Impact of PØD NuMu Samples in BANFF

Hogan, Matthew[1] and Toki, Walter[1]

May 27, 2019

[1] *Colorado State University, Fort Collins, USA*

Abstract

This is the abstract

Contents

List of Figures

List of Tables

1 PØD Selections and Data Samples

1.1 Sample Kinematics and Validation

This section examines the kinematics for each of selections while differentiating between water-in and water-out mode. The selection cuts were implemented in Psyche which is the software interface that BANFF uses to select events. An analysis of the kinematics are carefully cross validated with the same selection cuts in the T2K high level analysis framework called Highland. Comparing the results between Highland and Psyche is important since they are complementary frameworks within T2K. The data sets used in this analysis are runs 2-8 in both PØD water-in and water-out (air) modes as shown in Table 1.1.

1.2 PØD Water-Out Samples

This section shows the kinematic distributions for the PØD water-out samples. First an examination of the CC-Inclusive samples and the effects of the systematic weights will be explored. The samples are then examined as CC 1-track and CC N-tracks.

1.2.1 CC-Inclusive

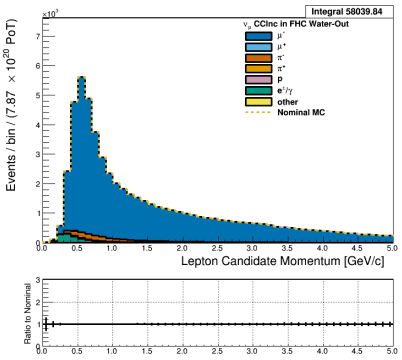
The CC-Inclusive sample cuts are discussed **??**. Since both flux and systematic weights are applied to all MC events in BANFF, it is important to validate the event weights. Using neither set of weights is referred to as the nominal MC.

1.2.1.1 ν_μ Selection in FHC Mode: Shown inFigures 1.1 to 1.7 are the momentum and $\cos\theta$ distributions for ν_μCC-Inclusive events in FHC mode. There are three pairs of P, θ figures with the same truth information break down accompanied by one of neutrino energy. The truth information categories are lepton candidate particle, NEUT reaction, and

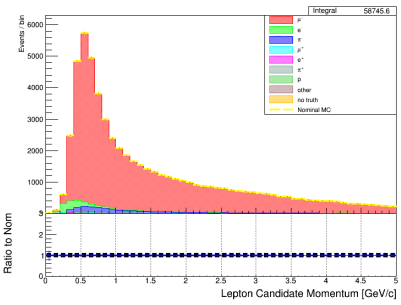
Run Period	Horn Current	PØD Status	Data POT $\left(\times 10^{20}\right)$	MC POT $\left(\times 10^{20}\right)$
2	+250 kA	Water	0.4339	12.03
		Air	0.3591	9.239
3b	+205 kA		0.2172	4.478
3c	+250 kA		1.364	26.32
4			1.782	34.99
		Water	1.642	34.97
5c	-250 kA		0.4346	22.77
6b		Air	1.288	14.17
6c			0.5058	5.275
6d			0.7753	6.884
6e			0.8479	8.594
7b		Water	2.436	33.70
8	+250 kA		1.580	26.46
		Air	4.148	36.06
Sand	FHC		-	11.19
Sand	RHC		-	12.92
2, 3b, 3c, 4, 8	FHC	Air	7.872	79.18
2, 4, 8		Water	3.657	73.47
6b, 6c, 6d, 6e	RHC	Air	3.417	34.92
5c, 7b		Water	2.871	56.48

Table 1.1: T2K MC and data POT divided by run periods. The bottom four rows are the aggregrated periods grouped by horn current and PØD status which is how the data analysis is performed.

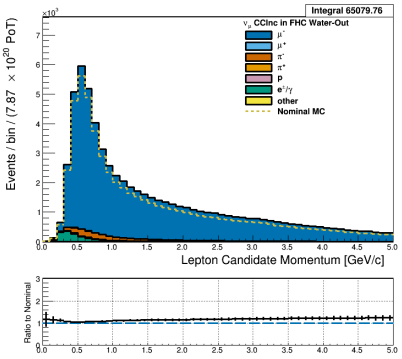
topology. Each figure consists of a set of four sub-figures which illustrate the application of flux and detector systematic weights.



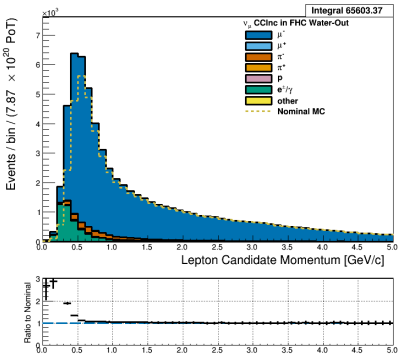
(a) Nominal MC



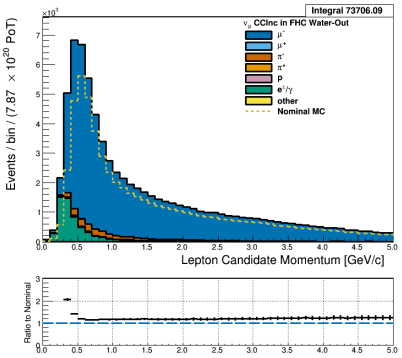
(b) Nominal MC from Highland2



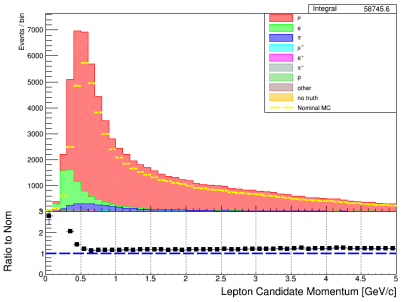
(c) Flux



(d) Systematics

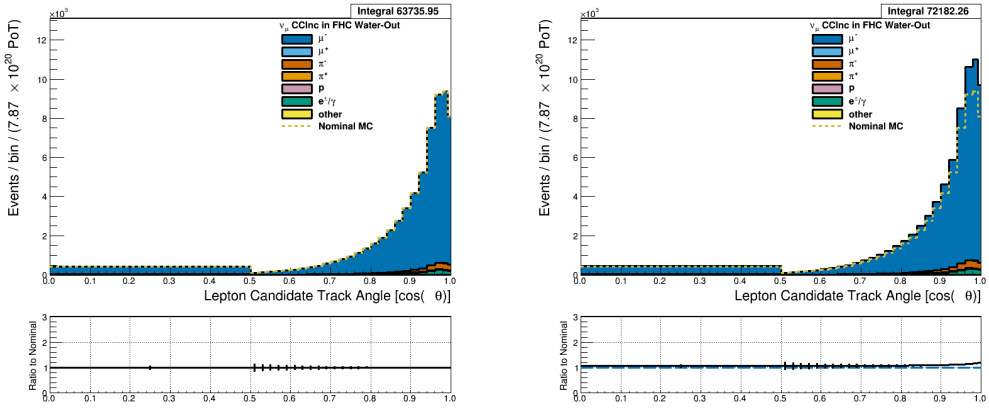


(e) Flux + systematics



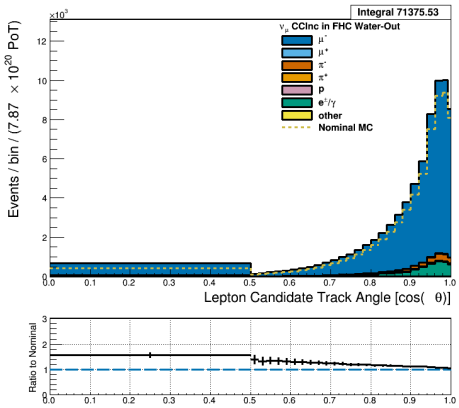
(f) Fully weighted in Highland2

Figure 1.1: Reconstructed lepton candidate momentum separated by true particle species for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).

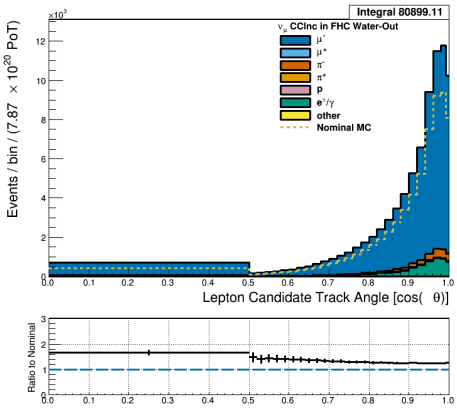


(a) Nominal MC

(b) Flux

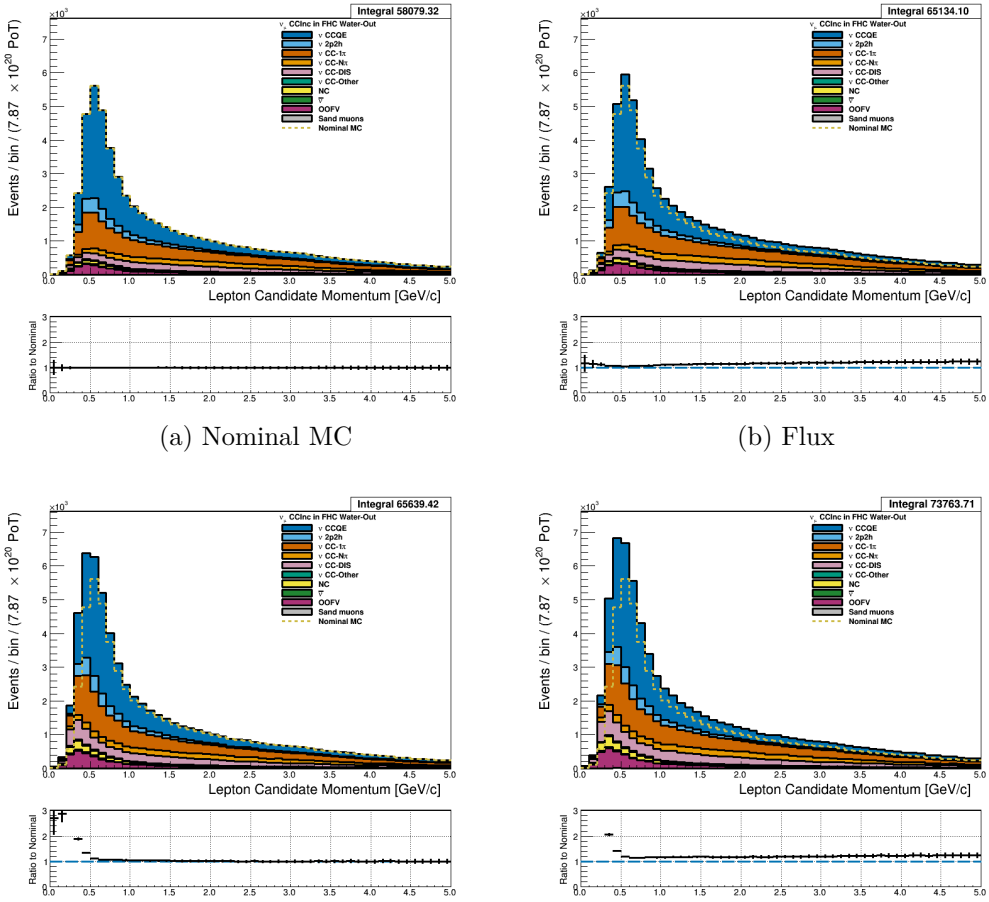


(c) Systematics



(d) Flux + systematics

Figure 1.2: Reconstructed lepton candidate angle separated by true particle species for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



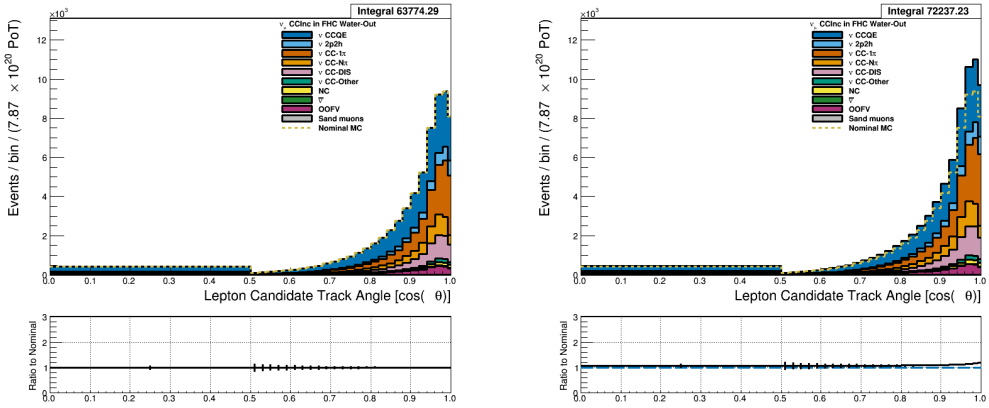
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.3: Reconstructed lepton candidate momentum separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



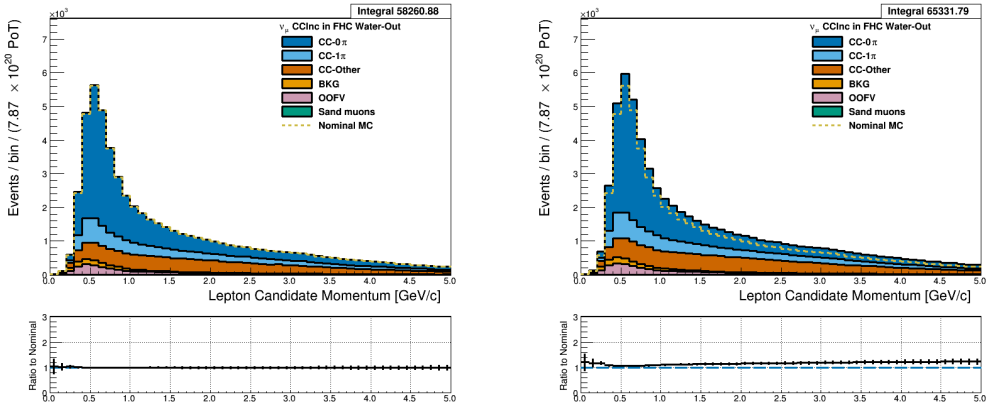
(a) Nominal MC

(b) Flux

(c) Systematics

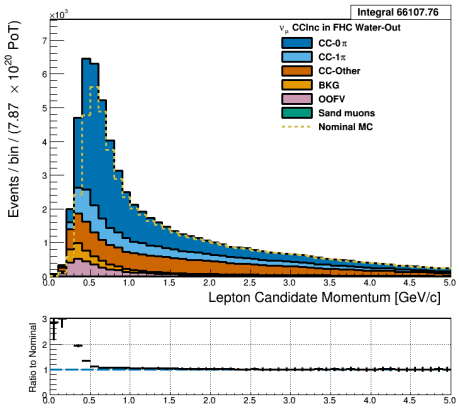
(d) Flux + systematics

Figure 1.4: Reconstructed lepton candidate $\cos\theta$ separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

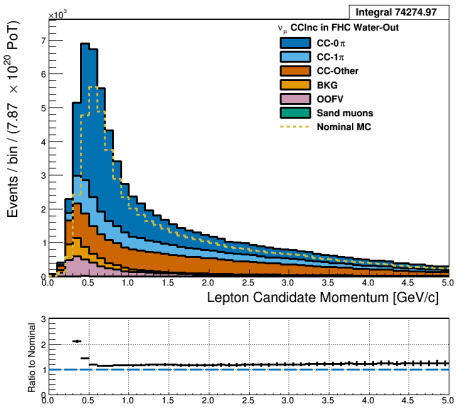


(a) Nominal MC

(b) Flux

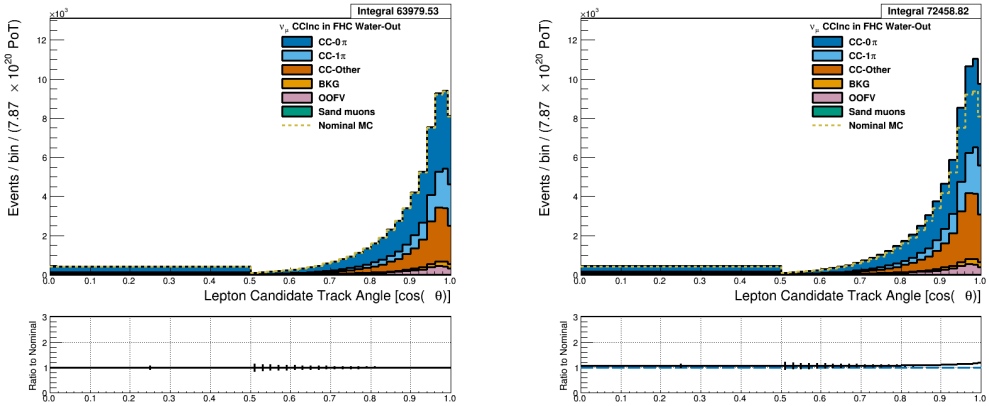


(c) Systematics



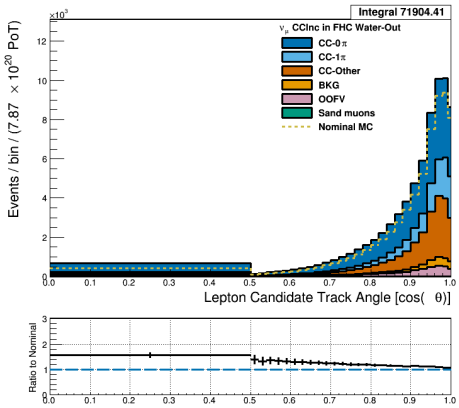
(d) Flux + systematics

Figure 1.5: Reconstructed lepton candidate momentum separated by topology for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

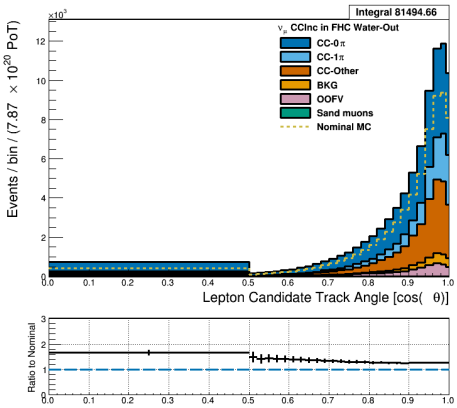


(a) Nominal MC

(b) Flux

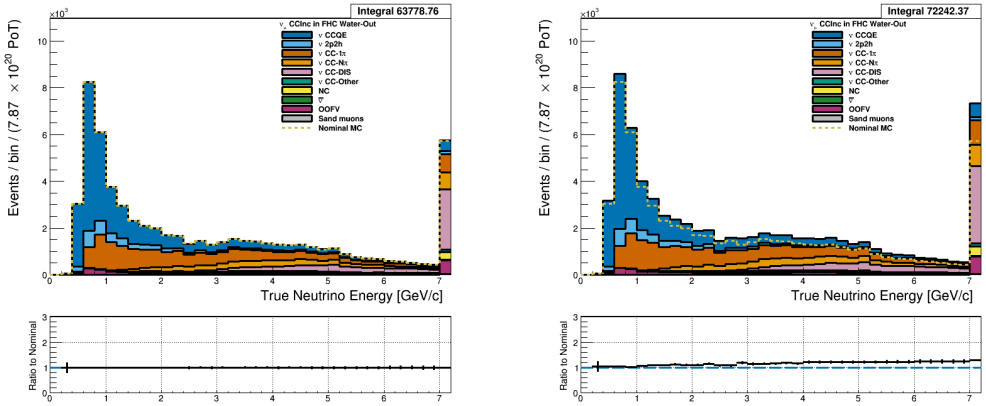


(c) Systematics



(d) Flux + systematics

Figure 1.6: Reconstructed lepton candidate $\cos\theta$ separated by topology for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



(a) Nominal MC

(b) Flux

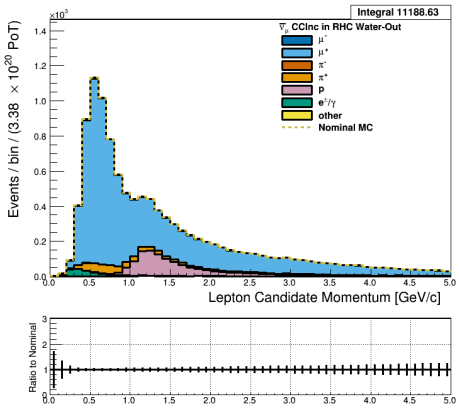
(c) Systematics

(d) Flux + systematics

Figure 1.7: True neutrino energy associated with the lepton candidate separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

1.2.1.2 $\overline{\nu}_\mu$ Selection in RHC Mode:

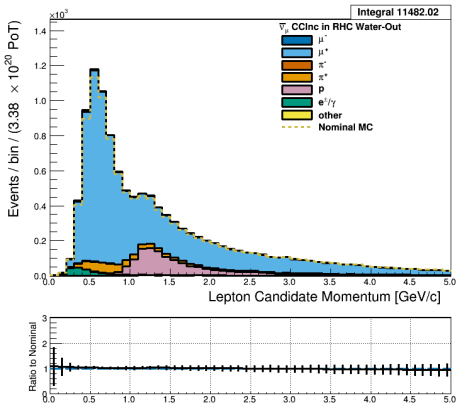
Shown in Figures 1.8 to 1.14 for $\overline{\nu}_\mu$CC-Inclusive events in RHC mode. There are three pairs of P, θ figures with the same truth information break down accompanied by one of neutrino energy. The truth information categories are lepton candidate particle, NEUT reaction, and topology. Each figure consists of a set of four sub-figures which illustrate the application of flux and detector systematic weights.



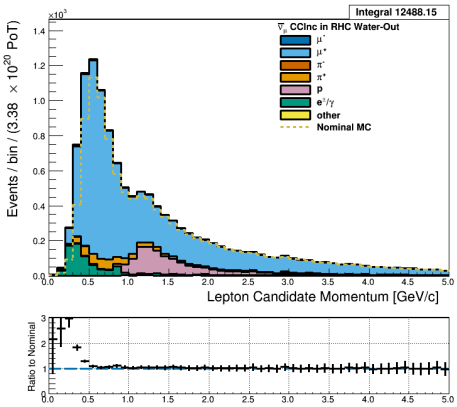
(a) Nominal MC

Sections/Figures/SamplesandSelections/numubarRHC/

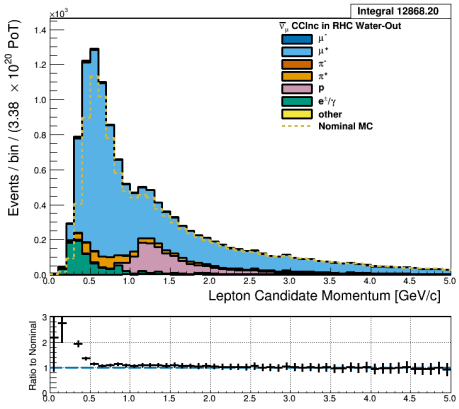
(b) Nominal MC from Highland2



(c) Flux



(d) Systematics

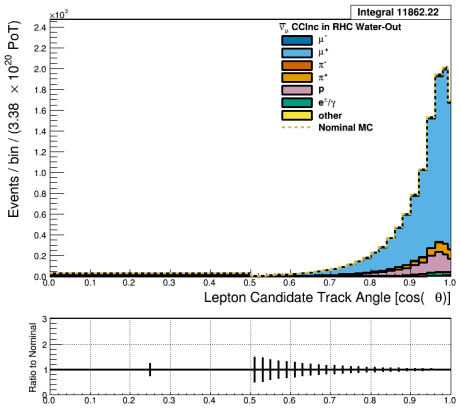


(e) Flux + systematics

Sections/Figures/SamplesandSelections/numubarRHC/

(f) Fully weighted in Highland2

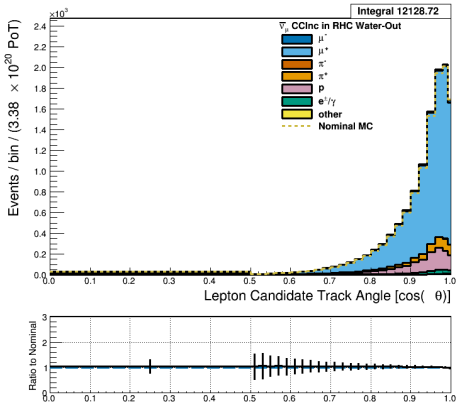
Figure 1.8: Reconstructed lepton candidate momentum separated by true particle species for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. Reconstructed lepton candidate angle separated by true particle species for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-in mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



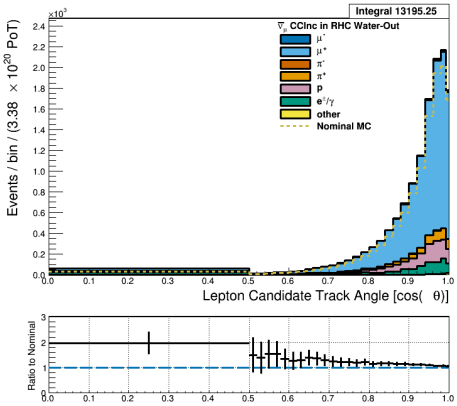
(a) Nominal MC

Sections/Figures/SamplesandSelections/numubarRHC/

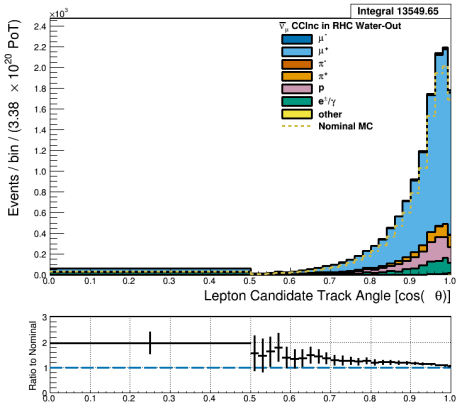
(b) Nominal MC from Highland2



(c) Flux



(d) Systematics

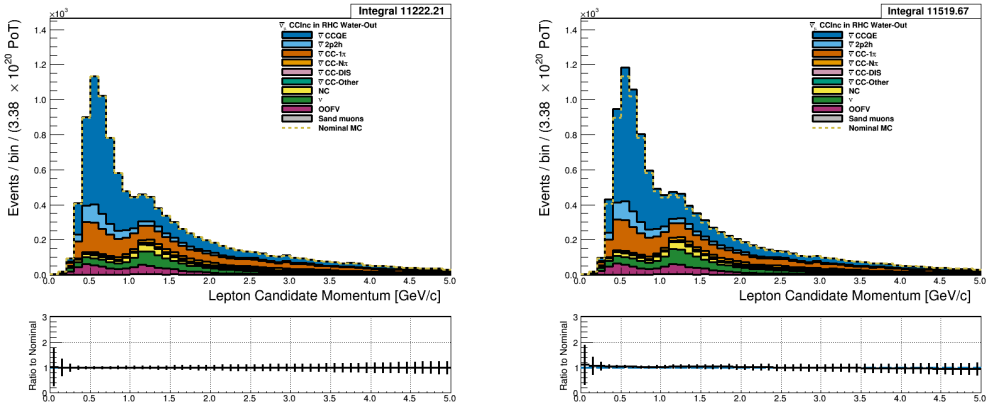


(e) Flux + systematics

Sections/Figures/SamplesandSelections/numubarRHC/

(f) Fully weighted in Highland2

Figure 1.9: Reconstructed lepton candidate angle separated by true particle species for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



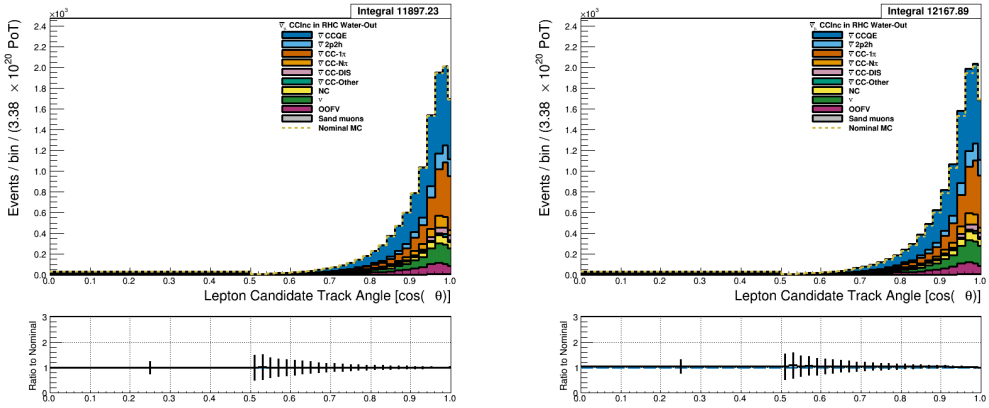
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.10: Reconstructed lepton candidate momentum separated by NEUT model interaction mode for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



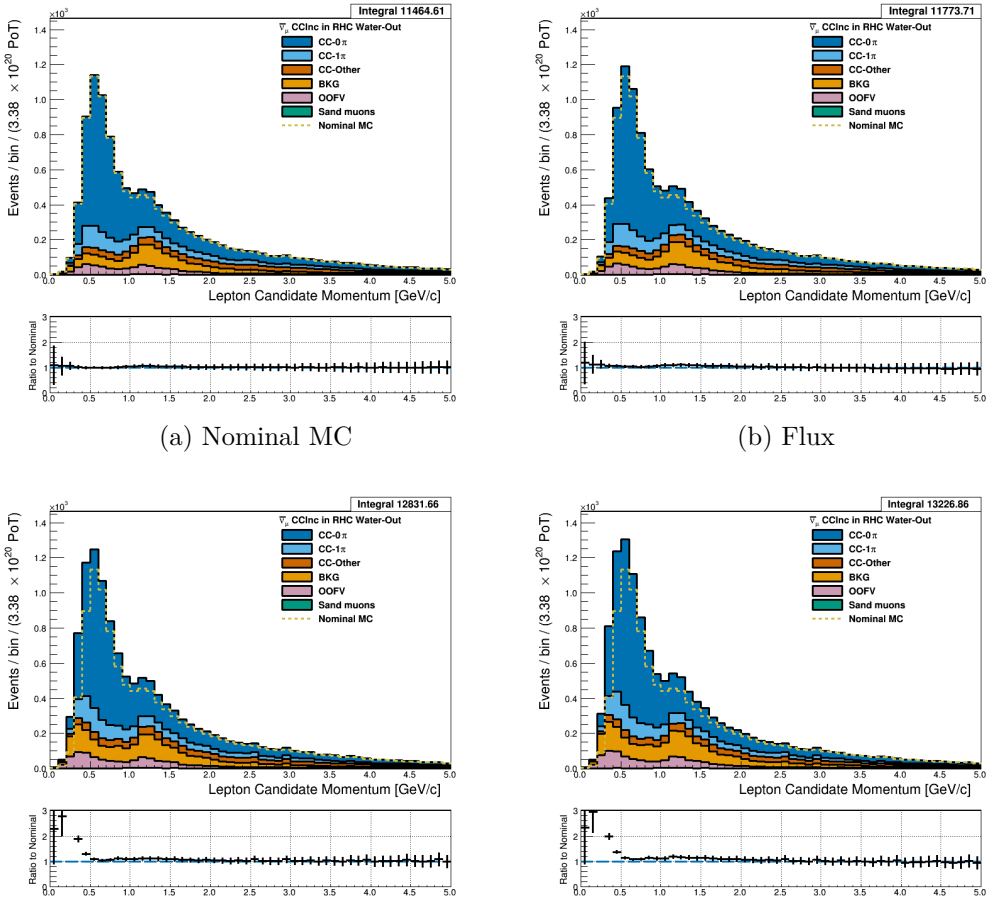
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.11: Reconstructed lepton candidate $\cos\theta$ separated by NEUT model interaction mode for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



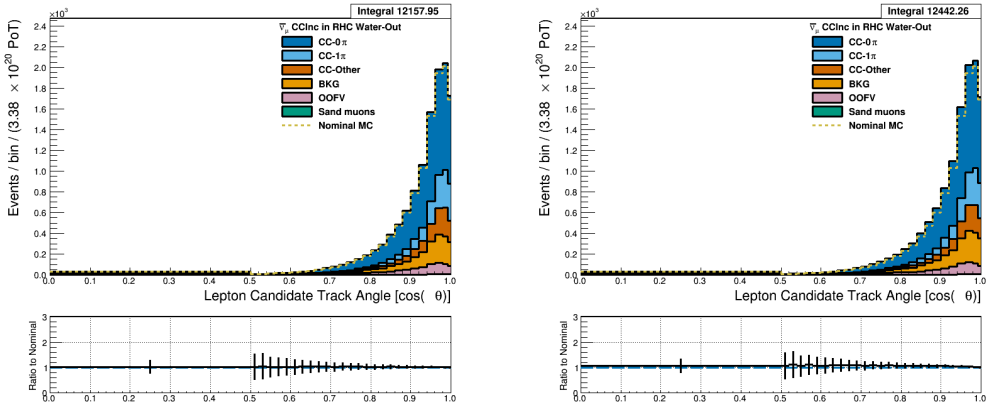
(a) Nominal MC

(b) Flux

(c) Systematics

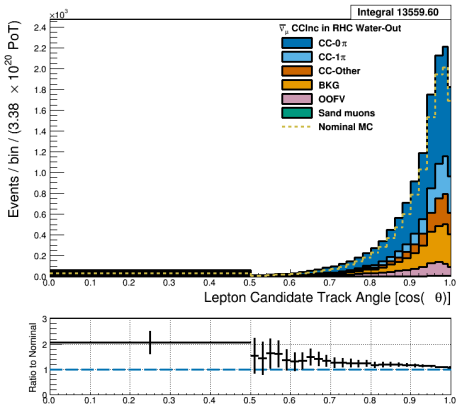
(d) Flux + systematics

Figure 1.12: Reconstructed lepton candidate momentum separated by topology for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

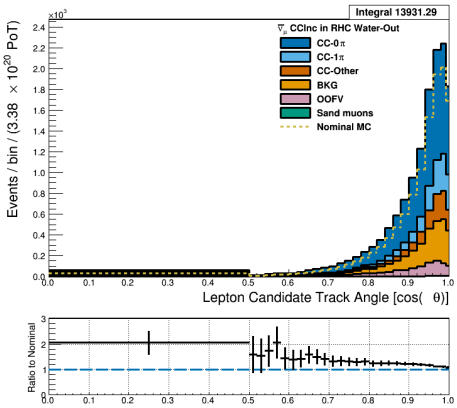


(a) Nominal MC

(b) Flux

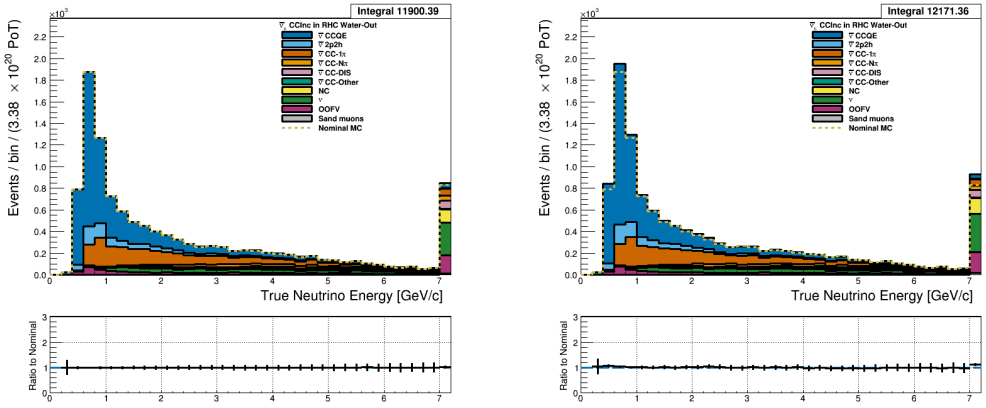


(c) Systematics



(d) Flux + systematics

Figure 1.13: Reconstructed lepton candidate $\cos\theta$ separated by topology for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



(a) Nominal MC

(b) Flux

(c) Systematics

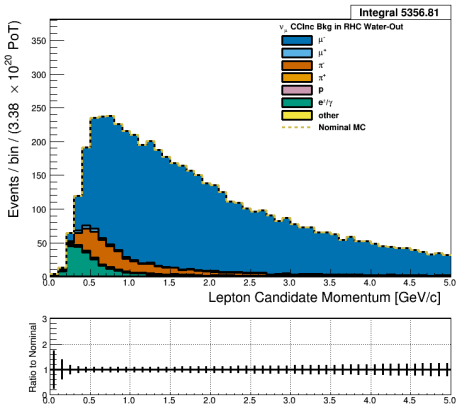
(d) Flux + systematics

Figure 1.14: True neutrino energy associated with the lepton candidate separated by NEUT model interaction mode for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

1.2.1.3 ν_μ Background Selection in RHC Mode:

Shown in Figures 1.15, 1.16 and 1.19 to 1.21 and ????

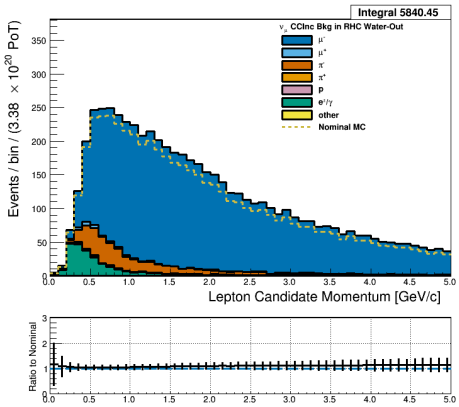
Add HL2 figures here



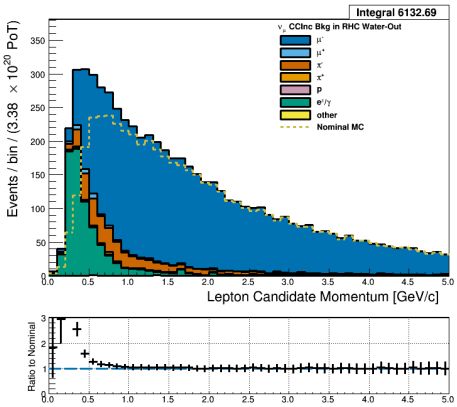
(a) Nominal MC

Sections/Figures/SamplesandSelections/numuFHC/CCI

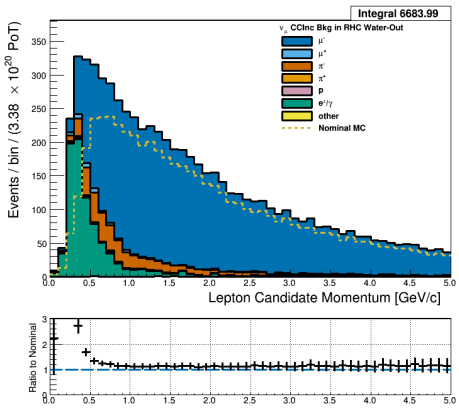
(b) Nominal MC from Highland2



(c) Flux



(d) Systematics

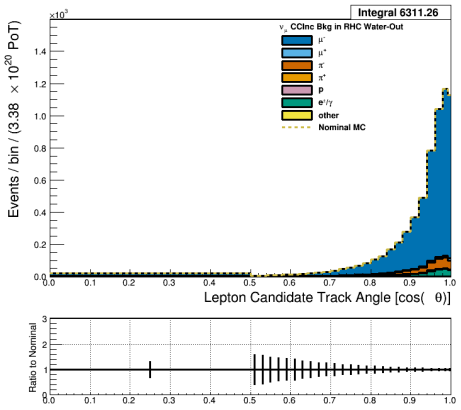


(e) Flux + systematics

Sections/Figures/SamplesandSelections/numuFHC/CCI

(f) Fully weighted in Highland2

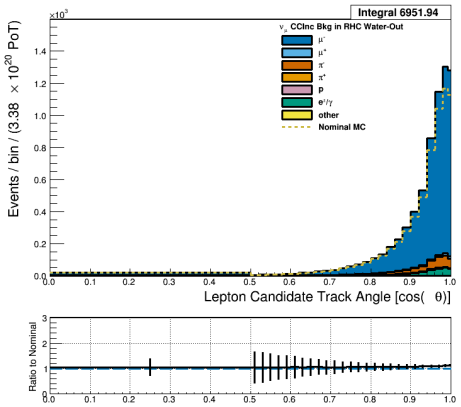
Figure 1.15: Reconstructed lepton candidate momentum separated by true particle species for RHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



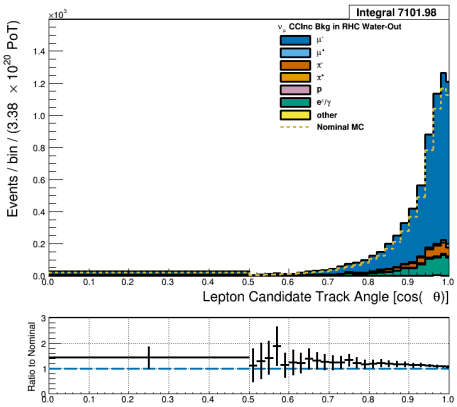
(a) Nominal MC

Sections/Figures/SamplesandSelections/numuFHC/CCI

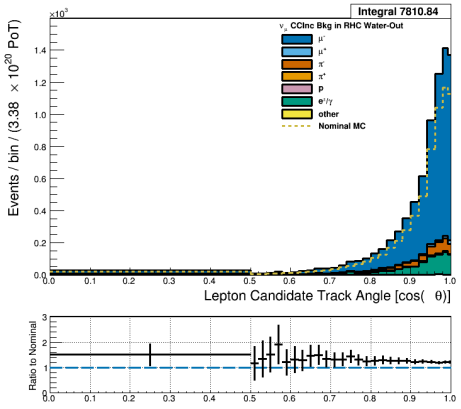
(b) Nominal MC from Highland2



(c) Flux



(d) Systematics

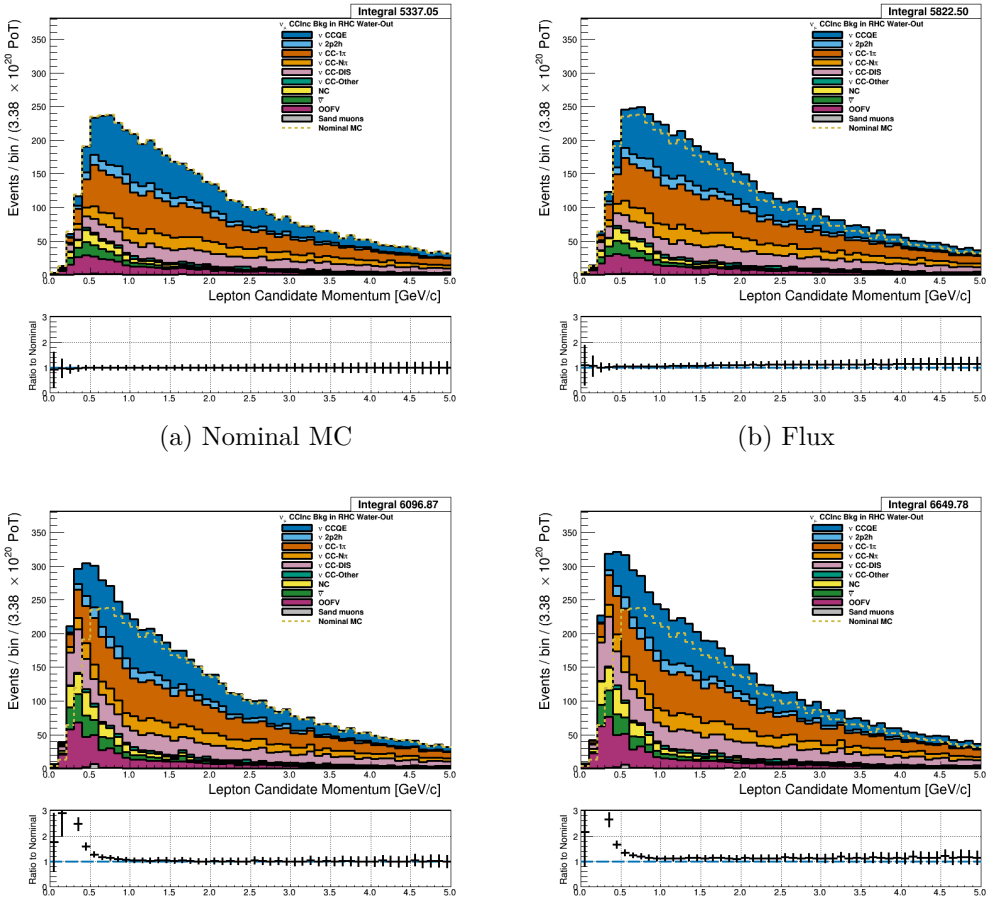


(e) Flux + systematics

Sections/Figures/SamplesandSelections/numuFHC/CCI

(f) Fully weighted in Highland2

Figure 1.16: Reconstructed lepton candidate angle separated by true particle species for RHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



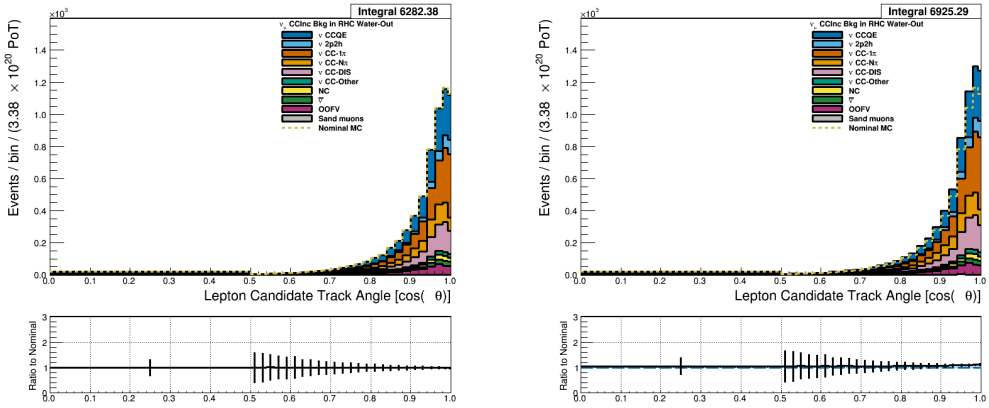
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.17: Reconstructed lepton candidate momentum separated by NEUT model interaction mode for RHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



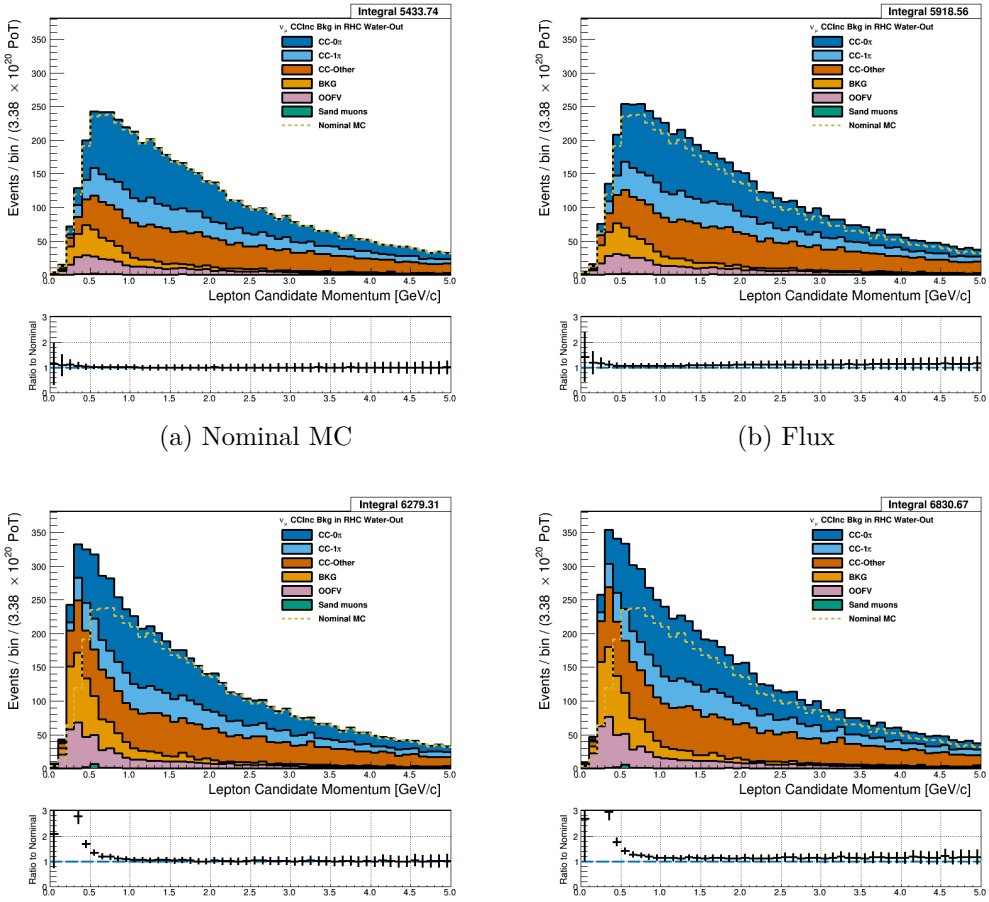
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.18: Reconstructed lepton candidate $\cos\theta$ separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



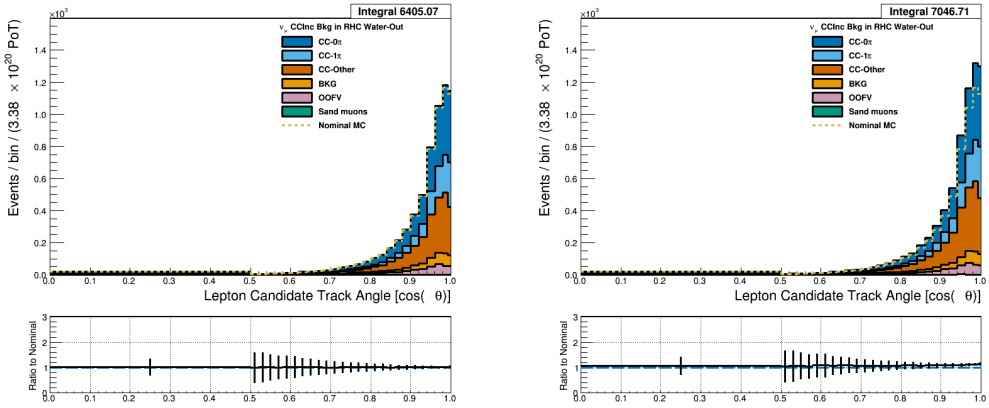
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.19: Reconstructed lepton candidate momentum separated by topology for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



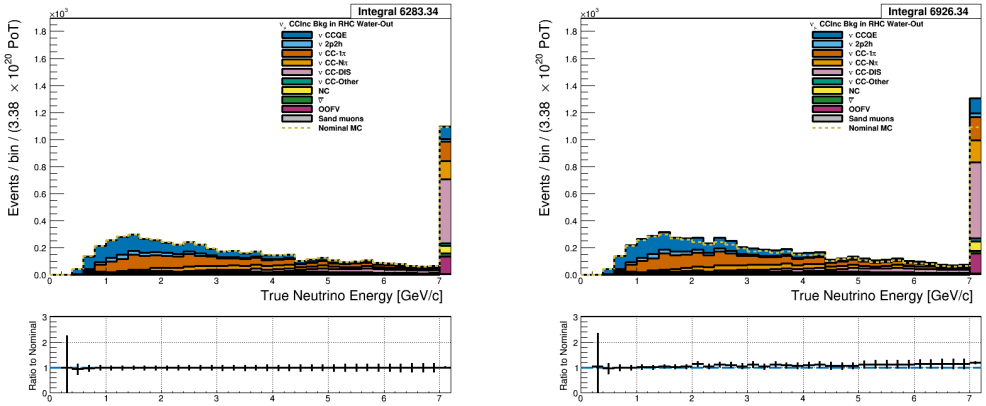
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.20: Reconstructed lepton candidate $\cos\theta$ separated by topology for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



(a) Nominal MC

(b) Flux

(c) Systematics

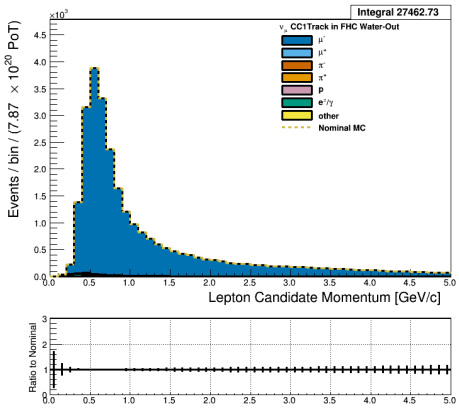
(d) Flux + systematics

Figure 1.21: True neutrino energy associated with the lepton candidate separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

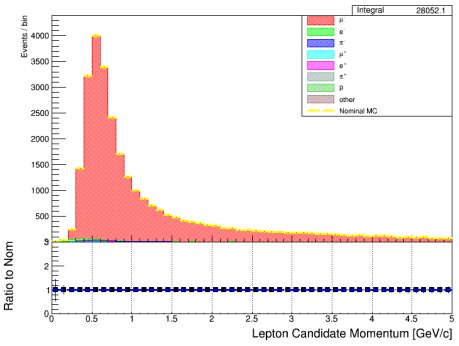
1.2.2 CC-1 Track (CCQE Enhanced)

1.2.2.1 ν_μ Selection in FHC Mode:

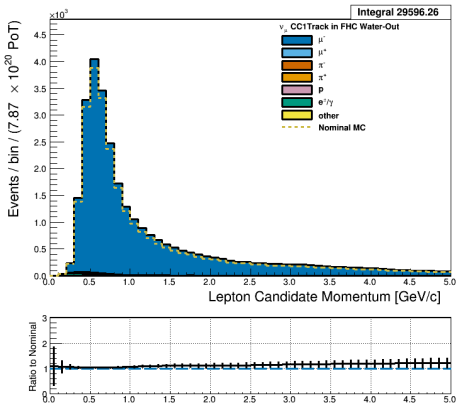
Shown in



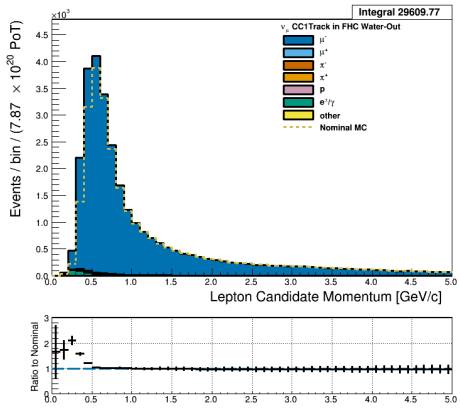
(a) Nominal MC



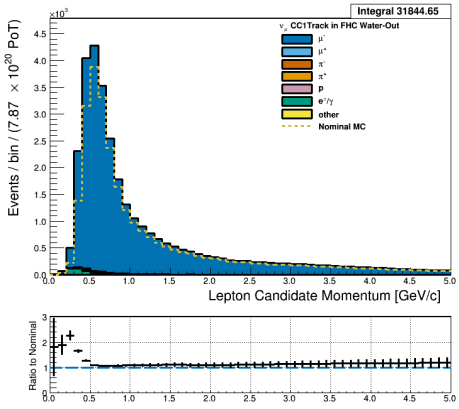
(b) Nominal MC from Highland2



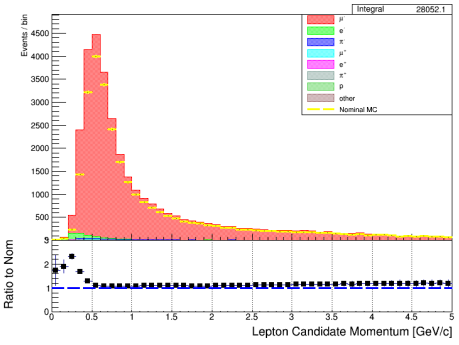
(c) Flux



(d) Systematics

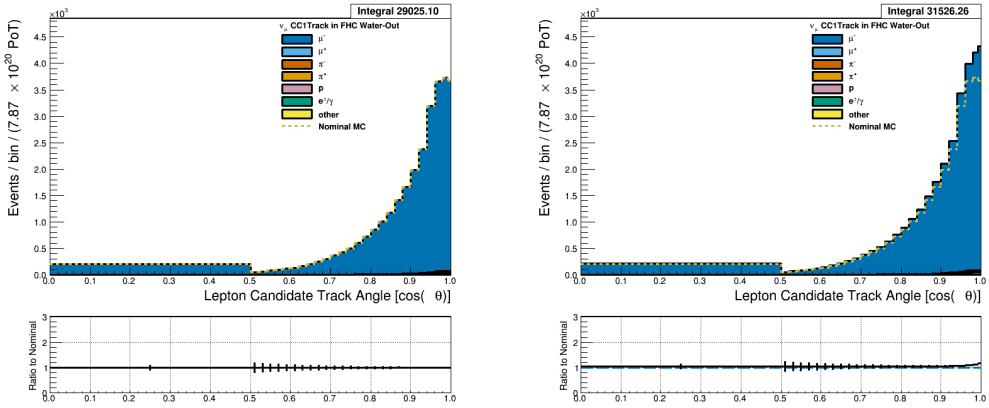


(e) Flux + systematics



(f) Fully weighted in Highland2

Figure 1.22: Reconstructed lepton candidate momentum separated by true particle species for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



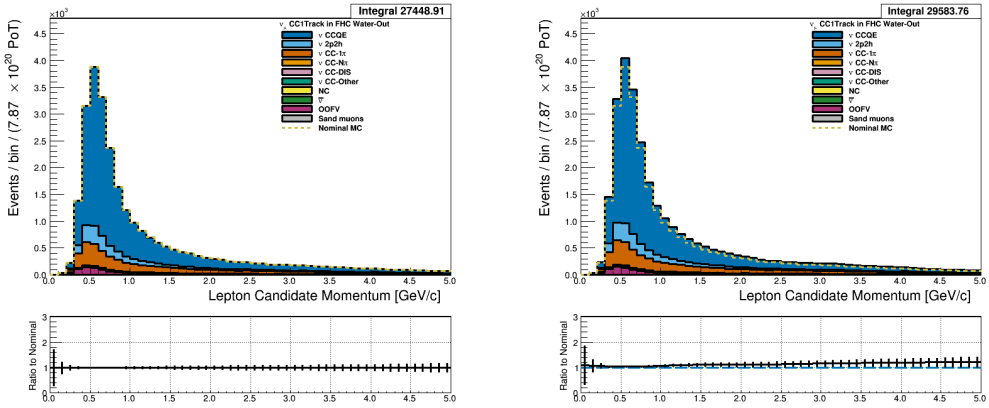
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.23: Reconstructed lepton candidate angle separated by true particle species for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



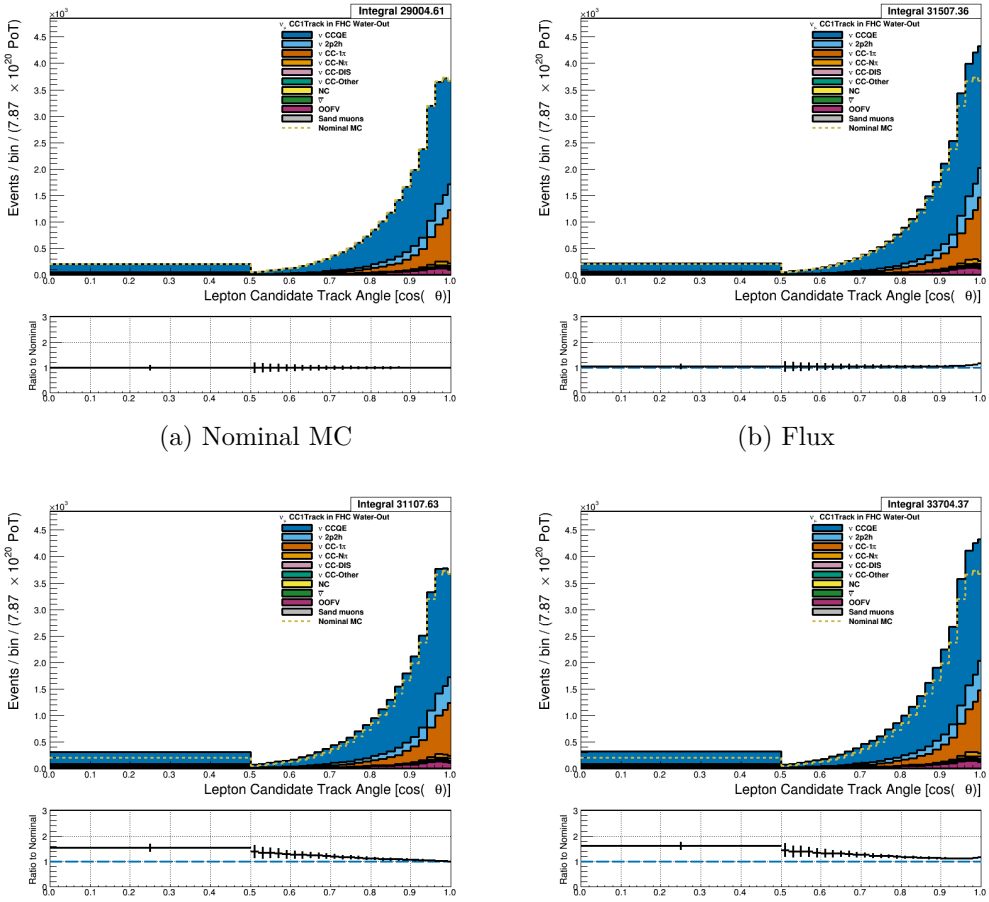
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.24: Reconstructed lepton candidate momentum separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



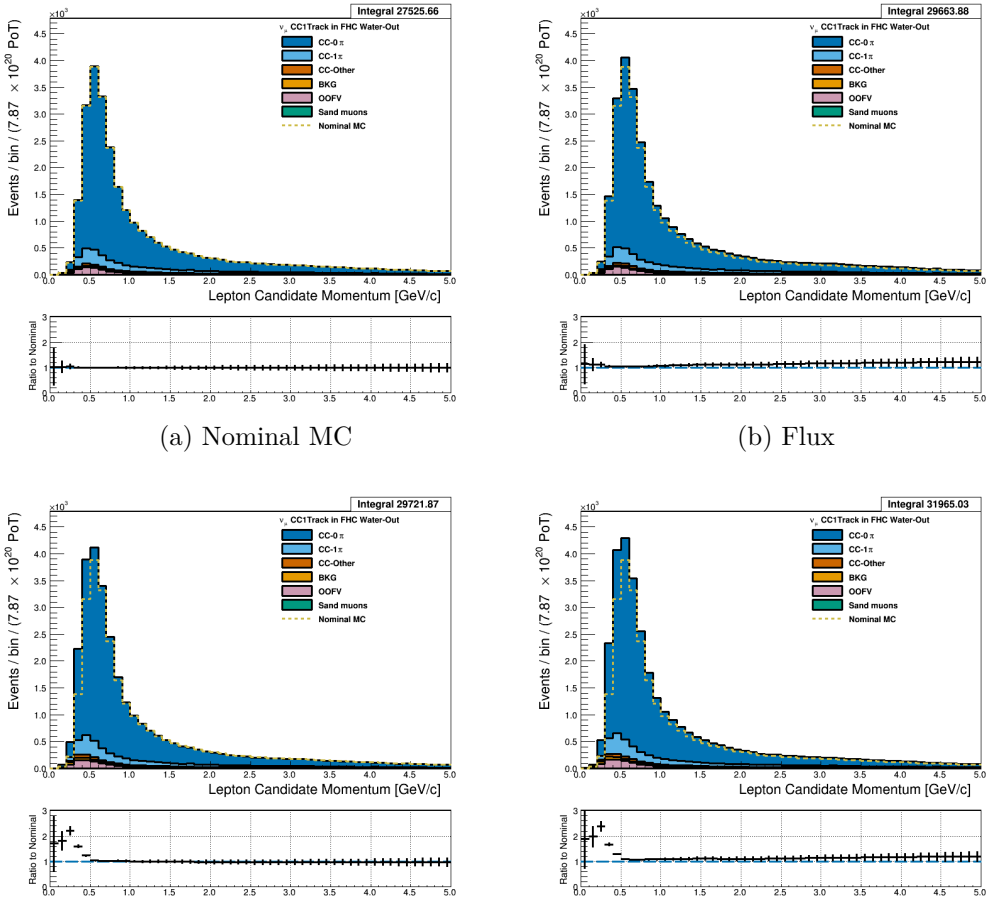
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.25: Reconstructed lepton candidate $\cos\theta$ separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



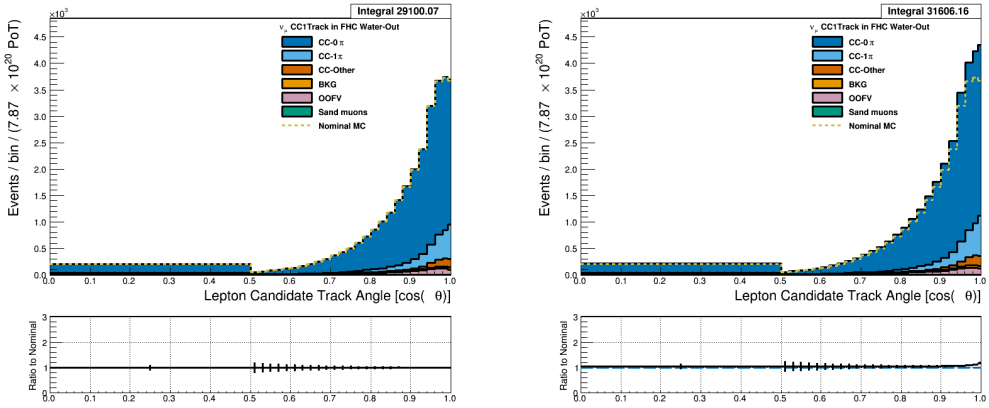
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.26: Reconstructed lepton candidate momentum separated by topology for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



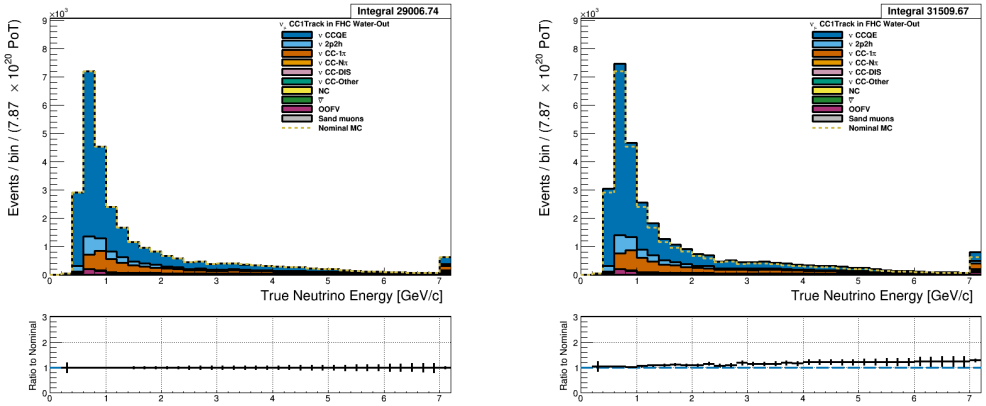
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.27: Reconstructed lepton candidate $\cos\theta$ separated by topology for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



(a) Nominal MC

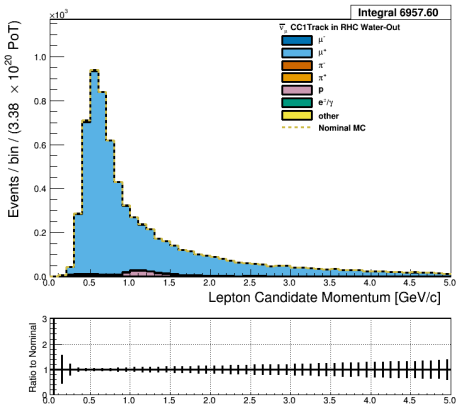
(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.28: True neutrino energy associated with the lepton candidate separated by NEUT model interaction mode for FHC ν_μ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

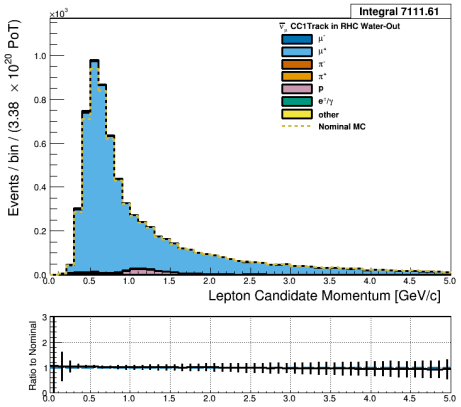
1.2.2.2 $\overline{\nu}_\mu$ Selection in RHC Mode: Figures



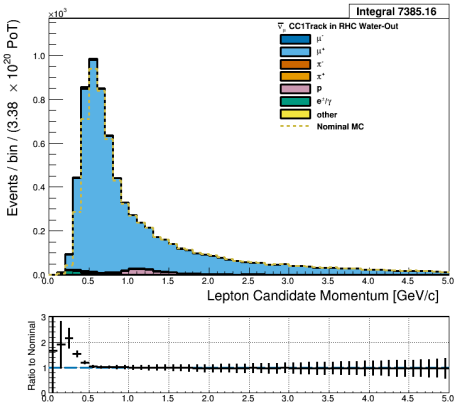
(a) Nominal MC

Sections/Figures/SamplesandSelections/numubarRHC/

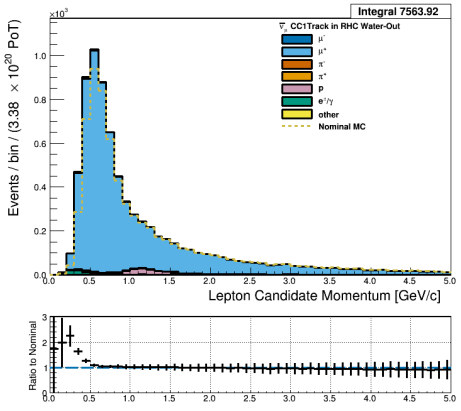
(b) Nominal MC from Highland2



(c) Flux



(d) Systematics

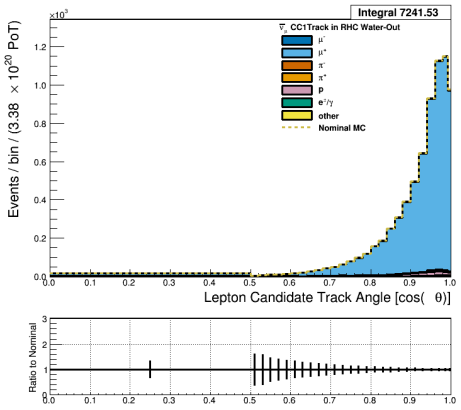


(e) Flux + systematics

Sections/Figures/SamplesandSelections/numubarRHC/

(f) Fully weighted in Highland2

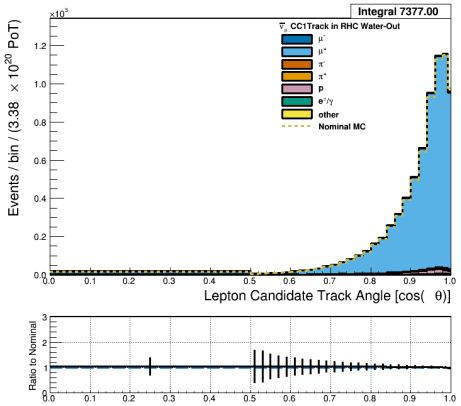
Figure 1.29: Reconstructed lepton candidate momentum separated by true particle species for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. Reconstructed lepton candidate angle separated by true particle species for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-in mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



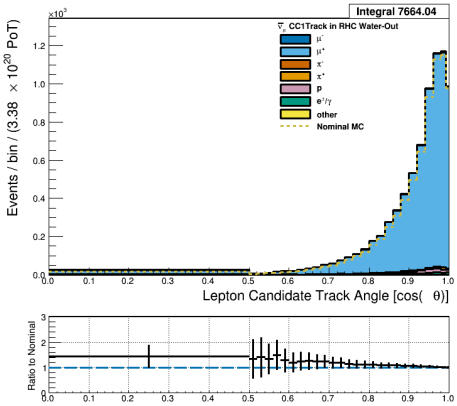
(a) Nominal MC

Sections/Figures/SamplesandSelections/numubarRHC/

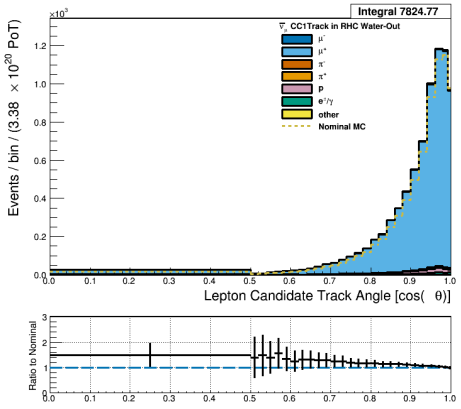
(b) Nominal MC from Highland2



(c) Flux



(d) Systematics

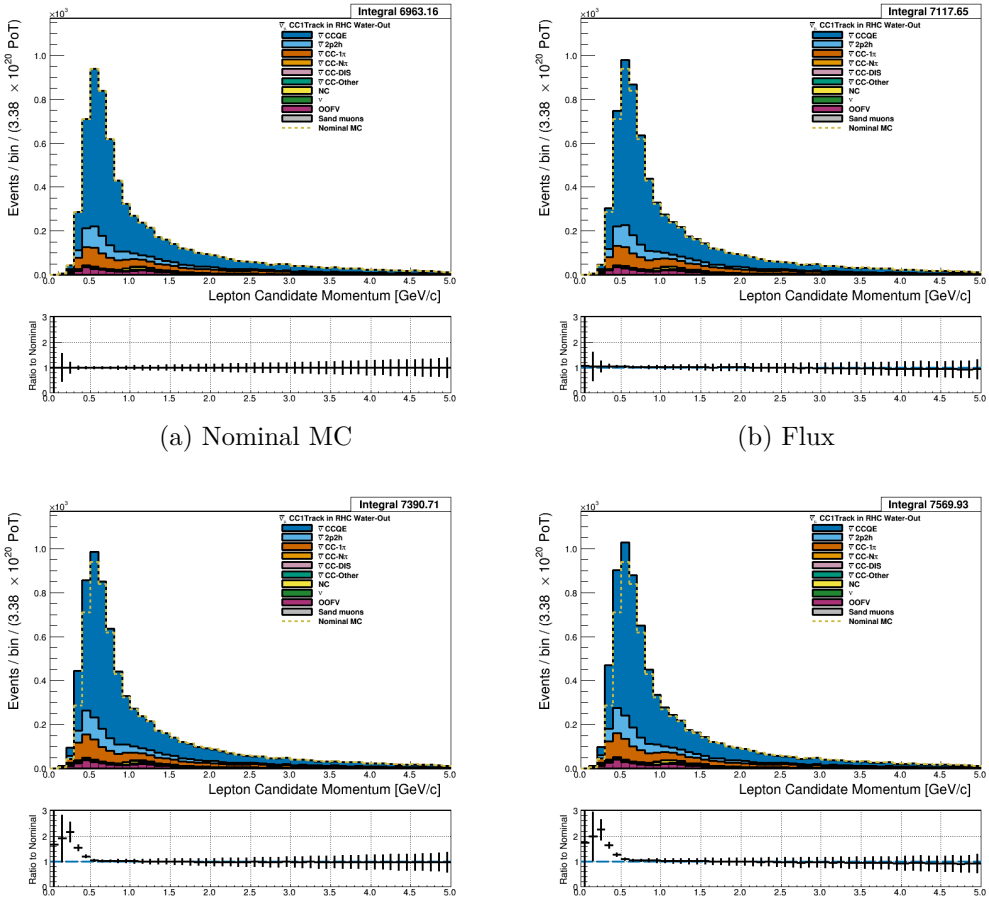


(e) Flux + systematics

Sections/Figures/SamplesandSelections/numubarRHC/

(f) Fully weighted in Highland2

Figure 1.30: Reconstructed lepton candidate angle separated by true particle species for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) Highland2 comparison for (a) without any weights applied using the "NOW" draw option. (c) The flux tuning is applied. (d) The systematic weighting is applied. (e) Both flux and systematic weighting is applied. (f) Highland2 comparison for (e).



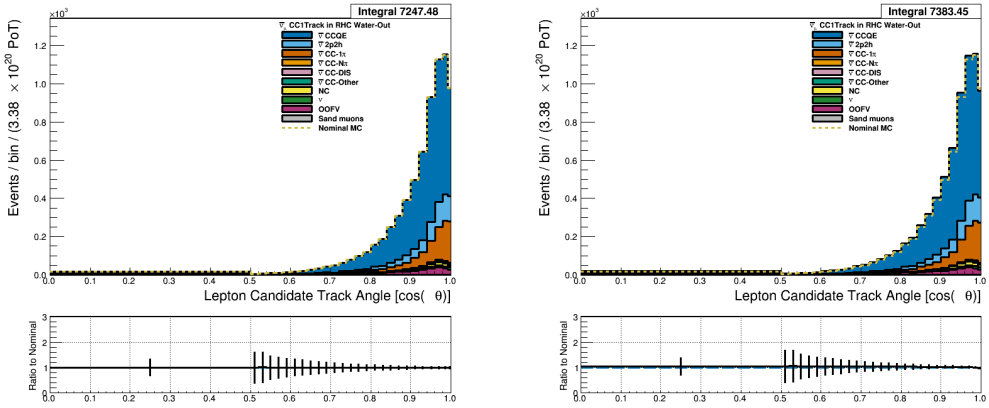
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.31: Reconstructed lepton candidate momentum separated by NEUT model interaction mode for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



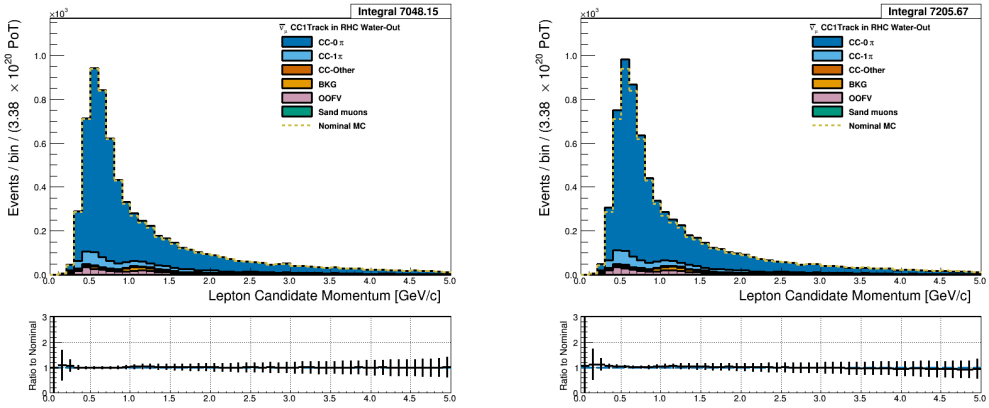
(a) Nominal MC

(b) Flux

(c) Systematics

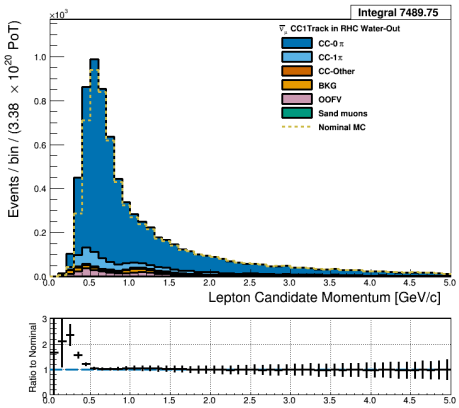
(d) Flux + systematics

Figure 1.32: Reconstructed lepton candidate $\cos\theta$ separated by NEUT model interaction mode for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

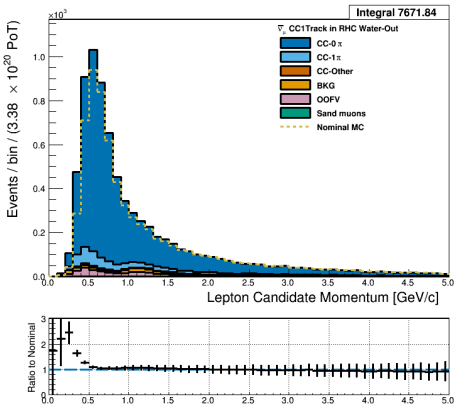


(a) Nominal MC

(b) Flux

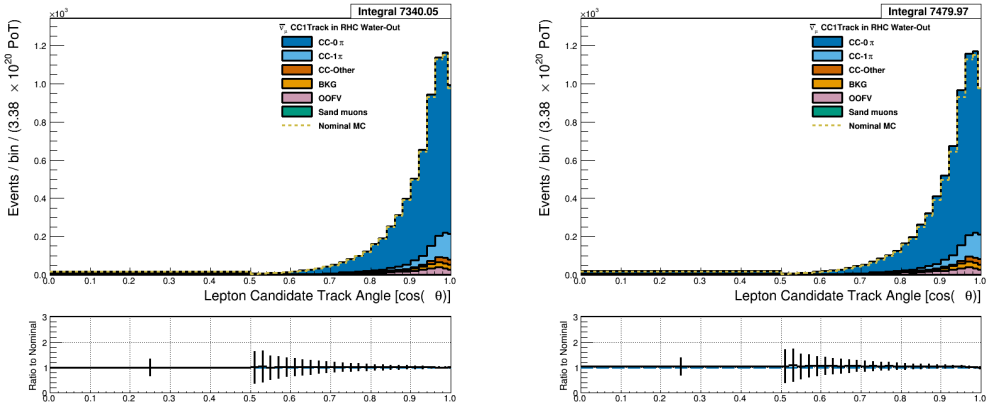


(c) Systematics



(d) Flux + systematics

Figure 1.33: Reconstructed lepton candidate momentum separated by topology for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



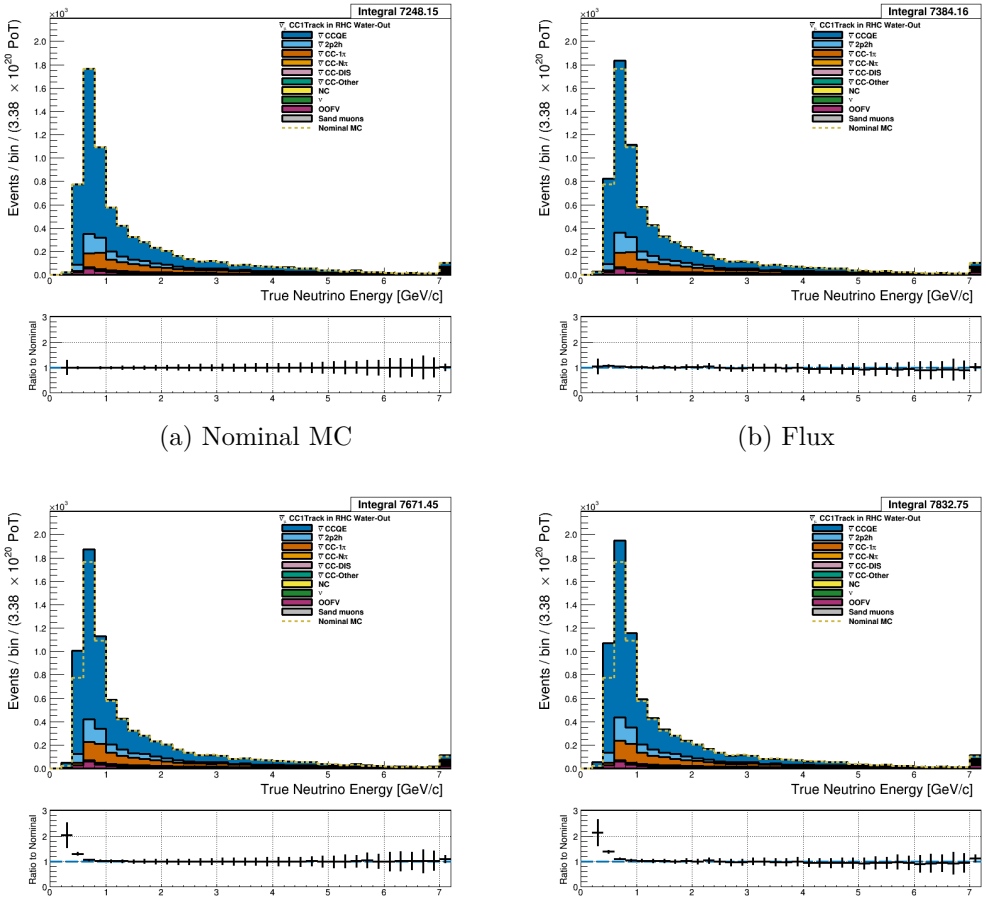
(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.34: Reconstructed lepton candidate $\cos\theta$ separated by topology for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.



(a) Nominal MC

(b) Flux

(c) Systematics

(d) Flux + systematics

Figure 1.35: True neutrino energy associated with the lepton candidate separated by NEUT model interaction mode for RHC $\overline{\nu}_\mu$ CC-Inc. events occurring in the PØD in water-out mode. (a) The nominal MC prediction without any weights applied. (b) The flux tuning is applied. (c) The systematic weighting is applied. (d) Both flux and systematic weighting is applied.

1.2.2.3 ν_μ Background Selection in RHC Mode: A-to

Add figures here

A-to

1.2.3 CC-N Tracks (CCnQE Enhanced)

Add figures here

1.2.4 Differences Between Water-Out and Water-In Samples

References

Nomenclature

BANFF The **b**eam **a**nd **n**ear detector task **f**orce is the group responsible for providing near detector constraints on cross section and flux model parameters.

CC-0π A **c**harged **c**urrent zero pion selection is an exclusive selection that selects neutrino interaction topologies only one MIP-like particle.

CC-Inclusive A **c**harged **c**urrent event selection that selects all neutrino interaction topologies with an outgoing charged lepton.

FD The **f**ar **d**etector refers to the particle detector in a long baseline neutrino oscillation experiment that is located far away from the neutrino production source where oscillated neutrinos are observed.

FGD A **f**ine **g**rain **d**etector is a detector made of closely spaced, small scintillating bars designed to provide precise resolution of charged particle tracks

FHC The **f**orward **h**orn **c**urrent beam configuration that focuses positively charged particles into the particle decay pipe. This configuration produces a very pure ν_μ neutrino beam

HMNT The **h**ighest **m**omentum **n**egatively-charged **t**rack in the bunch

HMPT The **h**ighest **m**omentum **p**ositively-charged **t**rack in the bunch

MIP A **m**inimum **i**onizing **p**article

ND280 The **N**ear **D**etector of T2K which is **280** meters away from the neutrino source.

ND The **n**ear **d**etector refers to the particle detector in a long baseline neutrino oscillation experiment that is located close to the neutrino production source before neutrino oscillations occur.

CECal The **C**entral **ECal** detector which is a part of the PØD inside ND280

PØD The π^0 detector (**pi-Ø d**etector)

PØDule A collection of two active scintillator bar layers inside the PØD

RHC The **r**everse **h**orn **c**urrent beam configuration that focuses negatively charged particles into the particle decay pipe. This configuration produces a $\overline{\nu}_\mu$ enriched neutrino beam with a significant ν_μ contribution.

FV The **f**iducial **v**olume of a detector is the region where the detector response is well understood

TPC A **t**ime **p**rojection **c**hamber is a device that detects and tracks charged particles with the application of strong electric fields

Tracker The region of ND280 consisting of two FGDs and TPCs

Global The Global reconstruction module responsible for making joined tracks between the subdetectors inside ND280

USECal The **U**p**s**tream **ECal** which is a part of the PØD inside ND280