Multi-ring ν_e CC1π^+ Selection Studies

Trevor Towstego
Multi-Ring ν_e CC1π^+ Meeting
May 3, 2019

Overview

- Updated new 1Re0de selection

  – More relevant training variables used

  – More relevant plots

- Attended hybrid sample meeting (Mine) on Tuesday

- Lepton Photon 2019

pre-BDT Cuts and BDT Training Variables

pre-BDT cuts		
Cut	**0 decay e**	**1 decay e**
FCFV	Wall > 50 cm	
not 1Re	not 1Re-like (TN319, no FCFV requirement)	
0 decay e	1 sub-event	2 sub-events
E_{rec}	E_{rec} < 1.5 GeV	

1Re0de BDT Training Variables	
Trial 1	**Trial 3**
up to 3-ring -ln(L) ratios $m_{\pi 0}$	up to 3-ring -ln(L) ratios $m_{\pi 0}$ 1R+2R fit momenta E_{rec} (CCQE) ToWall e (1Re) ToWall e_1 and e_2 (2Ree) p_{low} (2Ree) $\cos(\theta_{ee})$ (2Ree)

1Re0de Selection: Trial 1

visible FSP:	1e1π$^{+/-}$	1e	1e other	1μ1π$^{+/-}$	1μ	1μ other	0l1π$^+$	0l1π$^-$	0l1π^0	0lNπ	0l other	1e$^{+/-}$	other	FOM
FCFV	4.63	45.01	8.93	8.96	41.60	32.68	7.69	12.16	83.11	17.28	15.76	45.01	232.78	2.70
pre-BDT	2.45	6.92	3.88	3.22	25.21	7.20	7.07	11.41	75.78	10.43	13.91	6.92	160.56	0.53
post-BDT	0.21	4.15	0.15	0.02	0.07	0.05	0.07	0.09	2.46	0.18	0.19	4.15	3.50	1.50

NEUT mode:	ν_e CC1π$^+$	ν_e CCQE	ν_e CCNπ	ν_e CCDIS	ν_e CCother	$\overline{\nu}_e$ CC	ν_μ CC	NC				$\nu_e/\overline{\nu}_e$ CCQE	other	FOM
FCFV	9.04	39.19	2.29	1.12	4.10	2.82	83.28	135.95				40.68	237.13	2.44
pre-BDT	3.77	5.98	0.68	0.13	2.13	0.57	35.67	118.57				6.23	161.24	0.48
post-BDT	0.52	3.57	0.04	0.00	0.13	0.25	0.14	2.99				3.76	3.89	1.36

ν type:	osc ν_e CC	int ν_e CC	ν_μ CC	NC								osc $\nu_e/\overline{\nu}_e$ CC	other	FOM
FCFV	38.06	20.50	83.28	135.95								38.06	239.76	2.28
pre-BDT	8.79	4.46	35.67	118.57								8.79	158.68	0.68
post-BDT	3.01	1.51	0.14	2.99								3.01	4.64	1.09

Existing 1Re selections (TN319)

TN319 1-Ring Samples (10^{21} POT)				
Sample	osc ν_e CC	int ν_e CC	ν_μ CC	NC
ν_e CCQE	34.84	5.40	0.17	2.77
ν_e CC1π$^+$	4.61	0.76	0.11	0.25

1Re0de Selection: Trial 3

visible FSP:	1e1π$^{+/-}$	1e	1e other	1μ1π$^{+/-}$	1μ	1μ other	0l1π$^+$	0l1π$^-$	0l1π^0	0lNπ	0l other	1e$^{+/-}$	other	FOM
FCFV	4.63	45.01	8.93	8.96	41.60	32.68	7.69	12.16	83.11	17.28	15.76	45.01	232.78	2.70
pre-BDT	2.45	6.92	3.88	3.22	25.21	7.20	7.07	11.41	75.78	10.43	13.91	6.92	160.56	0.53
post-BDT	0.24	4.97	0.19	0.02	0.06	0.06	0.05	0.09	2.66	0.13	0.16	4.97	3.67	1.69

NEUT mode:	ν_e CC1π$^+$	ν_e CCQE	ν_e CCNπ	ν_e CCDIS	ν_e CCother	$\bar{\nu}_e$ CC	ν_μ CC	NC				$\nu_e/\bar{\nu}_e$ CCQE	other	FOM
FCFV	9.04	39.19	2.29	1.12	4.10	2.82	83.28	135.95				40.68	237.13	2.44
pre-BDT	3.77	5.98	0.68	0.13	2.13	0.57	35.67	118.57				6.23	161.24	0.48
post-BDT	0.62	4.29	0.05	0.00	0.17	0.28	0.14	3.09				4.50	4.15	1.53

ν type:	osc ν_e CC	int ν_e CC	ν_μ CC	NC								osc $\nu_e/\bar{\nu}_e$ CC	other	FOM
FCFV	38.06	20.50	83.28	135.95								38.06	239.76	2.28
pre-BDT	8.79	4.46	35.67	118.57								8.79	158.68	0.68
post-BDT	3.65	1.76	0.14	3.09								3.65	4.99	1.24

Existing 1Re selections (TN319)

TN319 1-Ring Samples (10^{21} POT)				
Sample	osc ν_e CC	int ν_e CC	ν_μ CC	NC
ν_e CCQE	34.84	5.40	0.17	2.77
ν_e CC1π$^+$	4.61	0.76	0.11	0.25

Trial 3 now performs slightly better than last week

1Re0de: Trial Comparison

		Trial 1	Trial 3
Final State Particles	**1e$^{+/-}$**	4.15	4.97
	other	3.50	3.67
	FOM	1.50	1.69
NEUT Mode	**$\nu_e/\bar{\nu}_e$ CCQE**	3.76	4.50
	other	3.89	4.15
	FOM	1.36	1.53
Neutrino Type	**osc $\nu_e/\bar{\nu}_e$ CC**	3.01	3.65
	other	4.64	4.99
	FOM	1.09	1.24

1Re0de BDT Training Variables	
Trial 1	**Trial 3**
up to 3-ring -ln(L) ratios $m_{\pi 0}$	up to 3-ring -ln(L) ratios $m_{\pi 0}$ 1R+2R fit momenta E_{rec} (CCQE) ToWall e (1Re) ToWall e_1 and e_2 (2Ree) p_{low} (2Ree) $\cos(\theta_{ee})$ (2Ree)

Variable Importance
From 1Re0de Trial 3 Training

- ToWall, $\cos(\theta_{ee})$, and $m_{\pi 0}$ are the most important

- Likelihood ratios of interest:

  - `nll6  := nll1rmu  - nll2rpie`
  - `nll5  := nll1rmu  - nll2repi`
  - `nll1  := nll1re   - nll1rmu`
  - `nll4  := nll1re   - nll2ree`
  - `nll7  := nll1rmu  - nll2ree`
  - `nll8  := nll2repi - nll2rpie`
  - `nll2  := nll1re   - nll2repi`
  - `nll3  := nll1re   - nll2rpie`
  - `nll10 := nll2rpie - nll2ree`
  - `nll9  := nll2repi - nll2ree`

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---------------------------------------------
Rank : Variable    : Variable Importance
---------------------------------------------
   1 : towall_e2   : 4.336e-02
   2 : cosee_rec   : 4.161e-02
   3 : m_pi0       : 3.459e-02
   4 : towall_e    : 3.316e-02
   5 : towall_e1   : 3.314e-02
   6 : pe_2rpie    : 3.291e-02
   7 : pe1_2ree    : 3.120e-02
   8 : e_rec_ccqe  : 3.082e-02
   9 : pe_2repi    : 3.070e-02
  10 : nll6        : 3.019e-02
  11 : pe_1re      : 2.970e-02
  12 : nll5        : 2.899e-02
  13 : pmu_1rmu    : 2.828e-02
  14 : nll1        : 2.762e-02
  15 : ppi_2rpie   : 2.677e-02
  16 : nll4        : 2.632e-02
  17 : nll7        : 2.589e-02
  18 : pe2_2ree    : 2.583e-02
  19 : nll8        : 2.461e-02
  20 : nll2        : 2.438e-02
  21 : nll3        : 2.414e-02
  22 : nll10       : 2.369e-02
  23 : nll9        : 2.364e-02
  24 : p_low_2ree  : 2.149e-02
  25 : nll18       : 2.090e-02
  26 : ppi_2repi   : 2.055e-02
  27 : nll17       : 2.053e-02
  28 : nll15       : 1.805e-02
  29 : nll13       : 1.786e-02
  30 : nll16       : 1.783e-02
  31 : nll21       : 1.753e-02
  32 : nll14       : 1.745e-02
  33 : nll11       : 1.688e-02
  34 : nll12       : 1.684e-02
  35 : nll19       : 1.682e-02
  36 : nll22       : 1.681e-02
  37 : nll20       : 1.633e-02
  38 : nll24       : 1.085e-02
  39 : nll25       : 1.067e-02
  40 : nll23       : 1.050e-02
  41 : nll26       : 1.045e-02
  42 : nll27       : 1.018e-02
  43 : nll28       : 9.965e-03
```

Variable Importance

From 2Reπ1de Trial 3 Training

- ToWall, $\cos(\theta_{e\pi})$, $m_{\pi 0}$, and p_{low} are the most important

- Likelihood ratios of interest:
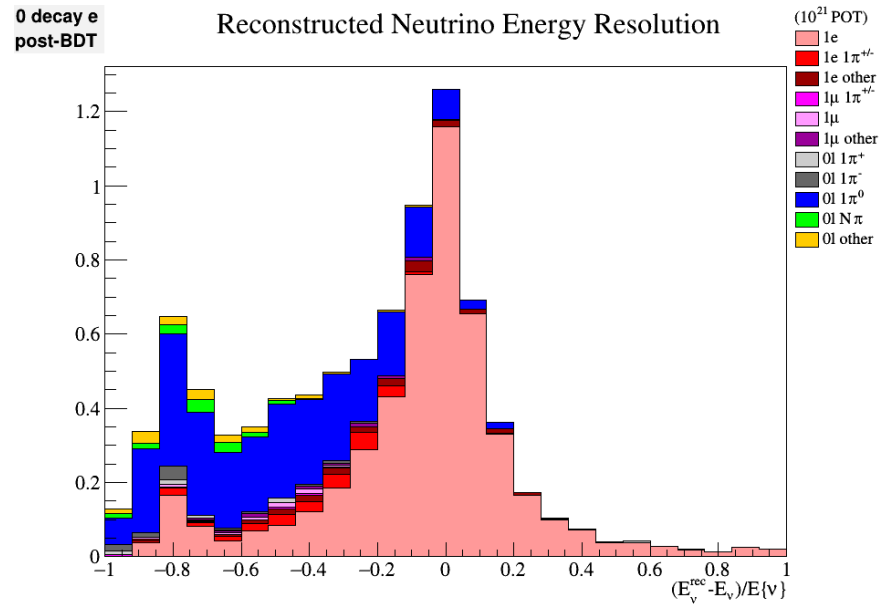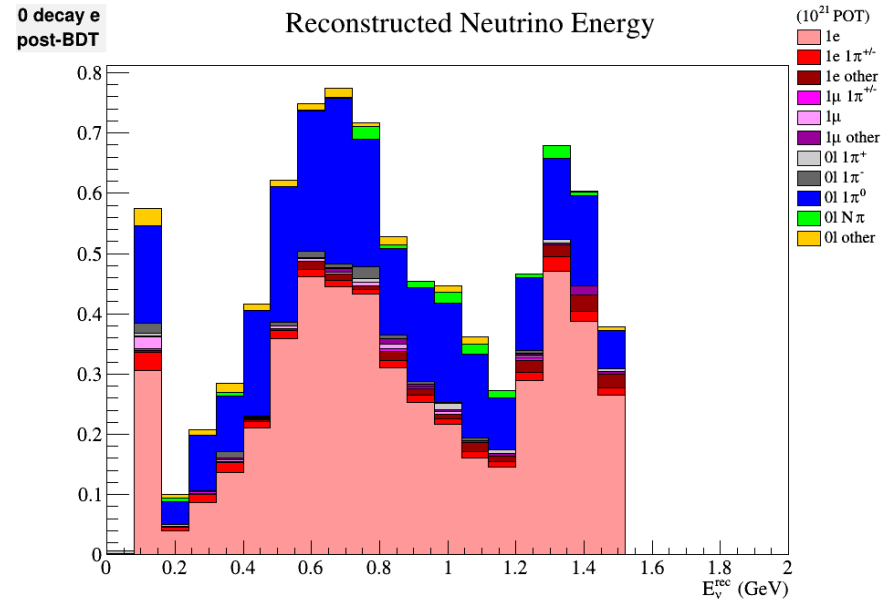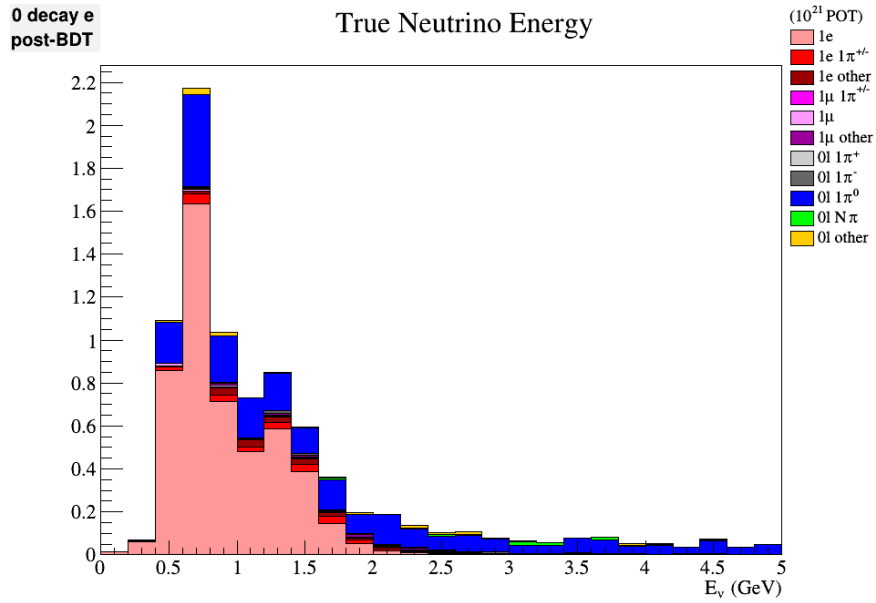 - `nll1  := nll1re   – nll1rmu`
  - `nll4  := nll1re   – nll2ree`
  - `nll6  := nll1rmu  – nll2rpie`
  - `nll2  := nll1re   – nll2repi`
  - `nll9  := nll2repi – nll2ree`
  - `nll5  := nll1rmu  – nll2repi`
  - `nll7  := nll1rmu  – nll2ree`
  - `nll8  := nll2repi – nll2rpie`
  - `nll3  := nll1re   – nll2rpie`
  - `nll10 := nll2rpie – nll2ree`

```
-----------------------------------------------
Rank : Variable      : Variable Importance
-----------------------------------------------
   1 : towall_pi2r   : 4.577e-02
   2 : cosepi_rec    : 4.311e-02
   3 : towall_e2r    : 4.248e-02
   4 : m_pi0         : 3.534e-02
   5 : p_low_2repi   : 3.270e-02
   6 : pe2_2ree      : 3.255e-02
   7 : d2se          : 3.130e-02
   8 : nll1          : 2.998e-02
   9 : nll4          : 2.913e-02
  10 : nll6          : 2.844e-02
  11 : pe1_2ree      : 2.818e-02
  12 : pe_2rpie      : 2.811e-02
  13 : nll2          : 2.688e-02
  14 : nll9          : 2.664e-02
  15 : pe_2repi      : 2.633e-02
  16 : ppi_2rpie     : 2.596e-02
  17 : pmu_1rmu      : 2.577e-02
  18 : pe_1re        : 2.535e-02
  19 : nll5          : 2.262e-02
  20 : nll7          : 2.228e-02
  21 : nll8          : 2.149e-02
  22 : nll3          : 2.063e-02
  23 : nll10         : 2.045e-02
  24 : nll14         : 1.944e-02
  25 : nll19         : 1.941e-02
  26 : nll11         : 1.936e-02
  27 : nll20         : 1.929e-02
  28 : nll18         : 1.918e-02
  29 : nll12         : 1.905e-02
  30 : nll16         : 1.867e-02
  31 : nll15         : 1.853e-02
  32 : nll22         : 1.828e-02
  33 : nll13         : 1.805e-02
  34 : nll21         : 1.771e-02
  35 : nll17         : 1.744e-02
  36 : ppi_2repi     : 1.552e-02
  37 : e_rec_cc1pi   : 1.446e-02
  38 : nll23         : 1.321e-02
  39 : nll28         : 1.252e-02
  40 : nll25         : 1.249e-02
  41 : nll26         : 1.215e-02
  42 : nll27         : 1.204e-02
  43 : nll24         : 1.169e-02
```
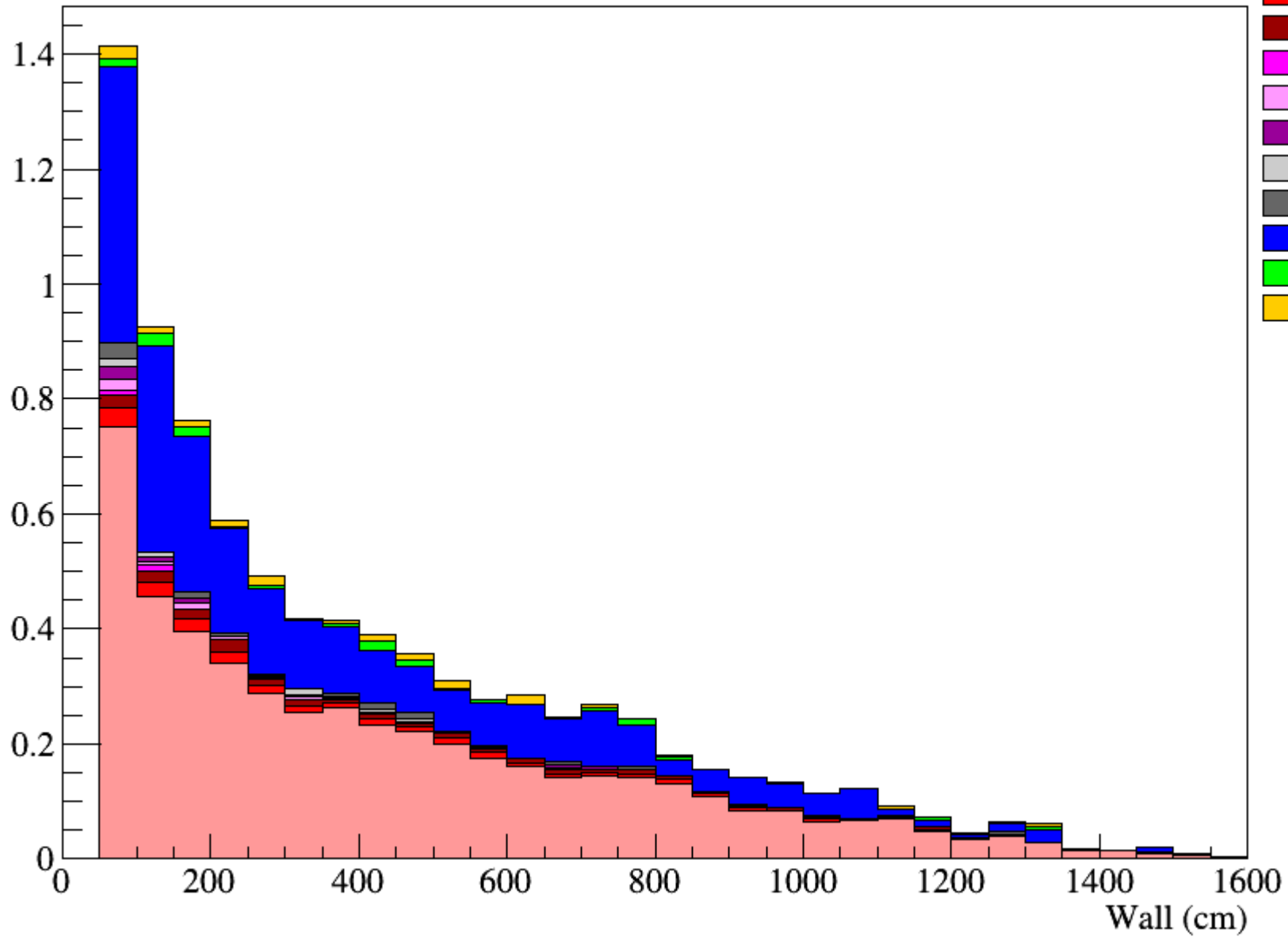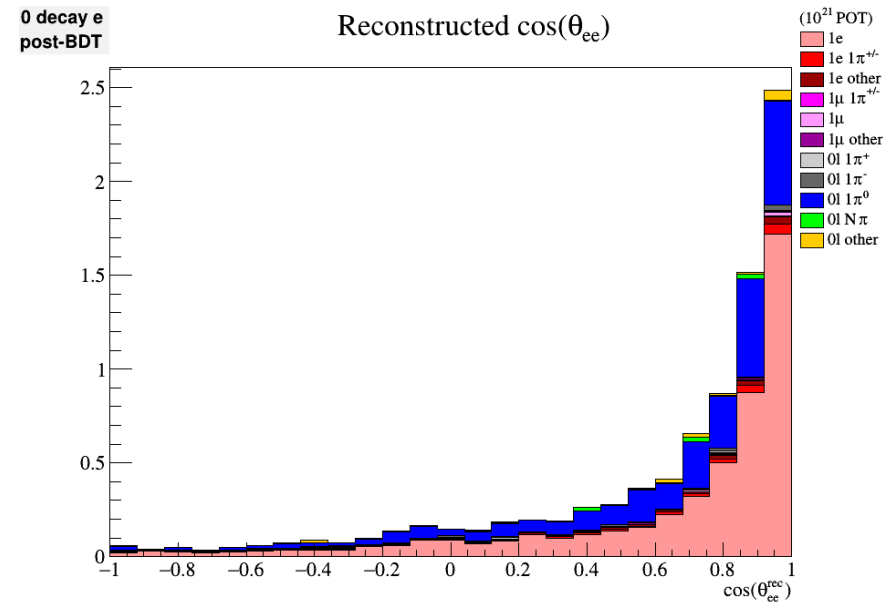
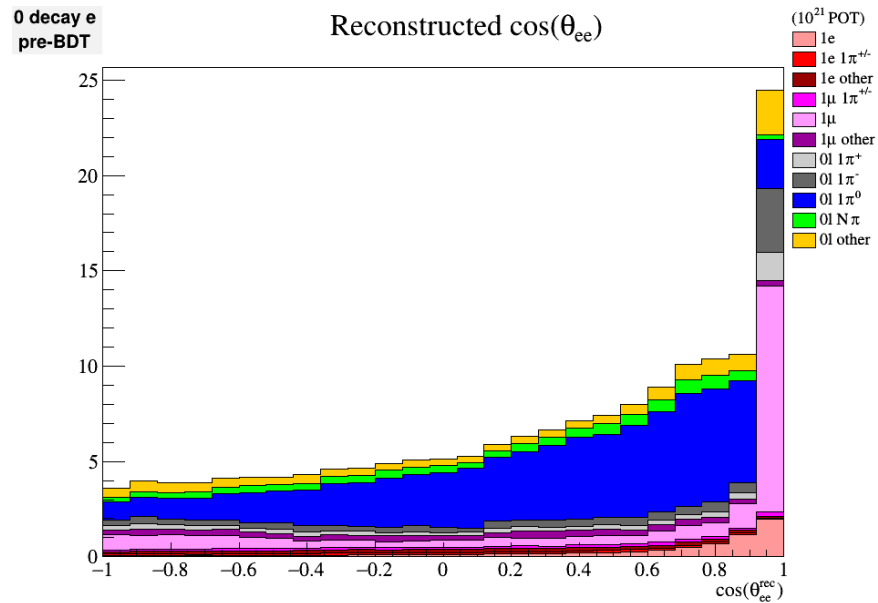# Kinematics Plots
1Re0de sample

Energy

0 decay e post-BDT

Wall

(10^{21} POT)
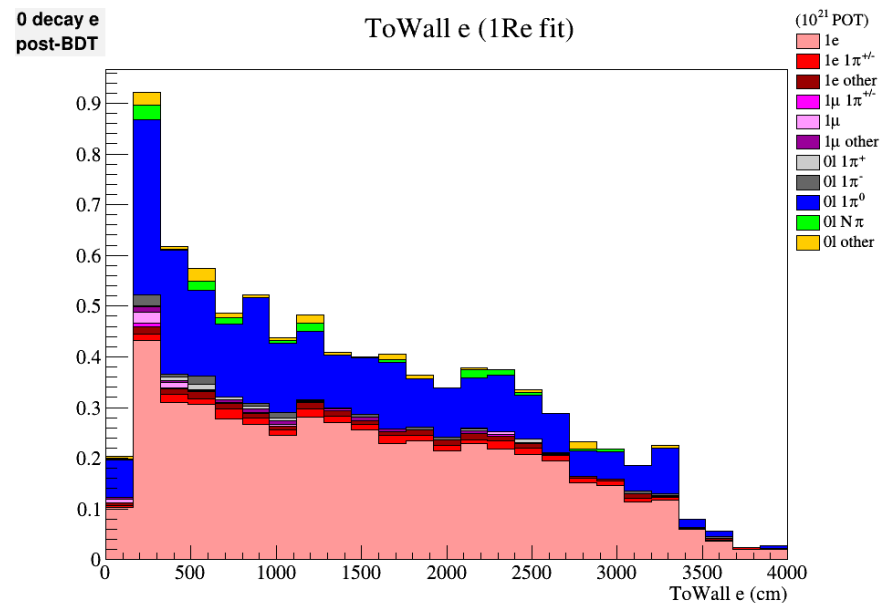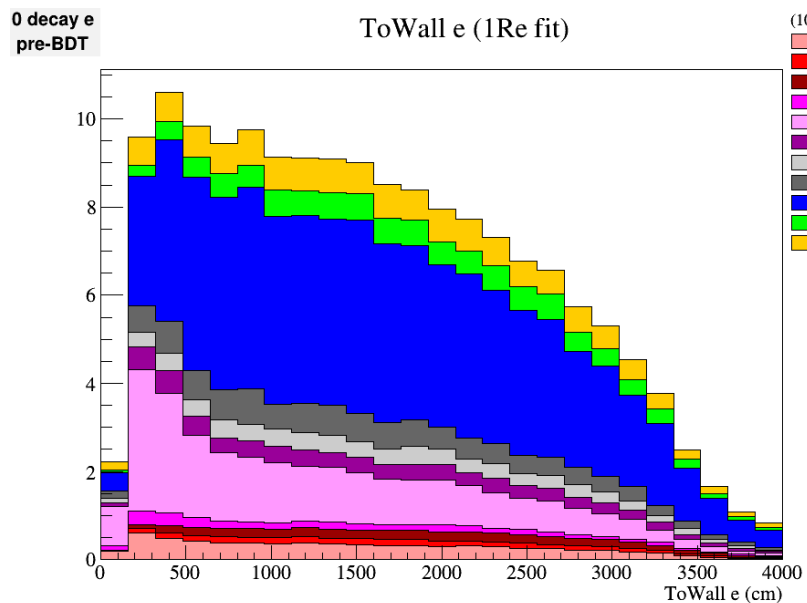
- 1e
- 1e $1\pi^{+/-}$
- 1e other
- 1μ $1\pi^{+/-}$
- 1μ
- 1μ other
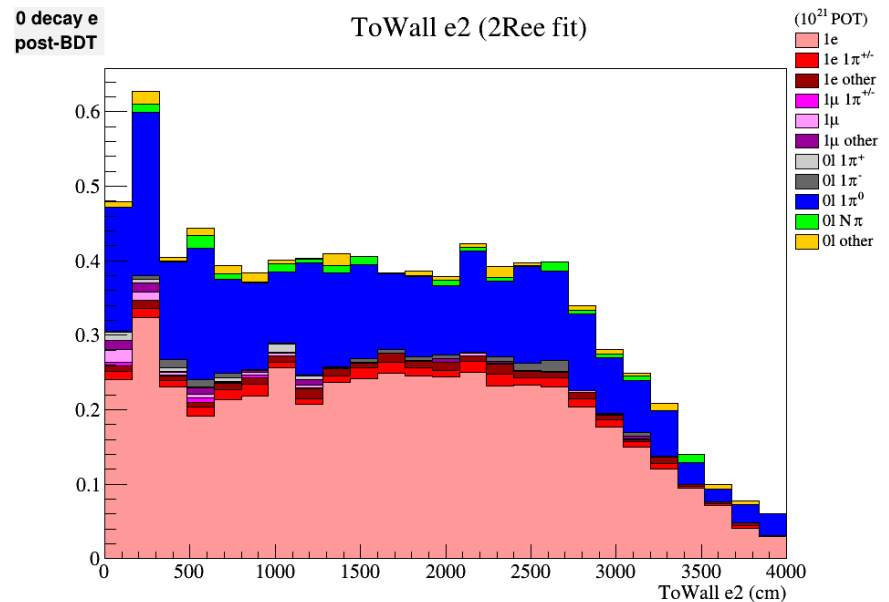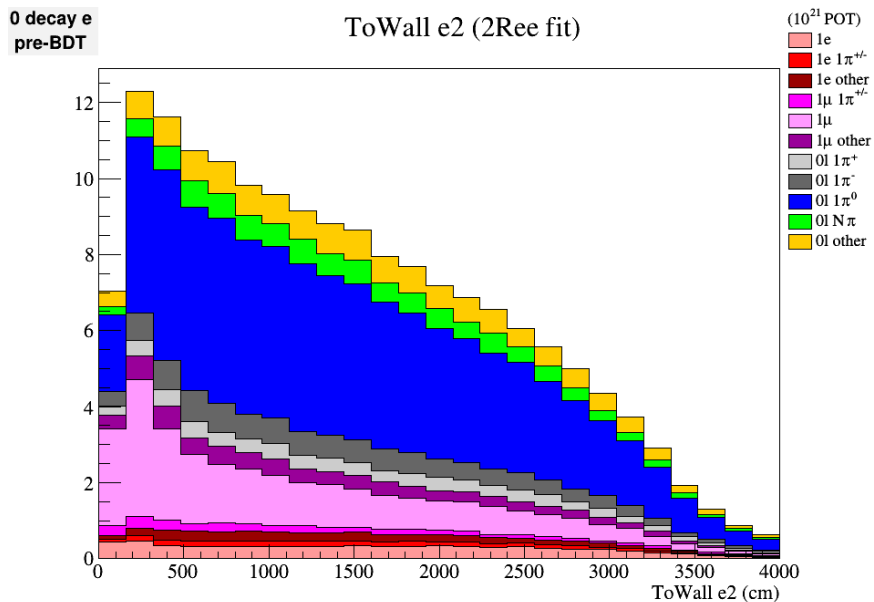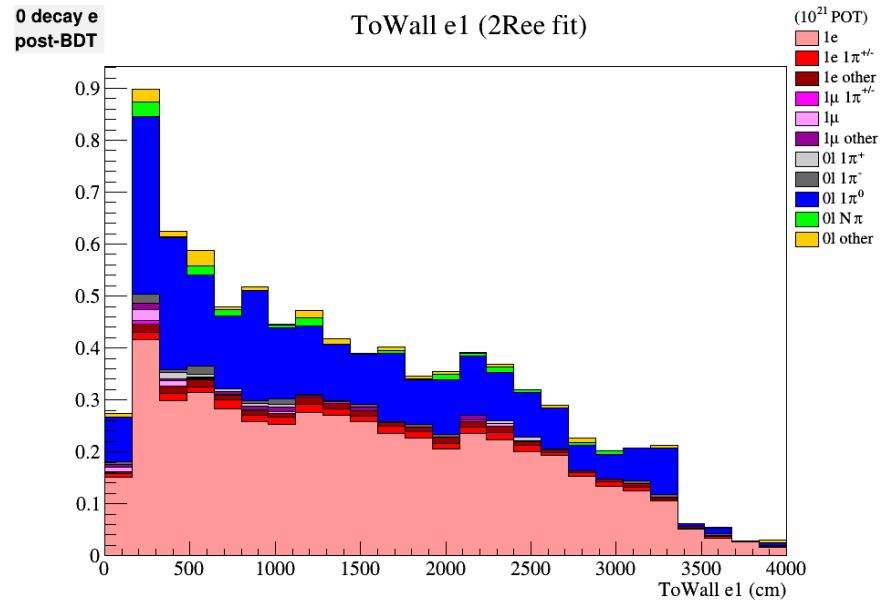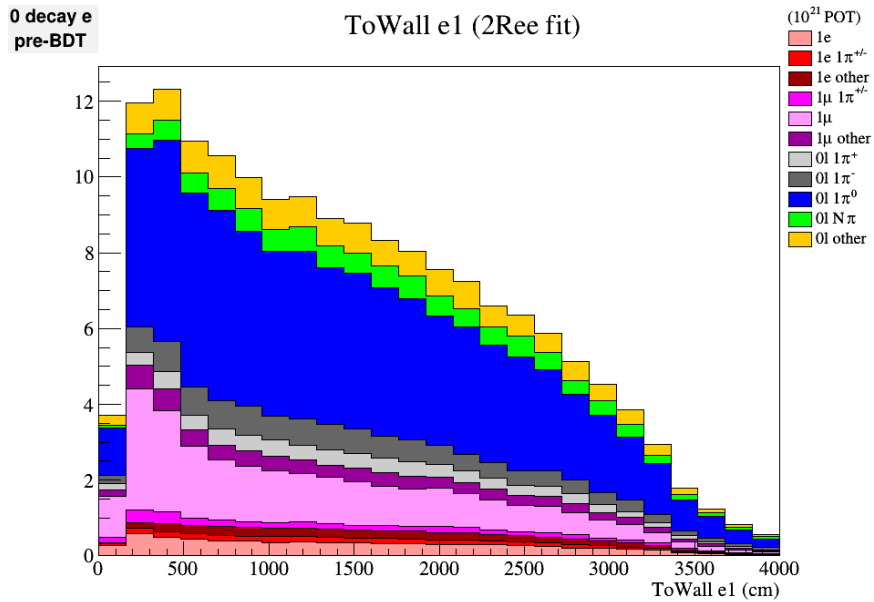- 0l $1\pi^+$
- 0l $1\pi^-$
- 0l $1\pi^0$
- 0l Nπ
- 0l other

Wall (cm)

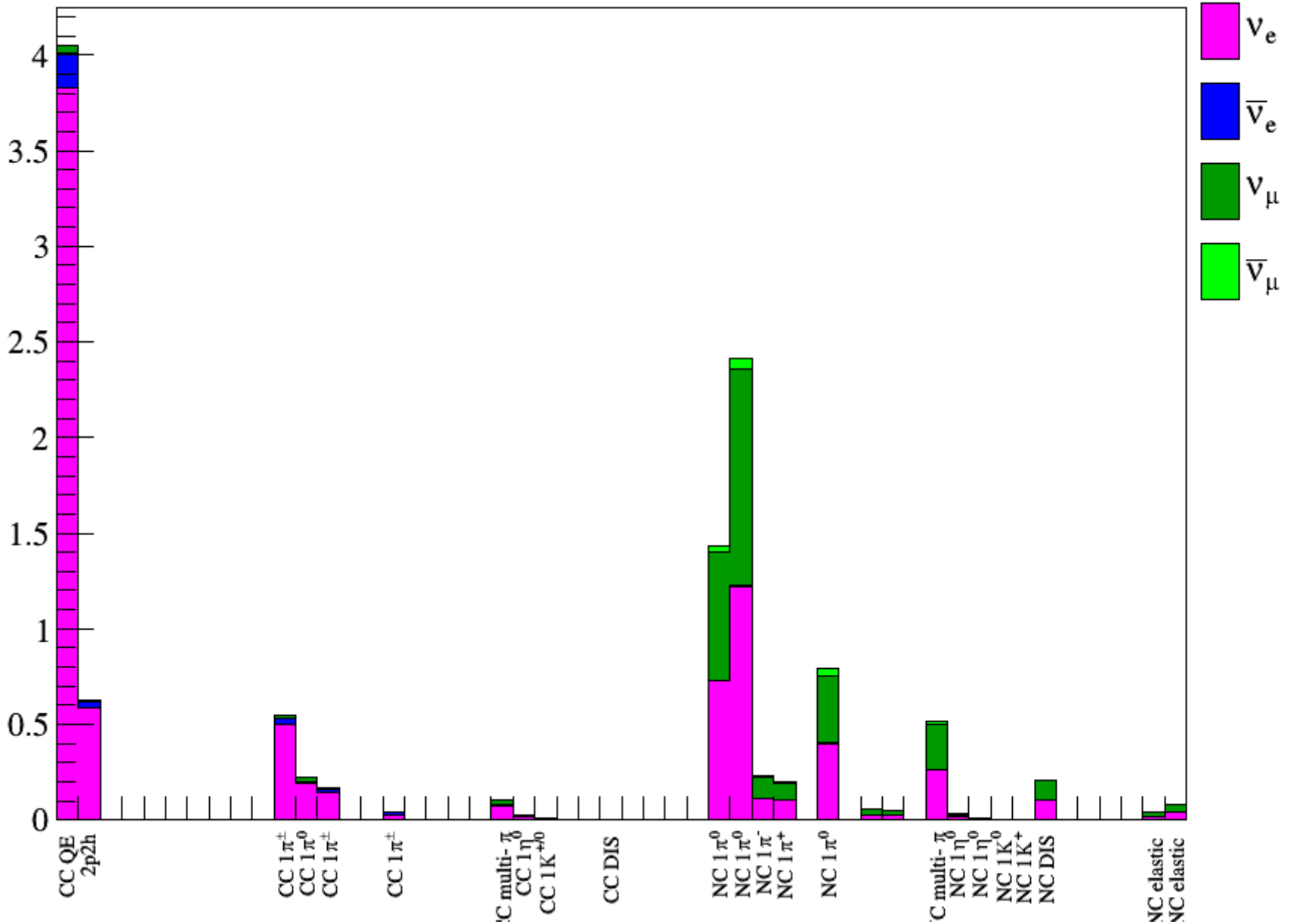# cos(θ$_{ee}$): pre- and post-BDT

ToWall e (1Re): pre- and post-BDT

ToWall e₁ and e₂ (2Ree): pre- and post-BDT

0 decay e post-BDT

Neutrino Interaction Mode (NEUT)

$(10^{21}\ \text{POT})$

Legend:
- ν_e
- $\overline{\nu}_e$
- ν_μ
- $\overline{\nu}_\mu$

Horizontal axis labels: CC QE, 2p2h, CC 1$\pi^\pm$, CC 1π^0, CC 1$\pi^\pm$, CC 1$\pi^\pm$, C multi-π, CC 1η^0, CC 1K^{+0}, CC DIS, NC 1π^0, NC 1π^0, NC 1π^-, NC 1π^+, NC 1π^0, C multi-π, NC 1η^0, NC 1η^0, NC 1K^0, NC 1K^+, NC DIS, NC elastic, NC elastic

NEUT Mode vs. Visible Final State Particles

0 decay e post-BDT

Optical Devices

- Have been shipped to TRIUMF
  - Via UPS, using the TRIUMF account
- Estimated delivery on Monday, May 6

Hybrid Sample

- Attended the hybrid sample meeting on Tuesday

- Yoshida-san has finished most of the work needed for the hybrid ν_μ CC1π^+ sample

- She provided me with her directory on sukap where her code is

  - I will adapt this to develop a ν_e CC1π^+ sample

Lepton Photon 2019

- August 5 – 10 in Toronto

- Should I attend?

- I would like to, but registration is quite expensive

  - $450 before May 31st

  - $550 before July 31st

  - $650 on-site