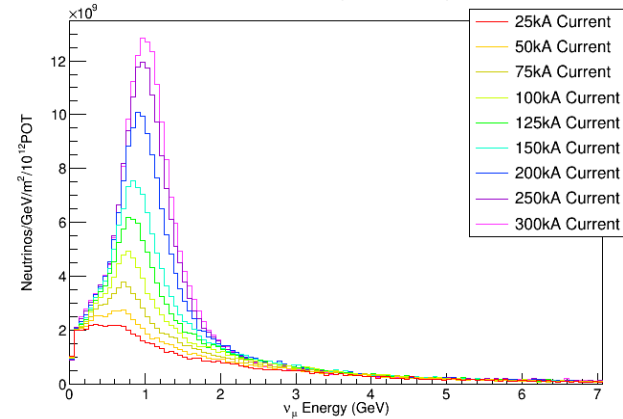
numu Neutrino Flux at ND, Horns A, Nu Mode



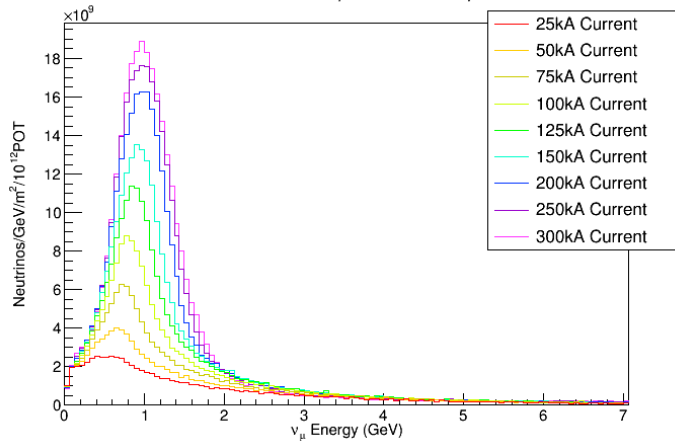
numu Neutrino Flux at ND, Horns A+B, Nu Mode



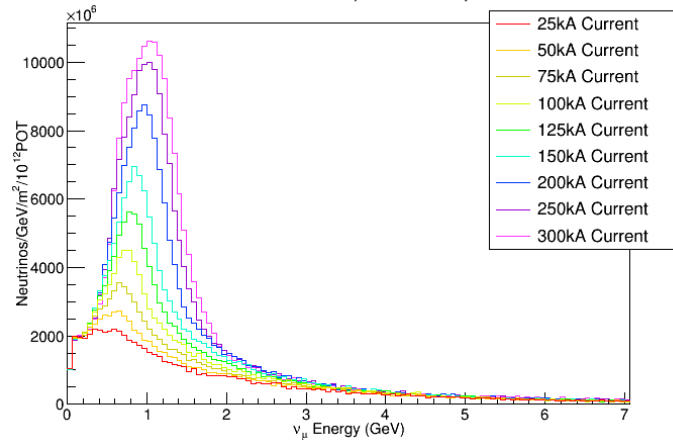
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode

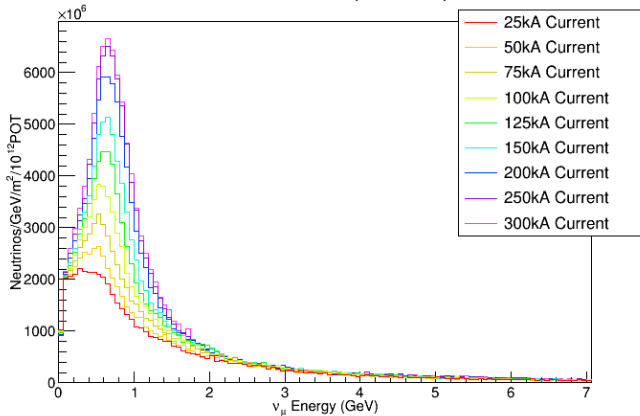


numu Neutrino Flux at ND, Horns B+C, Nu Mode

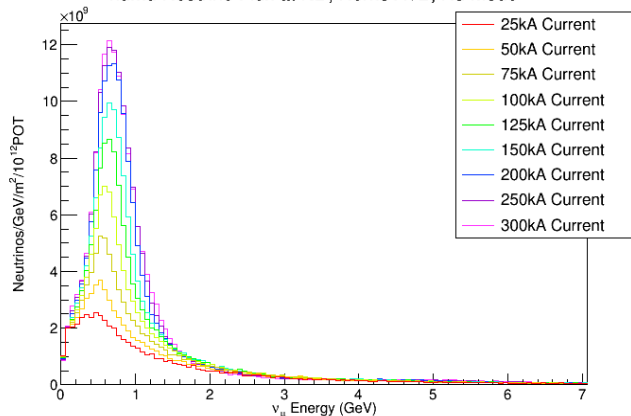


NuMu Fluxes 18m

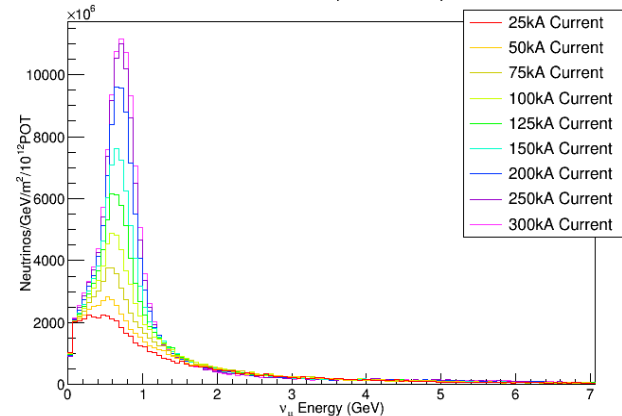
numu Neutrino Flux at ND, Horns A, Nu Mode



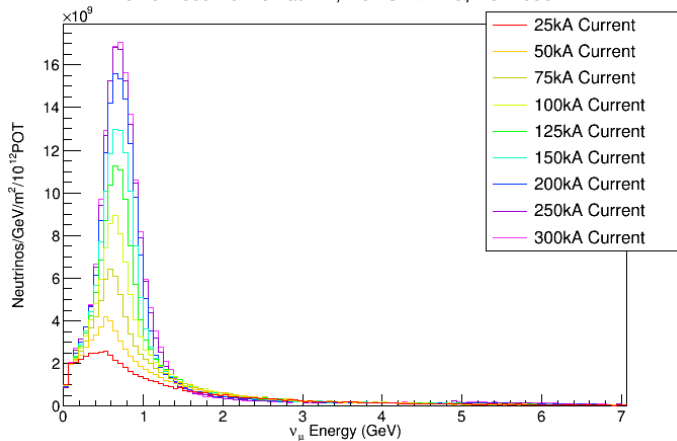
numu Neutrino Flux at ND, Horns A+B, Nu Mode



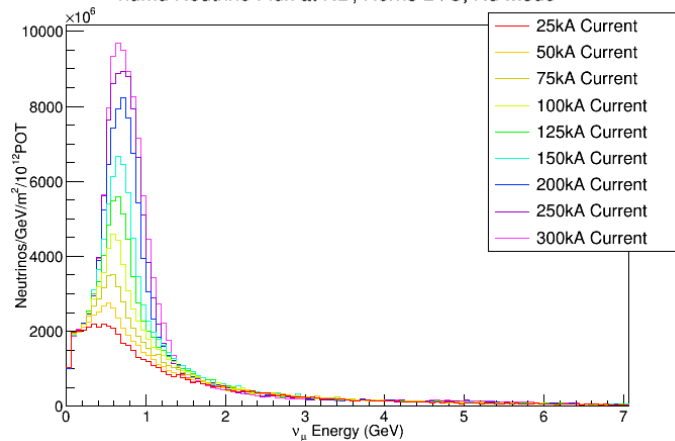
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode

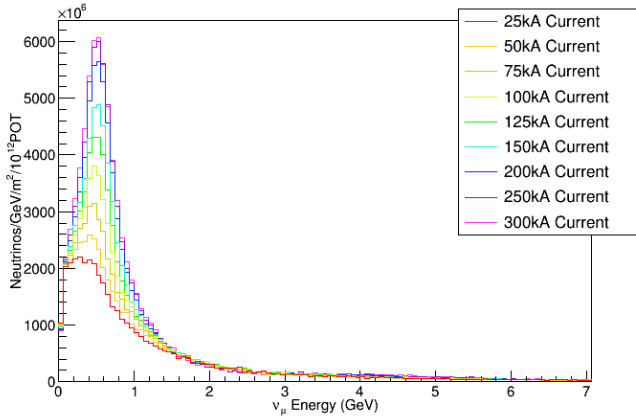


numu Neutrino Flux at ND, Horns B+C, Nu Mode

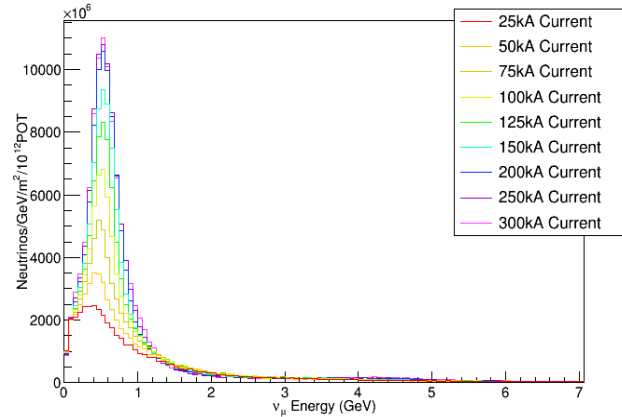


NuMu Fluxes 24m

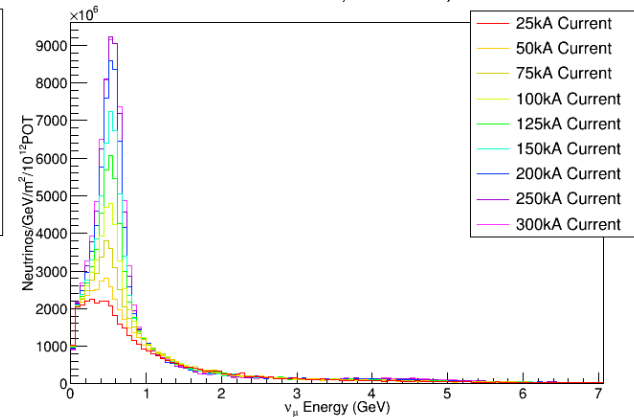
numu Neutrino Flux at ND, Horns A, Nu Mode



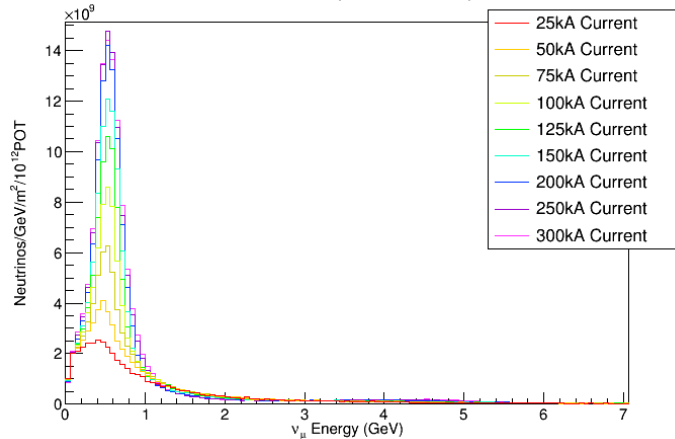
numu Neutrino Flux at ND, Horns A+B, Nu Mode



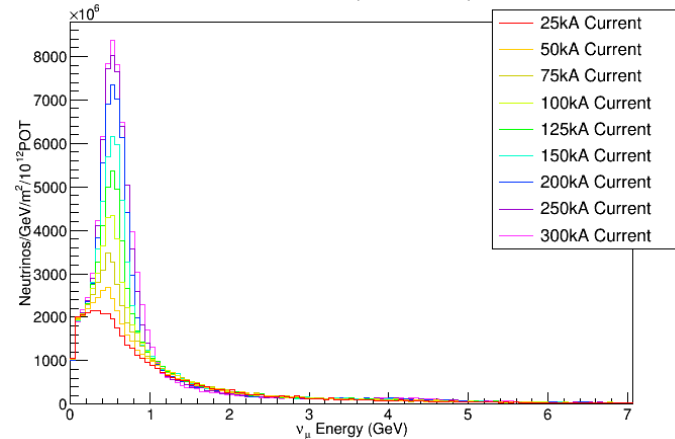
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode

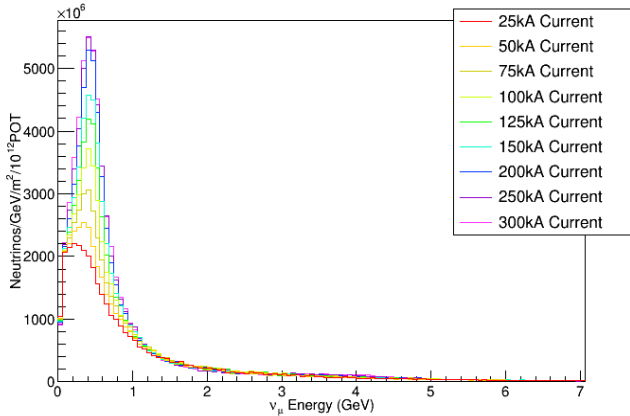


numu Neutrino Flux at ND, Horns B+C, Nu Mode

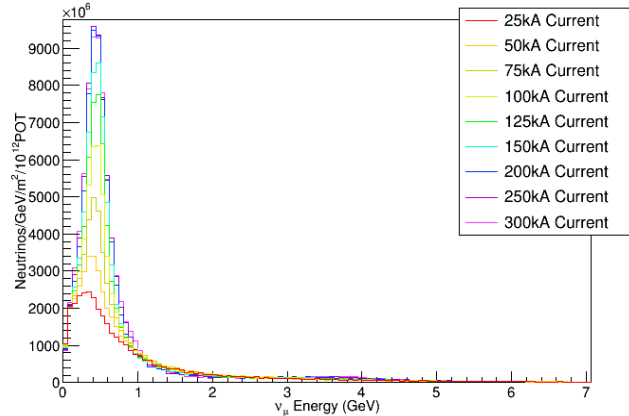


NuMu Fluxes 30m

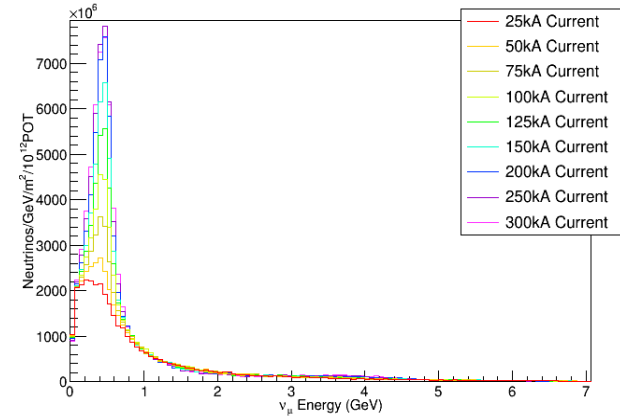
numu Neutrino Flux at ND, Horns A, Nu Mode



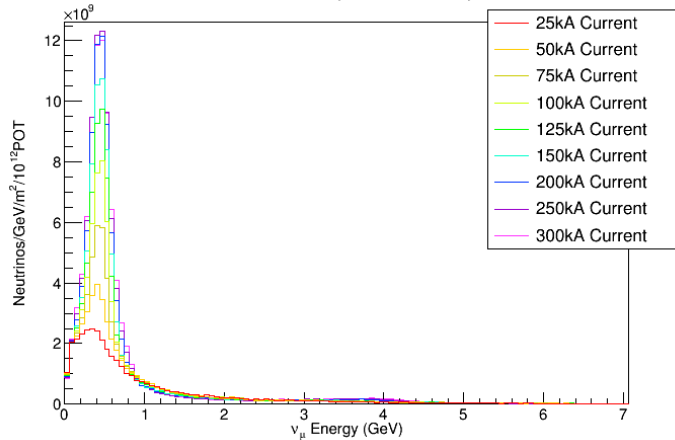
numu Neutrino Flux at ND, Horns A+B, Nu Mode



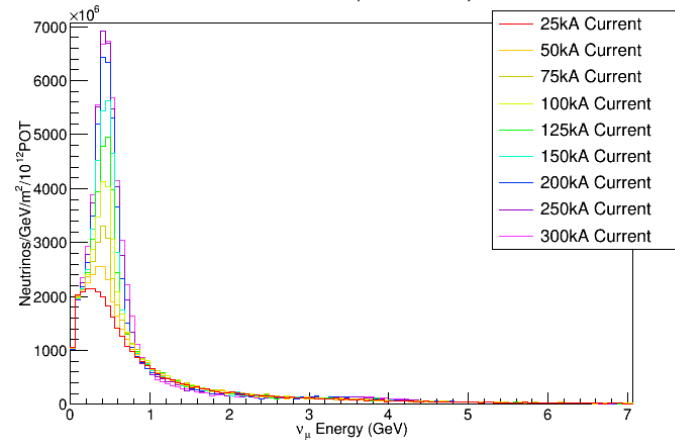
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode

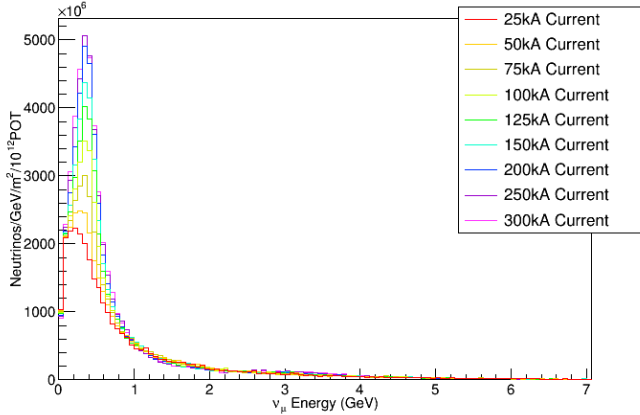


numu Neutrino Flux at ND, Horns B+C, Nu Mode

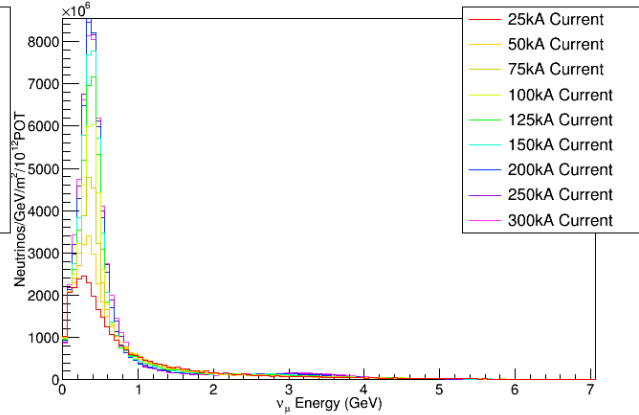


NuMu Fluxes 36m

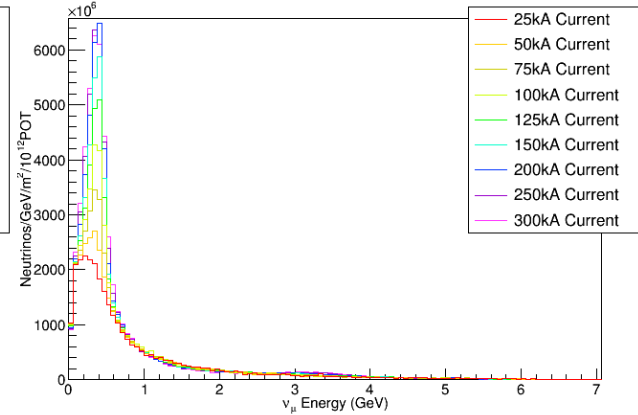
numu Neutrino Flux at ND, Horns A, Nu Mode



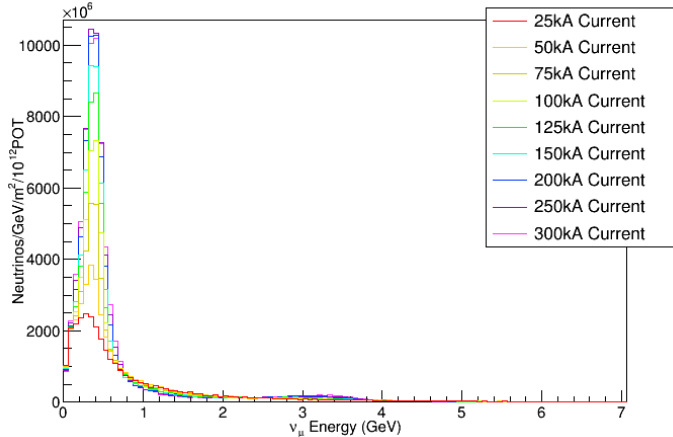
numu Neutrino Flux at ND, Horns A+B, Nu Mode



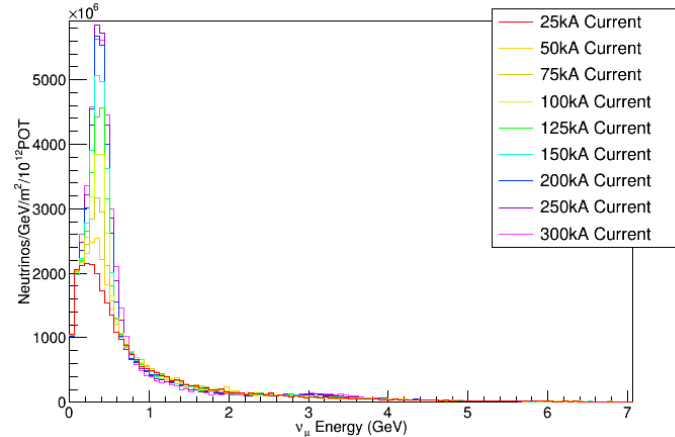
numu Neutrino Flux at ND, Horns A+C, Nu Mode



numu Neutrino Flux at ND, Horns A+B+C, Nu Mode



numu Neutrino Flux at ND, Horns B+C, Nu Mode





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Linear Combination Fit



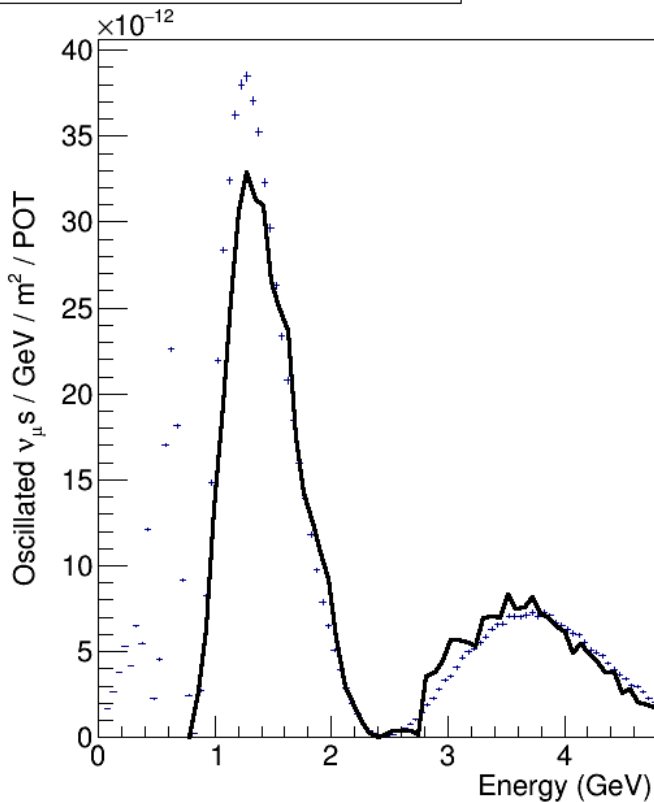
A linear combination of these ND neutrino fluxes can be superposed to fit a number of functions.

- Fits to FD oscillated flux
- Fits to several gaussian flux bites

Linear Combination Fit

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numu_fluxosc_forplots



numu_fluxosc_forplots

Entries	540805
Mean	2.1
Std Dev	1.543
0N3001	0.3014 ± 0.0015
0N3002	-0.1717 ± 0.0005
0N3004	0.01033 ± 0.00031
0N0752	-0.3151 ± 0.0014
0N1252	0.2271 ± 0.0014
0N1254	-0.08153 ± 0.00067
0N1505	0.0954 ± 0.0014

7 param fit

Range – 0.75 – 7.75GeV

• XMYYYZ
0-6 - Distance Off-Axis (x 6 metres)
N/A - NuMode / AntiNuMode
YYY = current
Z = Horn Config
1 - A
2 - A+B
3 - A+C
4 - A+B+C
5 - B+C

Linear Combination Fit

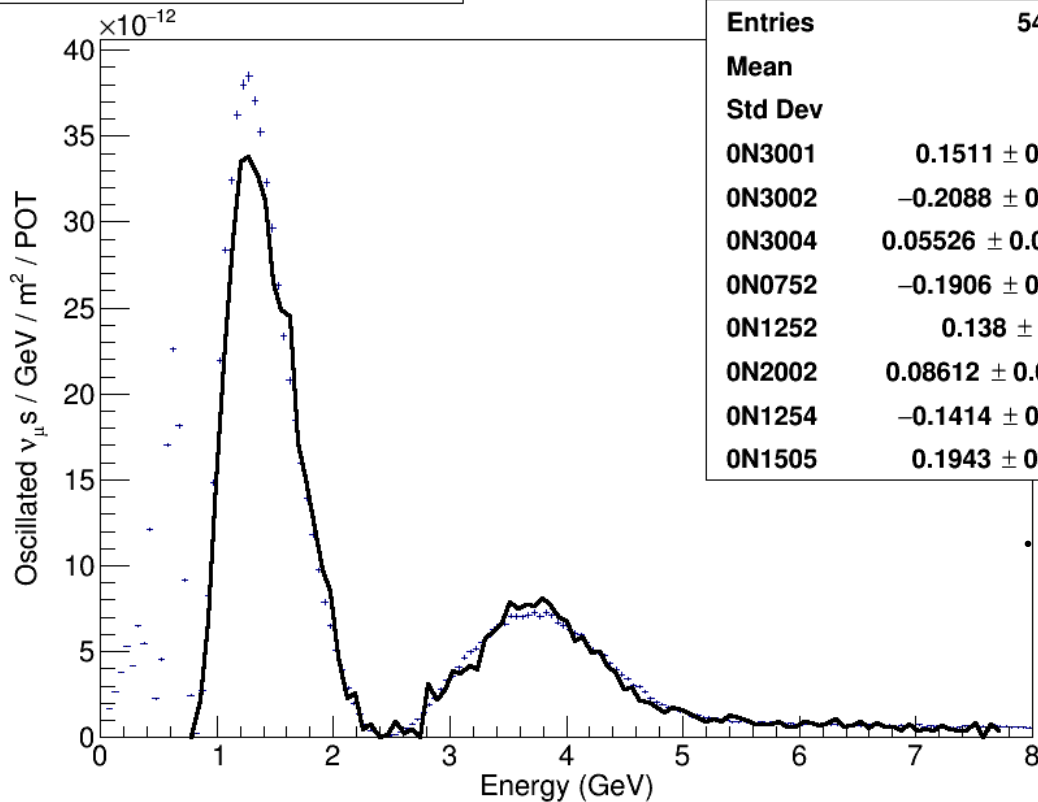
numu_fluxosc_forplots

numu_fluxosc_forplots

Entries	540805
Mean	2.1
Std Dev	1.543
0N3001	0.1511 ± 0.0022
0N3002	-0.2088 ± 0.0006
0N3004	0.05526 ± 0.00057
0N0752	-0.1906 ± 0.0019
0N1252	0.138 ± 0.002
0N2002	0.08612 ± 0.00091
0N1254	-0.1414 ± 0.0009
0N1505	0.1943 ± 0.0017

8 param fit

Range – 0.75 – 7.75GeV



XMYYZ
0-6 - Distance Off-Axis (x 6 metres)
N/A - NuMode / AntiNuMode
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Linear Combination Fit

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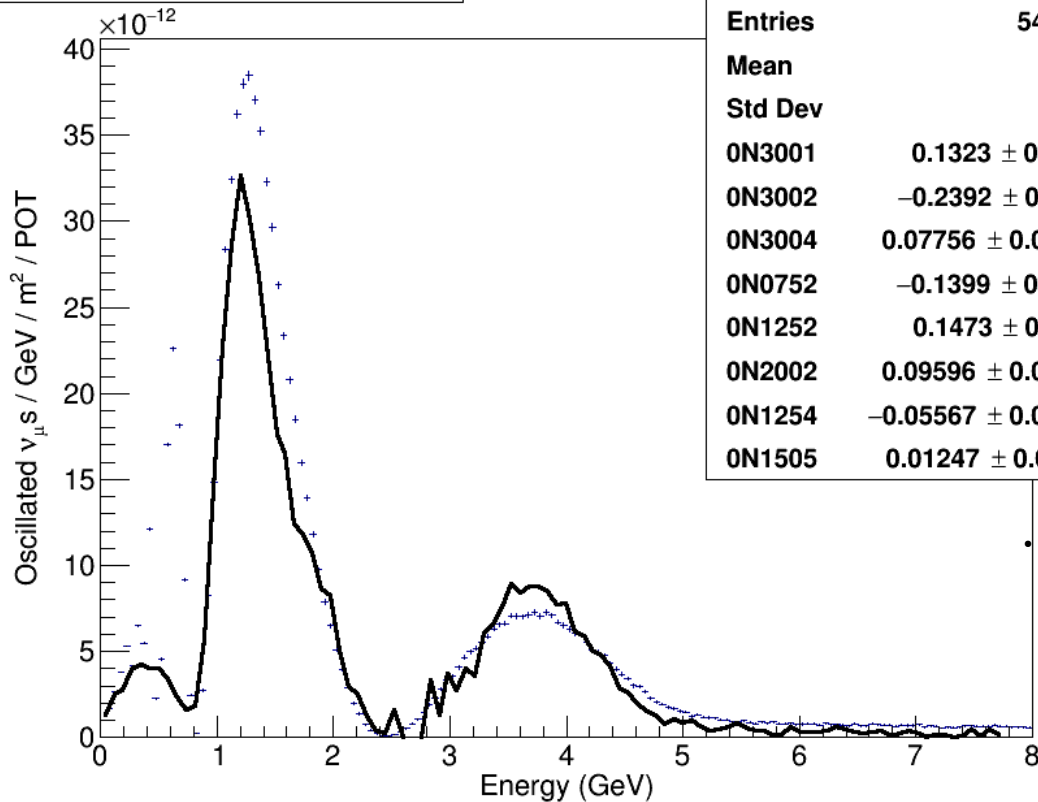
numu_fluxosc_forplots

numu_fluxosc_forplots

8 param fit

Range – 0.0 – 7.75GeV

Entries	540805
Mean	2.1
Std Dev	1.543
0N3001	0.1323 ± 0.0004
0N3002	-0.2392 ± 0.0006
0N3004	0.07756 ± 0.00024
0N0752	-0.1399 ± 0.0007
0N1252	0.1473 ± 0.0006
0N2002	0.09596 ± 0.00059
0N1254	-0.05567 ± 0.00073
0N1505	0.01247 ± 0.00041



XMYYZ
0-6 - Distance Off-Axis (x 6 metres)
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YYY = current
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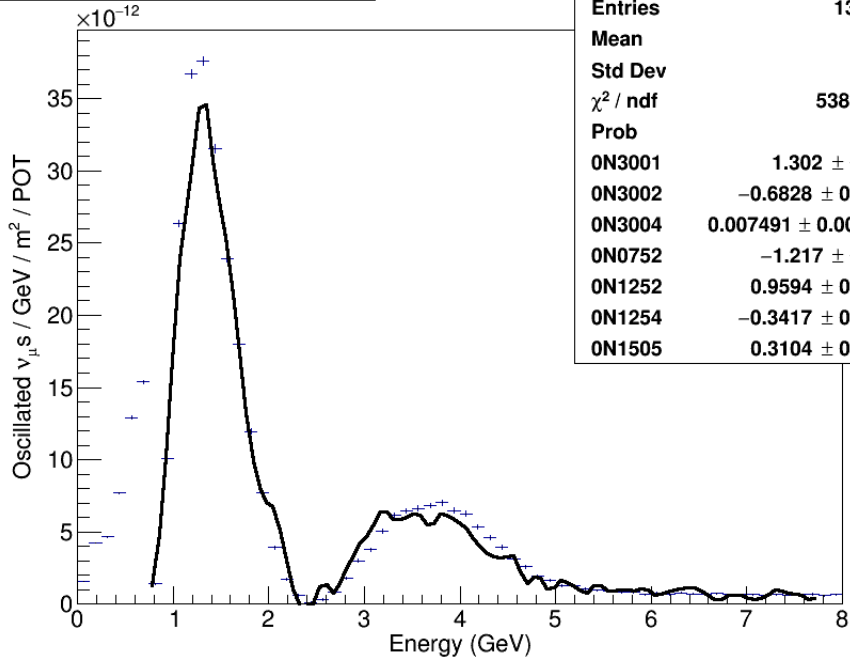
DUNE PRISM vs Horn Configs

WARWICK

XMYYYZ
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 1 - A
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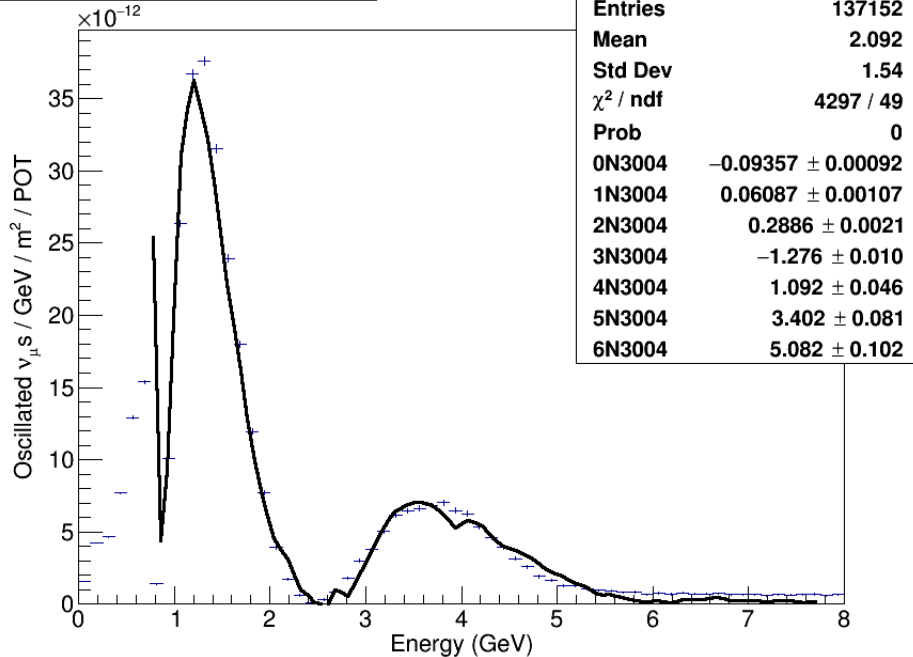
Horn Configs - 7 params

numu_fluxosc_forplots



DUNE PRISM

numu_fluxosc_forplots



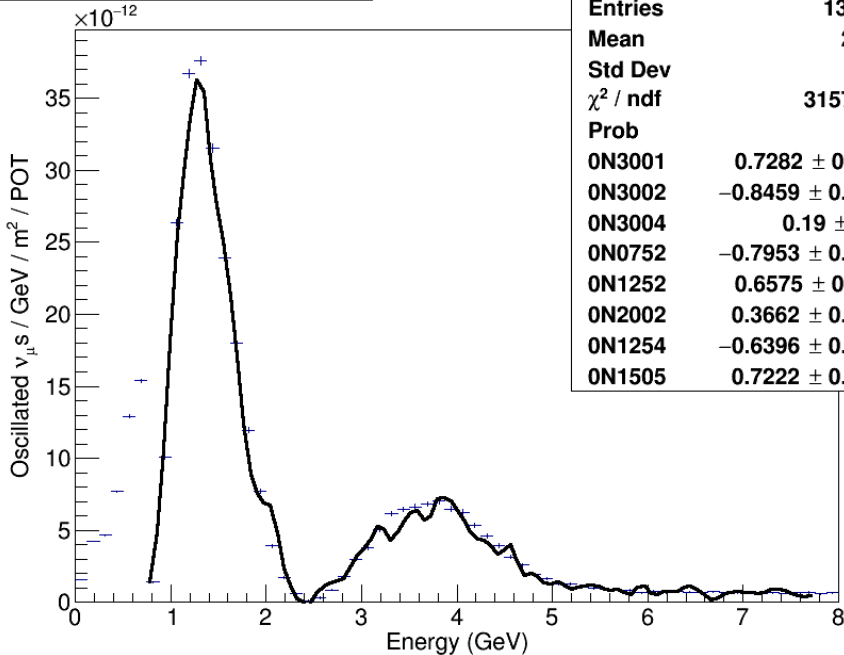
DUNE PRISM vs Horn Configs

WARWICK

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Horn Configs - 8 params

numu_fluxosc_forplots

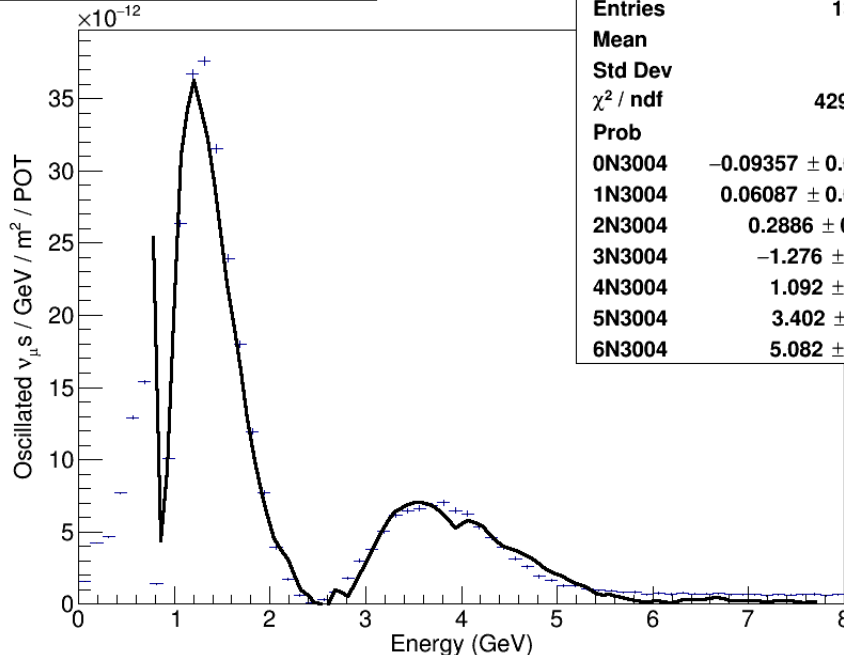


numu_fluxosc_forplots

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	3157 / 48
Prob	0
0N3001	0.7282 ± 0.0171
0N3002	-0.8459 ± 0.0057
0N3004	0.19 ± 0.00
0N0752	-0.7953 ± 0.0136
0N1252	0.6575 ± 0.0121
0N2002	0.3662 ± 0.0078
0N1254	-0.6396 ± 0.0085
0N1505	0.7222 ± 0.0139

DUNE PRISM

numu_fluxosc_forplots



numu_fluxosc_forplots

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	4297 / 49
Prob	0
0N3004	-0.09357 ± 0.00092
1N3004	0.06087 ± 0.00107
2N3004	0.2886 ± 0.0021
3N3004	-1.276 ± 0.010
4N3004	1.092 ± 0.046
5N3004	3.402 ± 0.081
6N3004	5.082 ± 0.102

DUNE PRISM vs Horn Configs

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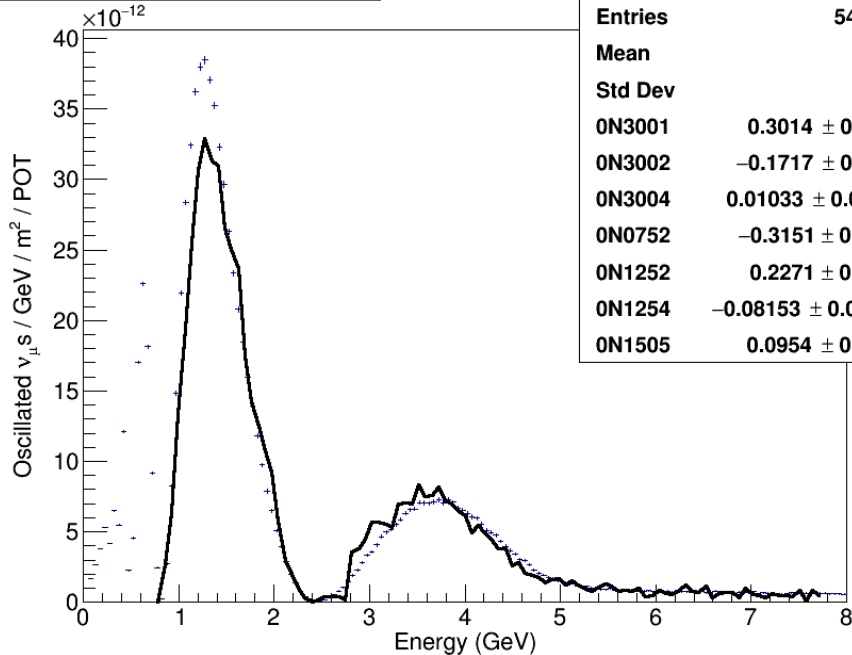
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Horn Configs – 7 params

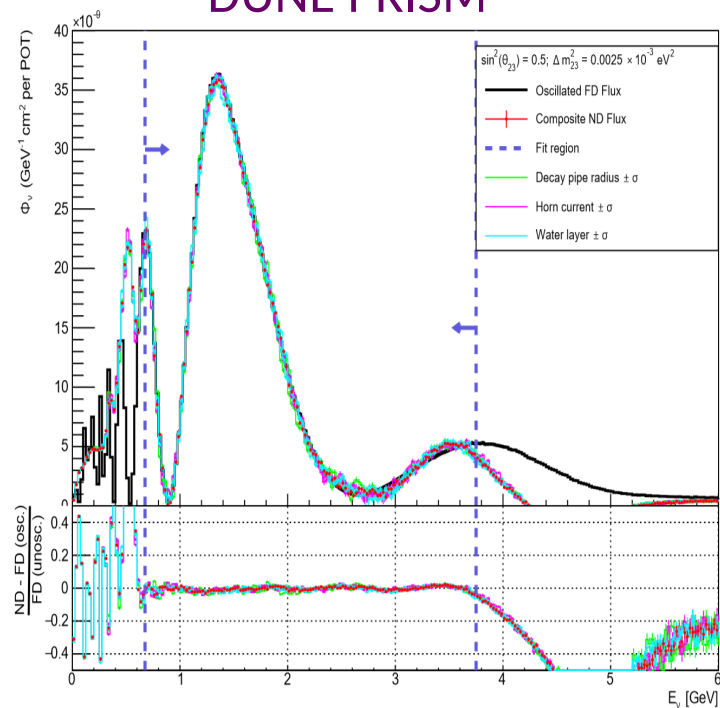
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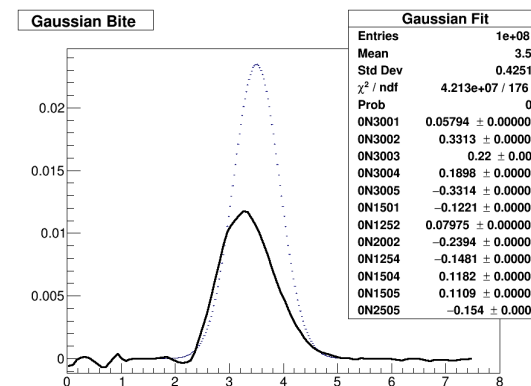
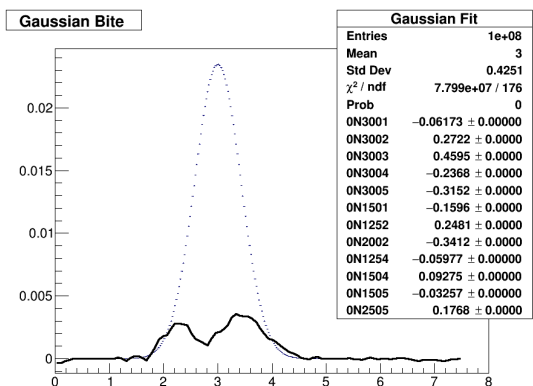
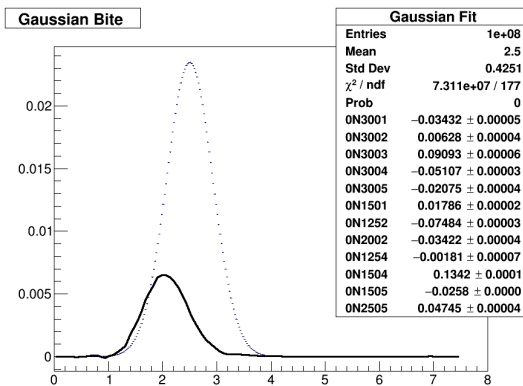
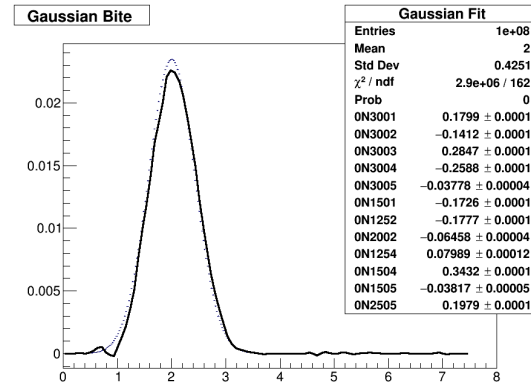
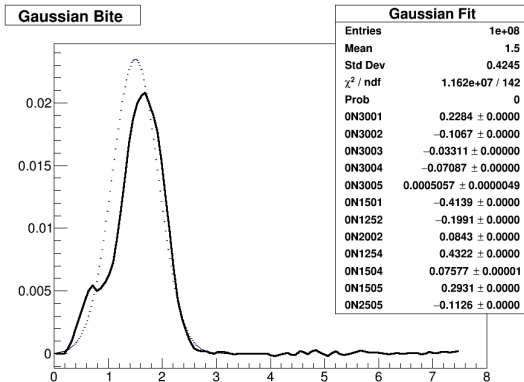
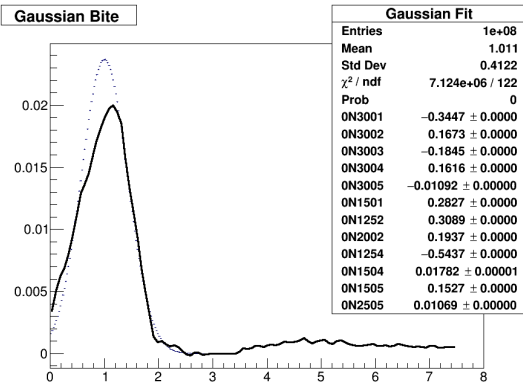
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0N1254	-0.08153 ± 0.00067
0N1505	0.0954 ± 0.0014



DUNE PRISM



Gaussian Fits



Concluding Remarks



- Current program used for fitting may be somewhat rudimentary compared to full DUNE PRISM analysis. Can aim to echo DUNE PRISM's fitting to improve quality of fit
- DUNE PRISM appears to provide a better fit quality (*how much* of this is due to fit program uncertain..), but this avenue may be complementary to DUNE PRISM and provide better coverage of some spectral regions – eg:
 - possible improvement to gaussian fits around 2 GeV,
 - off-axis + horn current could enable better fitting of lower end of spectrum (currently excluded from DUNE PRISM fit below 2nd Osc. Maximum ~0.7GeV),
- More direct coordination with DUNE PRISM / ND plans may provide better focus for further investigation. Currently have a LOT of potential parameters for fitting..
- Modelling response function *could* help find a good/optimal fit analytically

Bonus Slides



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Linear Combination Fit

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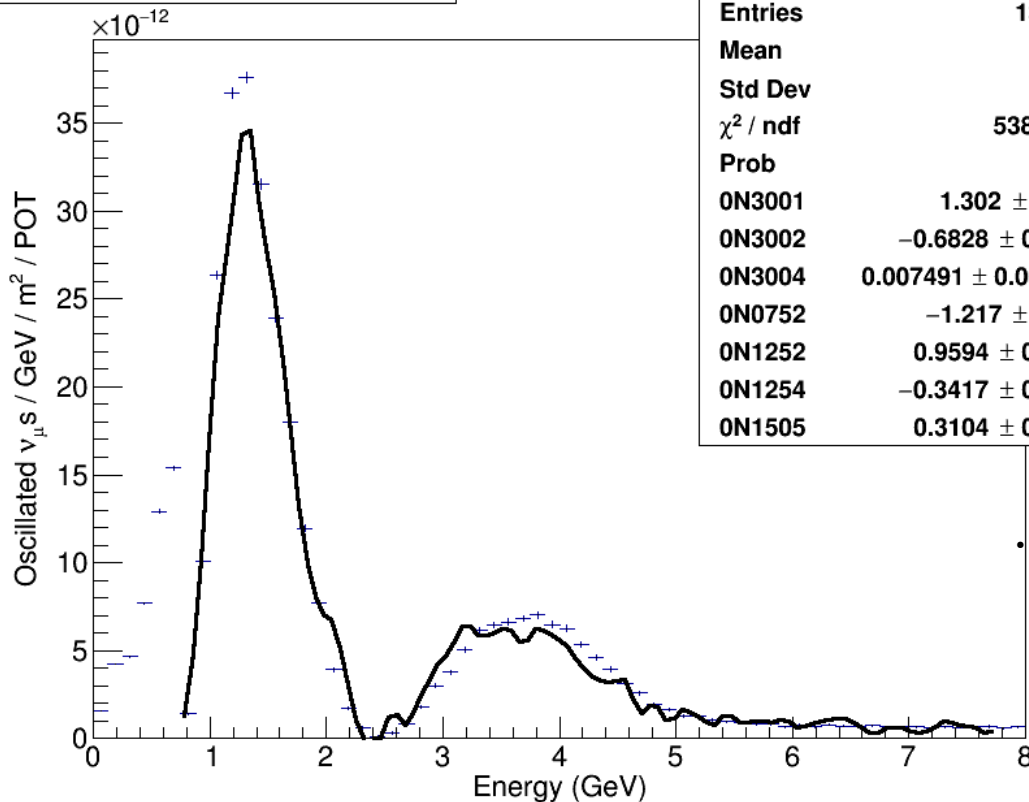
numu_fluxosc_forplots

numu_fluxosc_forplots

7 param fit

Range – 0.75 – 7.75GeV

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	5386 / 49
Prob	0
0N3001	1.302 ± 0.012
0N3002	-0.6828 ± 0.0045
0N3004	0.007491 ± 0.002556
0N0752	-1.217 ± 0.010
0N1252	0.9594 ± 0.0103
0N1254	-0.3417 ± 0.0057
0N1505	0.3104 ± 0.0109



XMYZZ
0-6 - Distance Off-Axis (x 6 metres)
N/A - NuMode / AntiNuMode
YYY = current
Z = Horn Config
1 - A
2 - A+B
3 - A+C
4 - A+B+C
5 - B+C

Linear Combination Fit

WARWICK

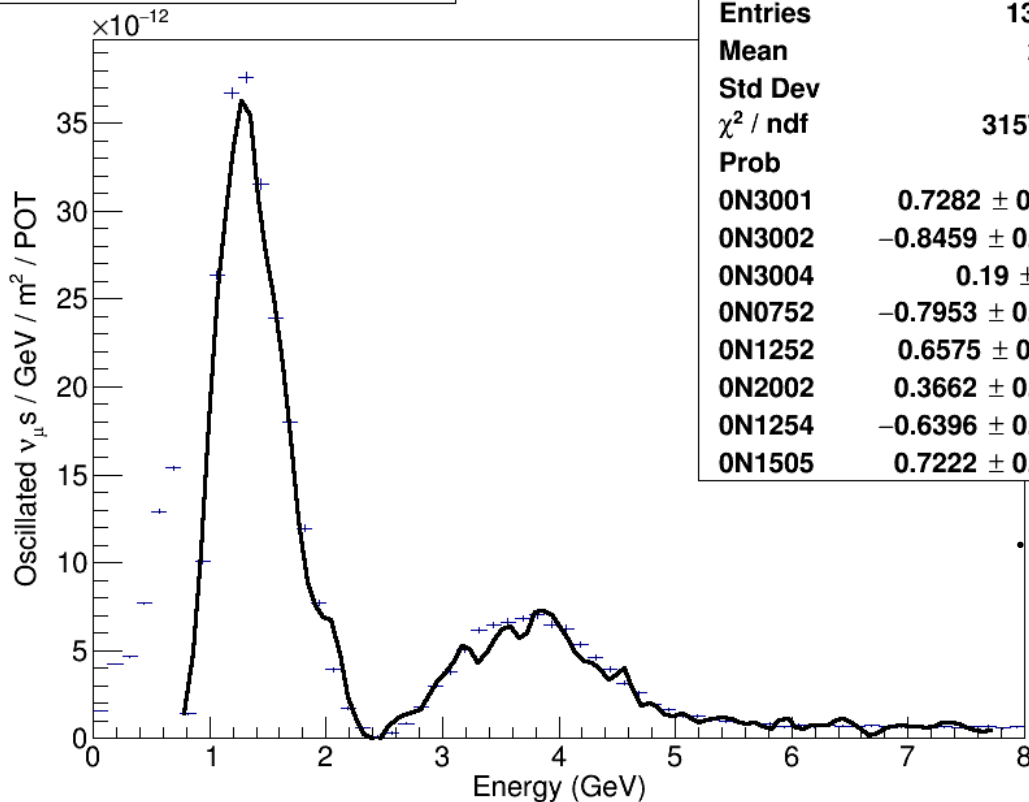
numu_fluxosc_forplots

numu_fluxosc_forplots

8 param fit

Range – 0.75 – 7.75GeV

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	3157 / 48
Prob	0
0N3001	0.7282 ± 0.0171
0N3002	-0.8459 ± 0.0057
0N3004	0.19 ± 0.00
0N0752	-0.7953 ± 0.0136
0N1252	0.6575 ± 0.0121
0N2002	0.3662 ± 0.0078
0N1254	-0.6396 ± 0.0085
0N1505	0.7222 ± 0.0139



XMYZZ
0-6 - Distance Off-Axis (x 6 metres)
N/A - NuMode / AntiNuMode
YYY = current
Z = Horn Config
1 - A
2 - A+B
3 - A+C
4 - A+B+C
5 - B+C

Linear Combination Fit

WARWICK

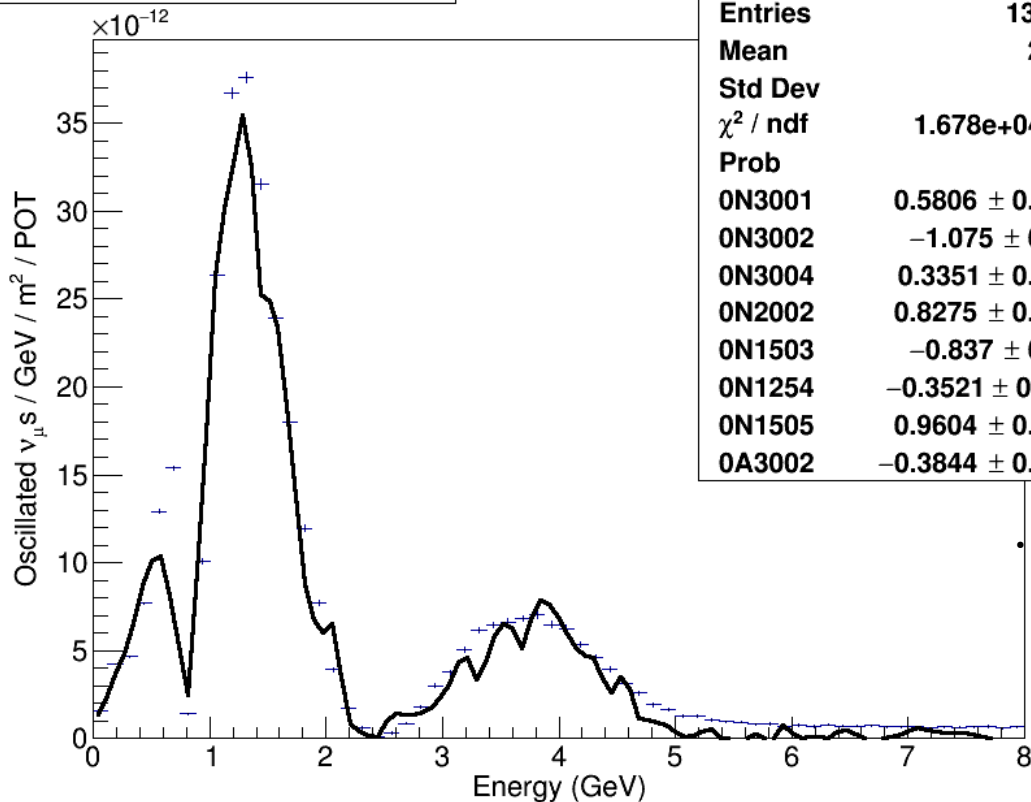
numu_fluxosc_forplots

numu_fluxosc_forplots

8 param fit

Range – 0.0 – 7.75GeV

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	1.678e+04 / 54
Prob	0
0N3001	0.5806 ± 0.0089
0N3002	-1.075 ± 0.004
0N3004	0.3351 ± 0.0022
0N2002	0.8275 ± 0.0054
0N1503	-0.837 ± 0.015
0N1254	-0.3521 ± 0.0111
0N1505	0.9604 ± 0.0109
0A3002	-0.3844 ± 0.0064



X M Y Y Z
0-6 - Distance Off-Axis (x 6 metres)
N / A - NuMode / AntiNuMode
Y Y Y = current
Z = Horn Config
1 - A
2 - A+B
3 - A+C
4 - A+B+C
5 - B+C

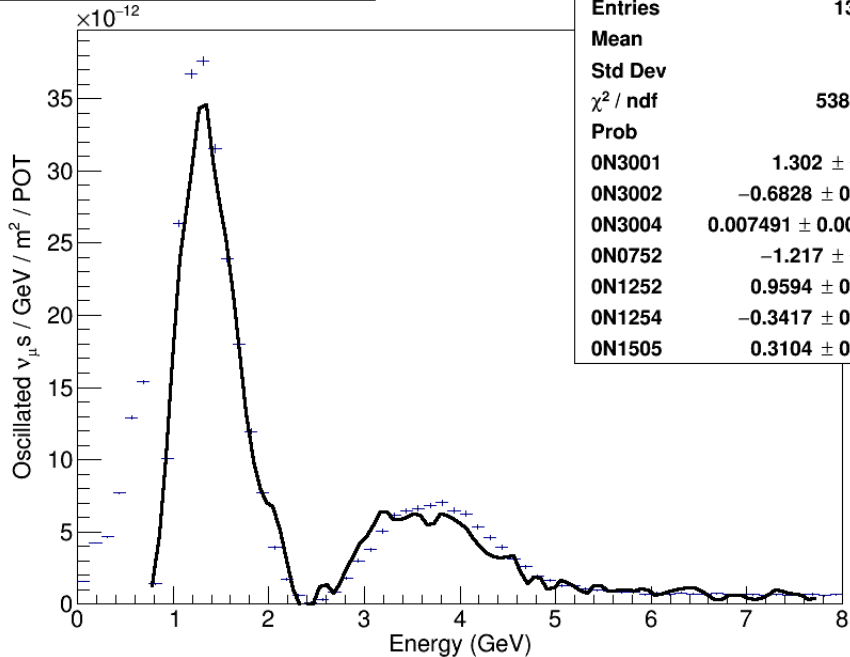
DUNE PRISM vs Horn Configs

WARWICK

XMYYYZ
 0-6 - Distance Off-Axis (x 6 metres)
 N/A - NuMode / AntiNuMode
 YY = current
 Z = Horn Config
 1 - A
 2 - A+B
 3 - A+C
 4 - A+B+C
 5 - B+C

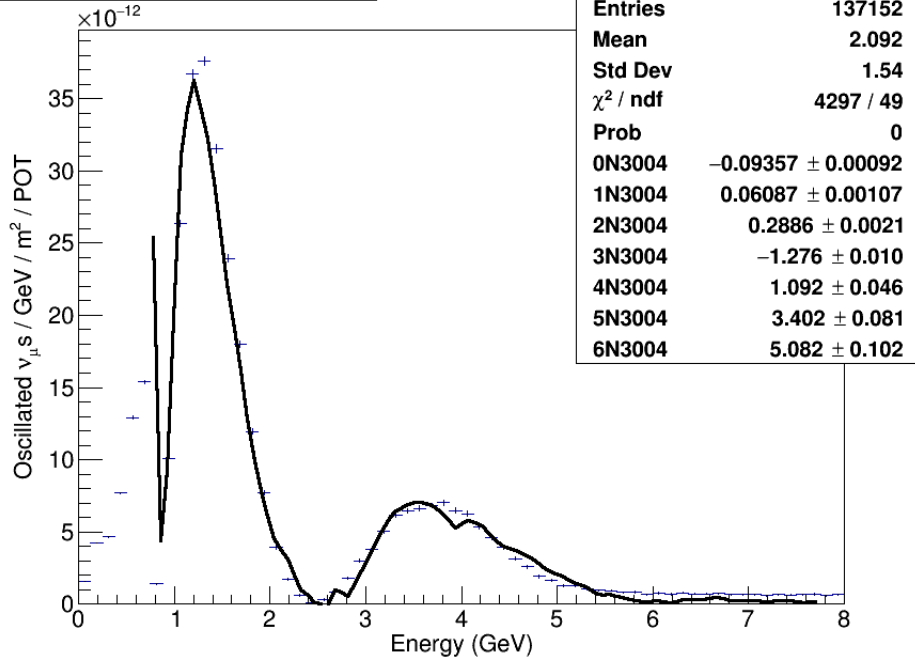
Horn Configs - 7 params

numu_fluxosc_forplots



DUNE PRISM

numu_fluxosc_forplots



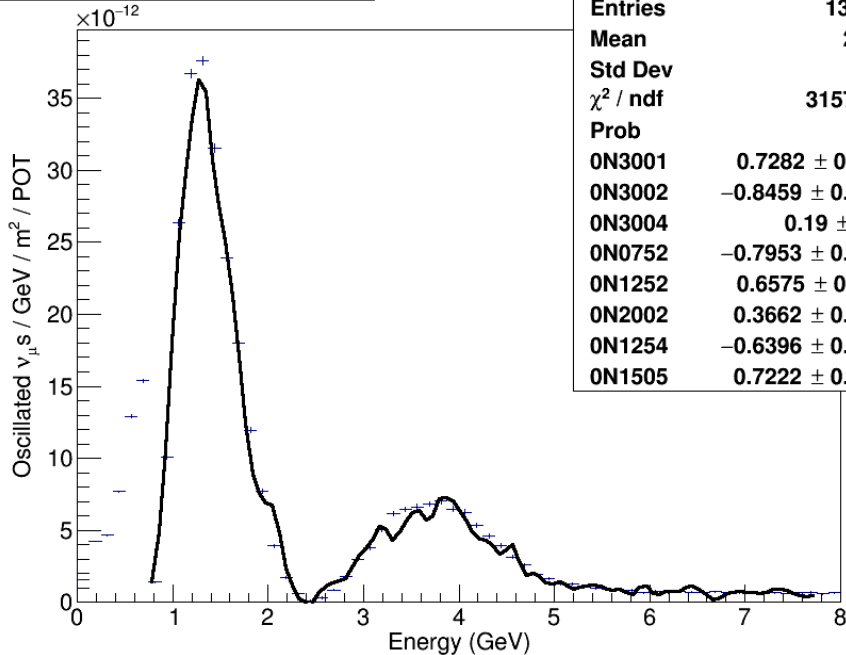
DUNE PRISM vs Horn Configs

WARWICK

XMYYYZ
 0-6 - Distance Off-Axis (x 6 metres)
 N/A - NuMode / AntiNuMode
 YYY = current
 Z = Horn Config
 1 - A
 2 - A+B
 3 - A+C
 4 - A+B+C
 5 - B+C

Horn Configs - 8 params

numu_fluxosc_forplots

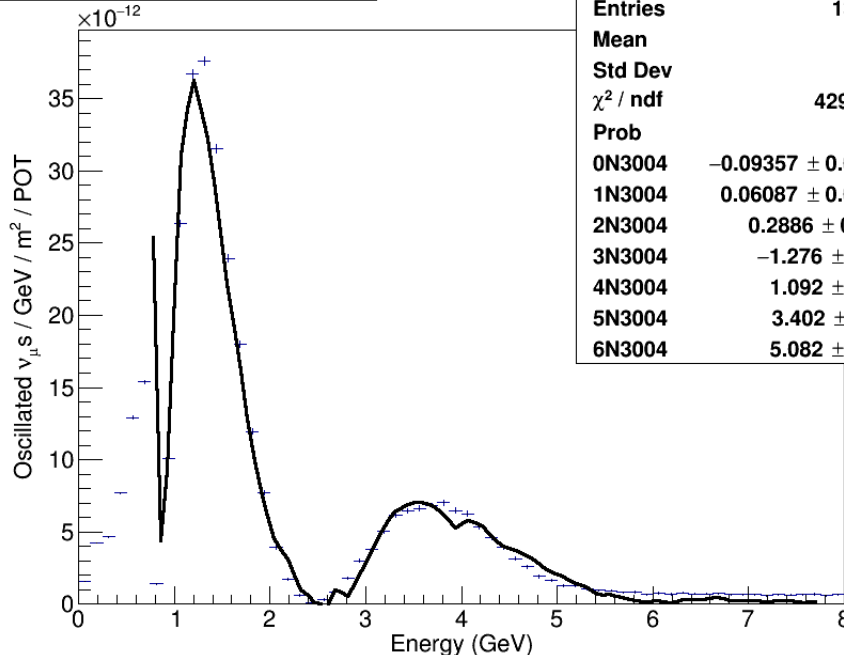


numu_fluxosc_forplots

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	3157 / 48
Prob	0
0N3001	0.7282 ± 0.0171
0N3002	-0.8459 ± 0.0057
0N3004	0.19 ± 0.00
0N0752	-0.7953 ± 0.0136
0N1252	0.6575 ± 0.0121
0N2002	0.3662 ± 0.0078
0N1254	-0.6396 ± 0.0085
0N1505	0.7222 ± 0.0139

DUNE PRISM

numu_fluxosc_forplots



numu_fluxosc_forplots

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	4297 / 49
Prob	0
0N3004	-0.09357 ± 0.00092
1N3004	0.06087 ± 0.00107
2N3004	0.2886 ± 0.0021
3N3004	-1.276 ± 0.010
4N3004	1.092 ± 0.046
5N3004	3.402 ± 0.081
6N3004	5.082 ± 0.102

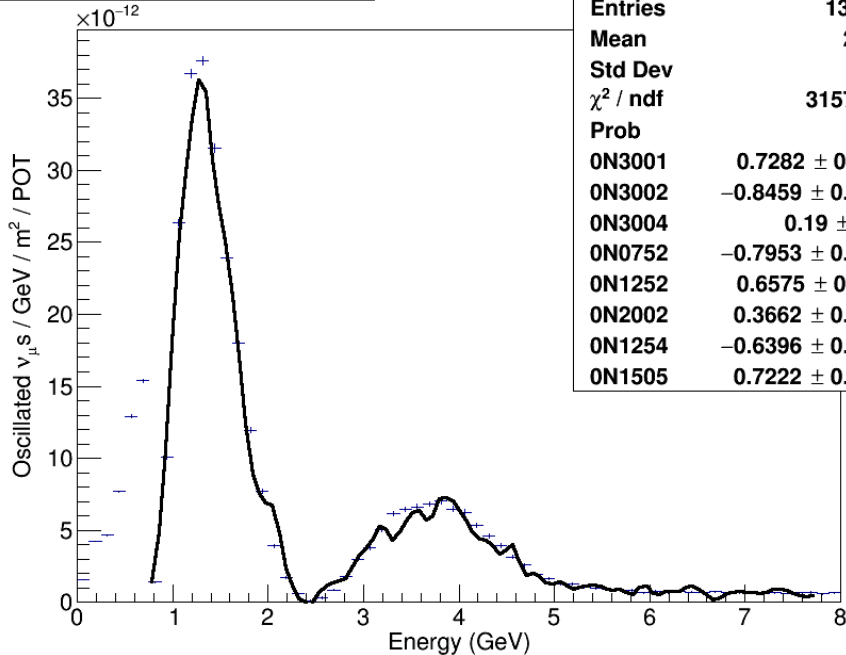
DUNE PRISM vs Horn Configs

WARWICK

XMYYZ
 0-6 - Distance Off-Axis (x 6 metres)
 N/A - NuMode / AntiNuMode
 YY = current
 Z = Horn Config
 1 - A
 2 - A+B
 3 - A+C
 4 - A+B+C
 5 - B+C

Horn Configs – 8 params

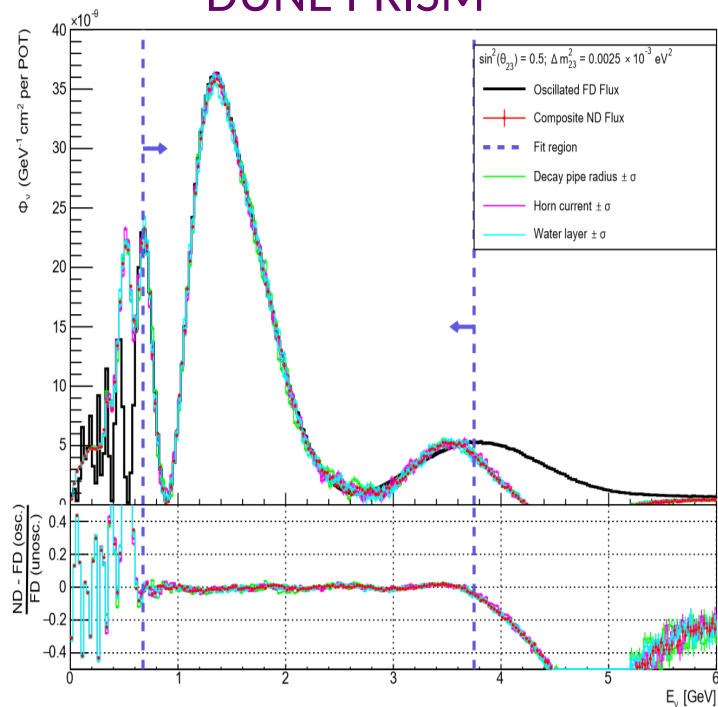
numu_fluxosc_forplots



numu_fluxosc_forplots

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	3157 / 48
Prob	0
0N3001	0.7282 ± 0.0171
0N3002	-0.8459 ± 0.0057
0N3004	0.19 ± 0.00
0N0752	-0.7953 ± 0.0136
0N1252	0.6575 ± 0.0121
0N2002	0.3662 ± 0.0078
0N1254	-0.6396 ± 0.0085
0N1505	0.7222 ± 0.0139

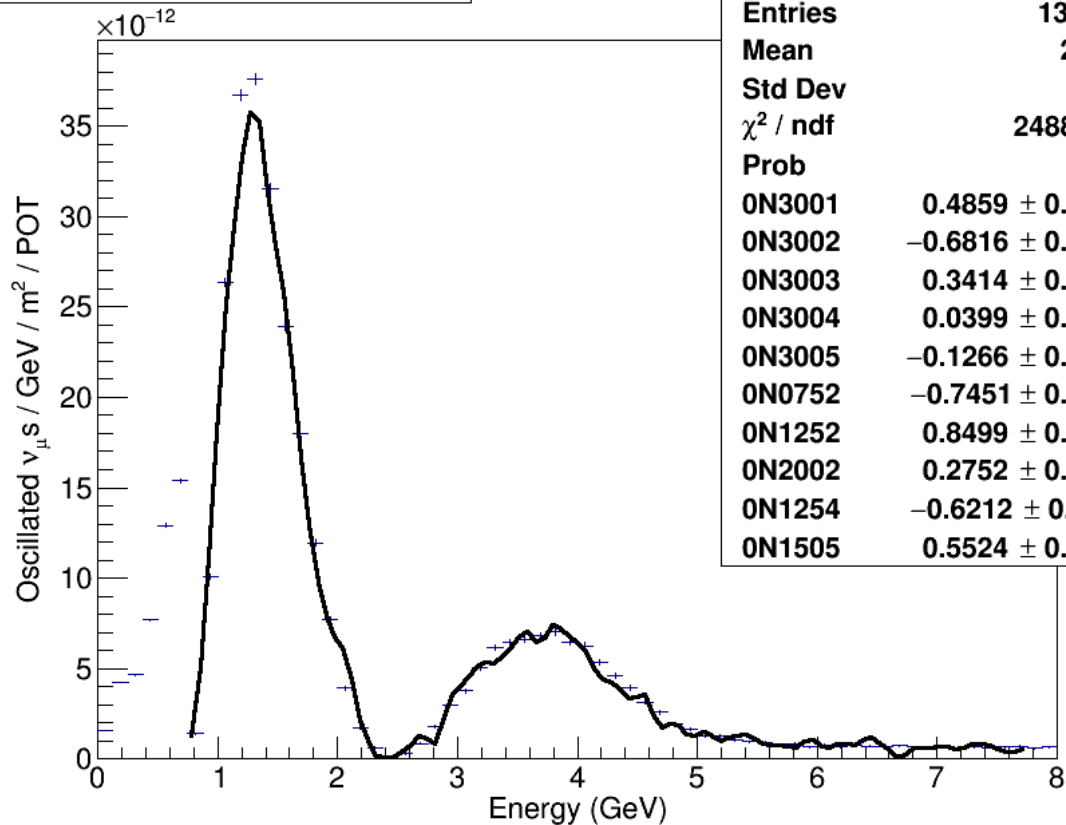
DUNE PRISM



10 Parameter Fit

XMYYZ
0-6 - Distance Off-Axis (x 6 metres)
N/A - NuMode / AntiNuMode
YYY = current
Z = Horn Config
1 - A
2 - A+B
3 - A+C
4 - A+B+C
5 - B+C

numu_fluxosc_forplots



numu_fluxosc_forplots

Entries	137152
Mean	2.092
Std Dev	1.54
χ^2 / ndf	2488 / 46
Prob	0
0N3001	0.4859 \pm 0.0195
0N3002	-0.6816 \pm 0.0093
0N3003	0.3414 \pm 0.0167
0N3004	0.0399 \pm 0.0083
0N3005	-0.1266 \pm 0.0049
0N0752	-0.7451 \pm 0.0138
0N1252	0.8499 \pm 0.0156
0N2002	0.2752 \pm 0.0124
0N1254	-0.6212 \pm 0.0161
0N1505	0.5524 \pm 0.0203

DUNE PRISM Fit

WARWICK

