README file for the data release of " Measurement of the muon neutrino charged-current single π^+ production on hydrocarbon using the T2K off-axis near detector ND280 "

The T2K Collaboration

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1 General

This data release contains the data corresponding to the article "Measurement of the muon neutrino charged-current single π^+ production on hydrocarbon using the T2K off-axis near detector ND280" published by T2K in Physica Review D (Arxiv: https://arxiv.org/abs/1909.03936)

We present the results both as ROOT and text files. The test files contain the cross-section results per bin followed by the covariance matrix. The lower and upper ends of each bin and the corresponding units are also shown.

2 $d\sigma/dp_\pi$

The files MomentumPion.root and MomentumPion.txt contain the $d\sigma/dp_\pi$ differential cross-section and the covariance matrix when the data is unfolded using the NEUT event generator. This data corresponds to Figure 14 in the paper.

The cross-section is computed within the following phase space constrains, see Table V in the paper:

- $\cos\theta_\mu \geq 0.2$.
- $p_\mu \geq 0.2$ GeV/c.
- $\cos\theta_\pi \geq 0.2$.

The momentum bins are defined in Table 1. The cross-section value in given in units of $10^{-38} cm^2/(GeV/c)/Nucleon$ and the covariance in units of $(10^{-38} cm^2/(GeV/c)/Nucleon)^2$

Table 1: Bin definition for the pion momentum cross-section.

Bin	Low End (GeV/c)	High End (GeV/c)
0	0.	0.2
1	0.2	0.3
2	0.3	0.4
3	0.4	0.5
4	0.5	0.5
5	0.6	0.7
6	0.7	0.8
7	0.8	0.9
8	0.9	1.0
9	1.0	1.1
10	1.1	1.2
11	1.2	1.3
12	1.3	1.4
13	1.4	1.6
14	1.6	2.0
15	2.0	3.0
16	3.0	15.0

3 $d\sigma/dQ^2$

The files Q2.root and Q2.txt contain the $d\sigma dQ^2$ cross-section and the covariance matrix associated when the data is unfolded using the NEUT event generator. This data corresponds to Figure 13 in the paper. The Q^2 is not unfolded to the true Q^2 value but to the reconstructed one without detector effects, following the equations (1) and (2) in the paper.

The cross-section is computed within the following phase space constrains:

- $\cos\theta_\mu \geq 0.2$.
- $p_\mu \geq 0.2$ GeV/c.
- $\cos\theta_\pi \geq 0.2$.
- $p_\pi \geq 0.2$ GeV/c.

The bins in Q^2 are defined in Table 2. The cross-section value in given in units of $10^{-38}cm^2/(GeV/c)^2/Nucleon$ and the covariance in units of $(10^{-38}cm^2/Nucleon)^2$.

Table 2: Bin definition for the Q^2 dependet cross-section.

Bin	Low End (GeV/c)	High End (GeV/c)
0	0.	0.1
1	0.1	0.2
2	0.2	0.3
3	0.3	0.4
4	0.4	0.5
5	0.5	0.6
6	0.6	0.7
7	0.7	0.8
8	0.8	0.9
9	0.9	1.0
10	1.0	1.2
11	1.1	1.4
12	1.4	1.6
13	1.6	1.8
14	1.8	2.0
15	2.0	3.3

4 $d\sigma/d\theta_\pi$

The files ThetaPion.root and ThetaPion.txt contain the $d\sigma/d\theta_\pi$ single differential cross-section and the covariance matrix associated. Data were unfolded using the NEUT event generator. This data corresponds to Figure 15 in the paper. The angle is computed with respect to the mean neutrino direction.

The cross-section is computed within the following phase space constrains:

- $\cos\theta_\mu \geq 0.2$.
- $p_\mu \geq 0.2$ GeV/c.
- $\cos\theta_\pi \geq 0.0$.

The angle bins are defined in Table 3. The cross-section value in given in units of $10^{-38}cm^2/rad/Nucleon$ and the covariance in units of $(10^{-38}cm^2/rad/Nucleon)^2$

Table 3: Bin definition for the pion angle single differential cross-section.

Bin	Low End (rad)	High End (rad)
0	0.	0.1
1	0.1	0.2
2	0.2	0.3
3	0.3	0.4
4	0.4	0.5
5	0.5	0.6
6	0.6	0.7
7	0.7	0.8
8	0.8	0.9
9	0.9	1.0
10	1.0	1.2
11	1.2	1.4
12	1.4	π

5 $d\sigma/d\theta_{\pi,\mu}$

The files Thetapimu.root and Thetapimu.txt contain $d\sigma/d\theta_{\pi,\mu}$ single differential cross-section with respect to the neutrino direction and the covariance matrix associated. Data were unfolded using the NEUT event generator. This data corresponds to Figure 16 in the paper.

The cross-section is computed within the following phase space constrains:

- $\cos\theta_{\mu} \geq 0.2$.
- $p_{\mu} \geq 0.2$ GeV/c.
- $\cos\theta_{\pi} \geq 0.2$.
- $p_{\pi} \geq 0.2$ GeV/c.

The pipon-muon angle bins are defined in Table 4. The cross-section value in given in units of $10^{-38} cm^2/rad/Nucleon$ and the covariance in units of $(10^{-38} cm^2/rad/Nucleon)^2$.

Table 4: Bin definition for the pion angle single differential cross-section.

Bin	Low End (rad)	High End (rad)
0	0.	0.1
1	0.1	0.2
2	0.2	0.3
3	0.3	0.4
4	0.4	0.5
5	0.5	0.6
6	0.6	0.7
7	0.7	0.8
8	0.8	0.9
9	0.9	1.0
10	1.0	1.2
11	1.2	1.4
12	1.4	1.6
13	1.6	1.8
14	1.8	2.0
15	2.0	π

6 $d\sigma/d\cos\theta_{Adler}$

The files theta_adler.root and theta_adler.txt contain the $d\sigma/d\cos\theta_{Adler}$ single differential cross-section and the covariance matrix associated. Data were unfolded using the NEUT event generator. This data corresponds to Figure 17 in the paper. θ_{Adler} is not unfolded to the true value but the observable without detector effects following the recipe described in section E.2 of the paper.

The $d\sigma/d\cos\theta_{Adler}$ is computed within the following phase space constrains:

- $\cos\theta_\mu \geq 0.2$.
- $p_\mu \geq 0.2$ GeV/c.
- $\cos\theta_\pi \geq 0.2$.
- $p_\pi \geq 0.2$ GeV/c.

The $theta_Adler$ angle bins are defined in Table 5. The cross-section value in given in units of $10^{-38} cm^2/Nucleon$ and the covariance in units of $(10^{-38} cm^2/Nucleon)^2$

Table 5: Bin definition for the pion angle single differential cross-section.

Bin	Low End (rad)	High End (rad)
0	-1.0	-0.9
1	-0.9	-0.8
2	-0.8	-0.7
3	-0.7	-0.6
4	-0.6	-0.5
5	-0.5	-0.4
6	-0.4	-0.3
7	-0.3	-0.2
8	-0.2	-0.1
9	-0.1	0.0
10	0.0	0.1
11	0.1	0.2
12	0.2	0.3
13	0.3	0.4
14	0.4	0.5
15	0.5	0.6
16	0.6	0.7
17	0.7	0.8
18	0.8	0.9
19	0.8	1.0

7 $d\sigma/\phi_{Adler}$

The files phi_adler.root and phi_adler.txt contain the cross-section $d\sigma/d\phi_{Adler}$ and the covariance matrix associated. Data were unfolded using the NEUT event generator. This data corresponds to Figure 17 in the paper. ϕ_{Adler} is not unfolded to the true value but to the observable without detector effects following the recipe described in section E.2 of the paper.

The $d\sigma/d\phi_{Adler}$ is computed within the following phase space constrains:

- $\cos\theta_\mu \geq 0.2$.
- $p_\mu \geq 0.2$ GeV/c.
- $\cos\theta_\pi \geq 0.2$.
- $p_\pi \geq 0.2$ GeV/c.

The ϕ_{Adler} angle bins are defined in Table 6. The cross-section value in given in units of $10^{-38} cm^2/rad/Nucleon$ and the covariance in units of $(10^{-38} cm^2/rad/Nucleon)^2$

Table 6: Bin definition for the pion angle single differential cross-section.

Bin	Low End (rad)	High End (rad)
0	$-\pi$	-2.8
1	-2.8	-2.4
2	-2.4	-2.0
3	-2.0	-1.6
4	-1.6	-1.2
5	-1.2	-0.8
6	-0.8	-0.4
7	-0.4	0.0
8	0.0	0.4
9	0.4	0.8
10	0.8	1.2
11	1.2	1.6
12	1.6	2.0
13	2.0	2.4
14	2.4	2.8
15	2.8	π

8 $d\sigma/dp_\mu d\cos\theta_\mu$

The files PmuThetamu.root and PmuThetamu.txt contain the $d\sigma/dp_\mu d\cos\theta_\mu$ double differential cross-section and the covariance matrix when the data is unfolded using the NEUT event generator. This data corresponds to Figure 12 in the paper. The covariance matrix is shown in Figure 11 in the paper.

The double differential cross-section is provided within the following phase space constrains, see Table V in the paper:

- $\cos\theta_\mu \geq 0.0$.
- The selection includes Michel Electron events to tag the pion.

The momentum and angle bins are defined in Table 7. The root file contains four histograms, each one corresponding to a bin in $\cos\theta_\mu$. The correspondence to angle bins is shown in Table 7. The cross-section value is given in units of $10^{-38} cm^2 c/GeV/Nucleon$ and the covariance matrix in units of $(10^{-38} cm^2 c/GeV/Nucleon)^2$

Table 7: Bin definition for the double differential cross-section.

Bin	$\cos\theta_\mu$ Low End	$\cos\theta_\mu$ High End	p_μ Low End (GeV/c)	p_μ High End (GeV/c)	Root histogram name
0	0.	0.8	0.	0.4	p_mu_theta_mu_0
1			0.4	1.2	
2			1.2	1.6	
3			1.6	2.0	
4			2.0	15.0	
5	0.8	0.85	0.	0.4	p_mu_theta_mu_1
6			0.4	1.2	
7			1.2	1.6	
8			1.6	2.0	
9			2.0	15.0	
10	0.85	0.9	0.	0.4	p_mu_theta_mu_2
11			0.4	1.2	
12			1.2	1.6	
13			1.6	2.0	
14			2.0	15.0	
15	0.9	1.0	0.	0.4	p_mu_theta_mu_3
16			0.4	1.2	
17			1.2	1.6	
18			1.6	2.0	
19			2.0	15.0	

The covariance matrix is stored in PmuThetamu.txt following the format:

$$(bin, bin) \quad covariance\, value$$

where "bin" is related to kinematical values following the relation in Table 7.

9 Flux

The files flux.txt and flux.root contain the integrated flux prediction at the near detector of the T2K experiment. This flux is given in units of the total number of neutrinos per unit of energy and area ($cm^{-2}/50MeV$) and it is computed by multiplying the flux for each period times the number of protons per target (0.556×10^{21}) .

The bin edges are listed in the flux.txt. The date structure in the file is given in Table 8.

Table 8: Bin definition for the double differential cross-section.

bin number	low end (GeV)	high end (GeV)	POT integrated flux $cm^{-2}/50MeV$