UNIVERSITY OF TORONTO

ν_e CCQE/CC1π^+ Selection Studies

Trevor Towstego

T2K-SK Meeting

May 13, 2019

Overview

- Investigated possibility of replacing the 2Reπ 0de (ν_e CC1π^+) selection with a 1Re 0de (ν_e "recovered" CCQE) selection
  - Compare results of different selections:

ν_e CC "inclusive" selection	
2Reπ 0de "exclusive" selection	1Re 0de selection

  - Motivation to move forward with 1Re 0de sample instead of 2Reπ 0de
- Hybrid eπ^+ sample progress

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	

BDT Training Variables	
<u>OLD</u>: 2Reπ 0de / ν_e CC 0de	**<u>NEW</u>: 1Re 0de**
up to 3-ring -ln(L) ratios	up to 3-ring -ln(L) ratios
$m_{\pi 0}$	$m_{\pi 0}$
1R+2R fit momenta	1R+2R fit momenta
E_{rec} ($CC1\pi^+$)	E_{rec} (CCQE)
	Wall
	ToWall e (1Re)
ToWall e and π (2Reπ)	ToWall e_1 and e_2 (2Ree)
p_{low} (2Reπ)	p_{low} (2Ree)
$\cos(\theta_{e\pi})$ (2Reπ)	$\cos(\theta_{ee})$ (2Ree)

ν_e CC 0de "Inclusive" Selection

BDT training signal = $\nu_e/\bar{\nu}_e$ CC

visible FSP:	1e1π$^{+/-}$	1e	1e other	1μ1π$^{+/-}$	1μ	1μ other	0l1π^{+}	0l1π^{-}	0l1π^{0}	0lNπ	0l other		1e all	other	
	1.25	3.50	1.54	0.15	0.16	0.72	0.41	0.44	3.51	1.63	0.86		6.29	7.89	
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					$\nu_e/\bar{\nu}_e$ CC	other	
	1.85	3.10	0.27	0.06	0.80	0.21	1.03	6.86					6.29	7.89	
ν type:	osc ν_e CC	int ν_e CC	ν_μ CC	NC									osc $\nu_e/\bar{\nu}_e$ CC	other	FOM
	4.58	1.71	1.03	6.86									4.58	9.60	1.22

Values outlined in red roughly indicate which events the BDT is trained to select for.

$$\mathrm{FOM} = \frac{S}{\sqrt{S+B}}$$

2Reπ 0de “Exclusive” Selection

BDT training signal = $1e^{+/-}1\pi^{+/-}$

visible FSP:	$1e1\pi^{+/-}$	1e	1e other	$1\mu1\pi^{+/-}$	1μ	1μ other	$0l1\pi^{+}$	$0l1\pi^{-}$	$0l1\pi^{0}$	0lNπ	0l other		$1e^{+/-}1\pi^{+/-}$	other	
	0.42	0.00	0.02	0.01	0.01	0.02	0.03	0.03	0.02	0.03	0.00		0.42	0.17	
NEUT mode:	ν_e $CC1\pi^{+}$	ν_e CCQE	ν_e CCNπ	ν_e CCDIS	ν_e CCother	$\bar{\nu}_e$ CC	ν_μ CC	NC					$\nu_e/\bar{\nu}_e$ $CC1\pi^{+}$	other	
	0.38	0.01	0.02	0.00	0.01	0.02	0.04	0.10					0.38	0.21	
ν type:	osc ν_e CC	int ν_e CC	ν_μ CC	NC									osc $\nu_e/\bar{\nu}_e$ CC	other	FOM
	0.31	0.14	0.04	0.10									0.31	0.28	0.41

Values outlined in red roughly indicate which events the BDT is trained to select for.

$$\mathrm{FOM} = \frac{S}{\sqrt{S+B}}$$

1Re 0de Selection

BDT training signal = $1e^{+/-}$

visible FSP:	$1e1\pi^{+/-}$	1e	1e other	$1\mu1\pi^{+/-}$	1μ	1μ other	$0l1\pi^{+}$	$0l1\pi^{-}$	$0l1\pi^{0}$	0lNπ	0l other		$1e^{+/-}$	other	
	0.24	4.88	0.19	0.01	0.06	0.05	0.04	0.08	2.34	0.13	0.17		4.88	3.30	
NEUT mode:	ν_e $CC1\pi^{+}$	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	
	0.61	4.20	0.05	0.01	0.16	0.27	0.12	2.76					4.40	3.77	
ν type:	osc ν_e CC	int ν_e CC	ν_μ CC	NC									osc $\nu_e/\bar{\nu}_e$ CC	other	FOM
	3.58	1.72	0.12	2.76									3.58	4.60	1.25

Values outlined in red roughly indicate which events the BDT is trained to select for.

$$\mathrm{FOM} = \frac{S}{\sqrt{S+B}}$$

ν_e CC vs 2Reπ vs 1Re: Summary

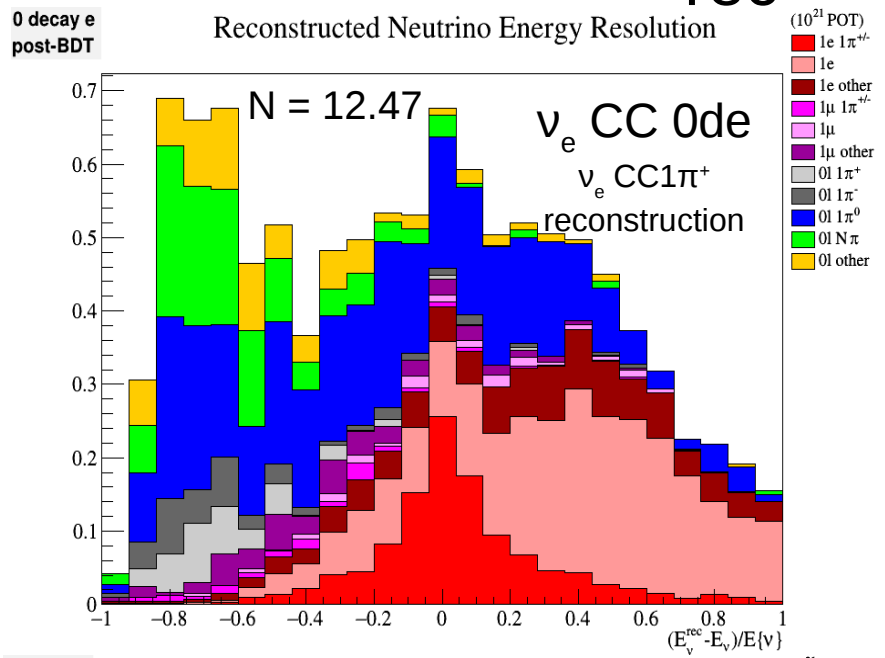
	ν_e CC 0de Inclusive		2Reπ 0de Exclusive		1Re 0de	
Final State Particles	**$1e^{+/-}$ all**	6.29	**$1e^{+/-}1\pi^{+/-}$**	0.42	**$1e^{+/-}$**	4.88
	other	7.89	**other**	0.17	**other**	3.30
NEUT Mode	**$\nu_e/\bar{\nu}_e$ CC**	6.29	**$\nu_e/\bar{\nu}_e$ CC1π^+**	0.38	**$\nu_e/\bar{\nu}_e$ CCQE**	4.40
	other	7.89	**other**	0.21	**other**	3.77
Neutrino Type	**osc $\nu_e/\bar{\nu}_e$ CC**	4.58	**osc $\nu_e/\bar{\nu}_e$ CC**	0.31	**osc $\nu_e/\bar{\nu}_e$ CC**	3.58
	other	9.60	**other**	0.28	**other**	4.60
	FOM	1.22	**FOM**	0.41	**FOM**	1.25

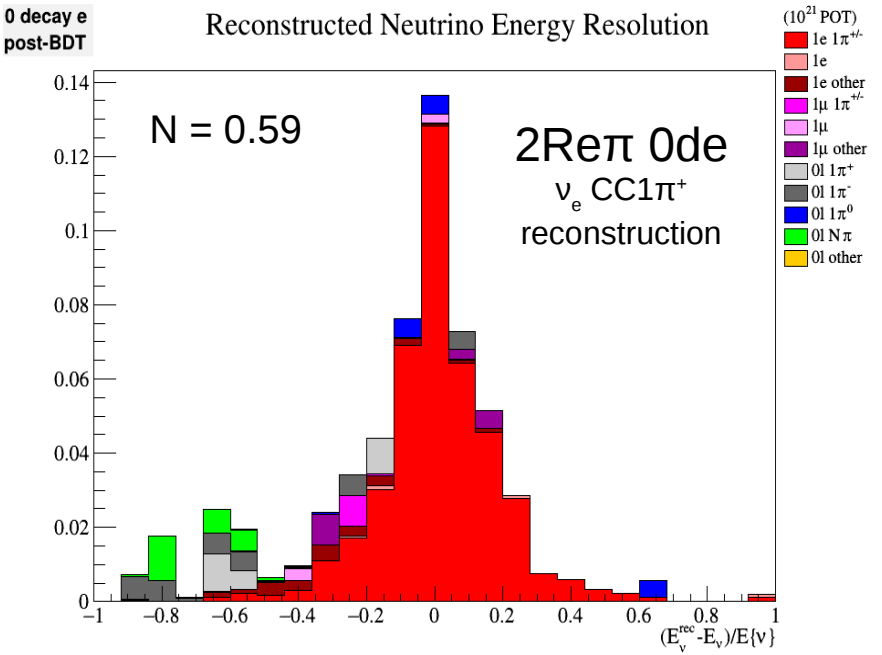
Existing 1Re selections (TN319)

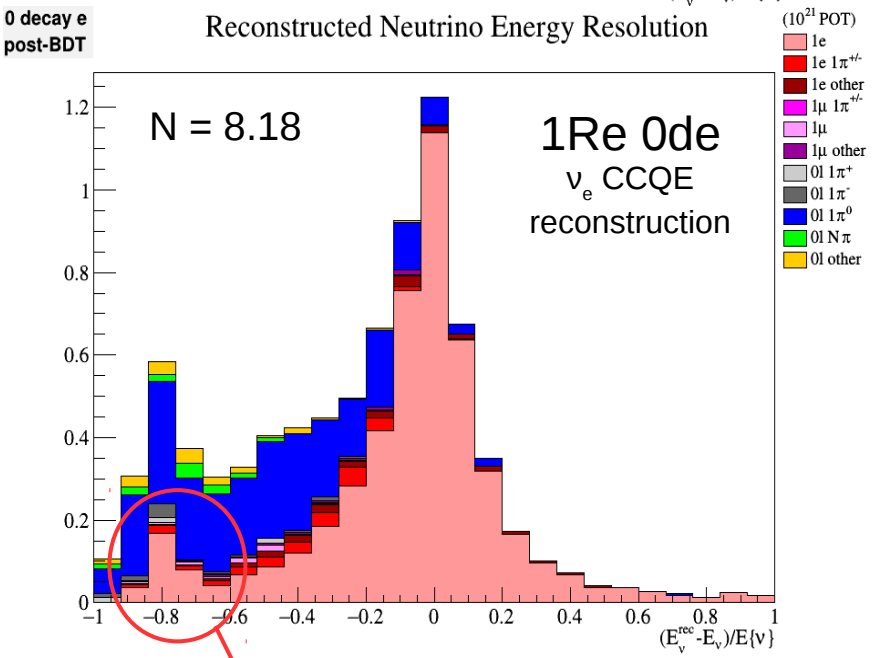
TN319 1-Ring Samples (10^{21} POT)				
Sample	**osc ν_e CC**	**int ν_e CC**	**ν_μ CC**	**NC**
ν_e CCQE	**34.84**	5.40	0.17	2.77
ν_e CC1π^+	**4.61**	0.76	0.11	0.25

- ν_e CC 0de “inclusive” sample has large number of events, but with poor purity
  - Though FOM is quite high, it does not account for systematics that would be introduced by large number of backgrounds and problematic energy reconstruction
- 2Reπ 0de “exclusive” sample has much better purity, but very low statistics, resulting in a low FOM
- 1Re 0de sample has fairly high statistics, with fair purity. FOM is greatest for this sample
  - Fair compromise between statistics, purity, and gives greatest FOM

E_{rec} Resolution







- 2Reπ 0de sample is relatively pure, but statistics are very low
- Many backgrounds present in ν_e CC 0de "inclusive" sample
  - large number of NCπ^0 and NCmulti-π events
  - Energy reconstruction may become problematic when selecting for CCQE, CC1π^+, and CCother in the same sample
- 1Re 0de sample has fair number of statistics, with NCπ^0 as main background

Primarily ν_e CC1π^+ events with π^+ below visible threshold

Proposed Samples Summary

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	

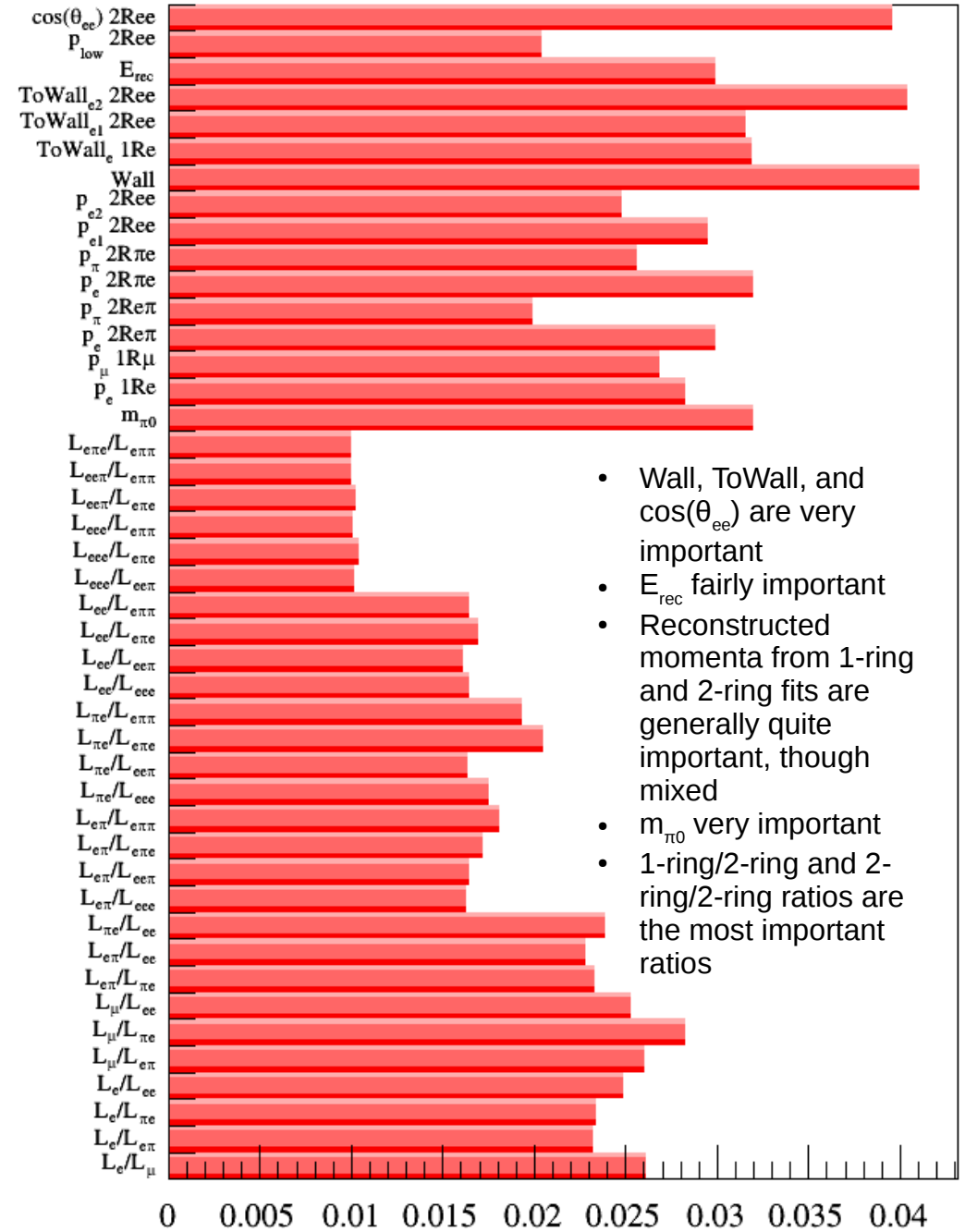
BDT Training Variables	
1Re 0de	**2Reπ 1de**
up to 3-ring -ln(L) ratios $m_{\pi 0}$ 1R+2R fit momenta E_{rec} (CCQE) Wall ToWall e (1Re) ToWall e_1 and e_2 (2Ree) p_{low} (2Ree) $\cos(\theta_{ee})$ (2Ree)	up to 3-ring -ln(L) ratios $m_{\pi 0}$ 1R+2R fit momenta E_{rec} ($CC1\pi^+$) Wall ToWall e and π (2Reπ) d_{2se} p_{low} (2Reπ) $\cos(\theta_{e\pi})$ (2Reπ)

		1Re 0de		2Reπ 1de	
Final State Particles	**$1e^{+/-}$**	4.88	**$1e^{+/-}1\pi^{+/-}$**	1.95
	other	3.30	**other**	1.02
NEUT Mode	**$\nu_e/\bar{\nu}_e$ CCQE**	4.40	**$\nu_e/\bar{\nu}_e$ $CC1\pi^+$**	2.02
	other	3.77	**other**	0.95
Neutrino Type	**osc $\nu_e/\bar{\nu}_e$ CC**	3.58	**osc $\nu_e/\bar{\nu}_e$ CC**	1.63
	other	4.60	**other**	1.34
	FOM	1.25	**FOM**	0.95

	Sample Summary (Existing + New)				
	Sample	**osc ν_e CC**	**int ν_e CC**	**ν_μ CC**	**NC**
TN319	**ν_e CCQE**	34.84	5.40	0.17	2.77
	ν_e $CC1\pi^+$	4.61	0.76	0.11	0.25
New	**1Re 0de**	3.58	1.72	0.12	2.76
	2Reπ 1de	1.63	0.53	0.39	0.42

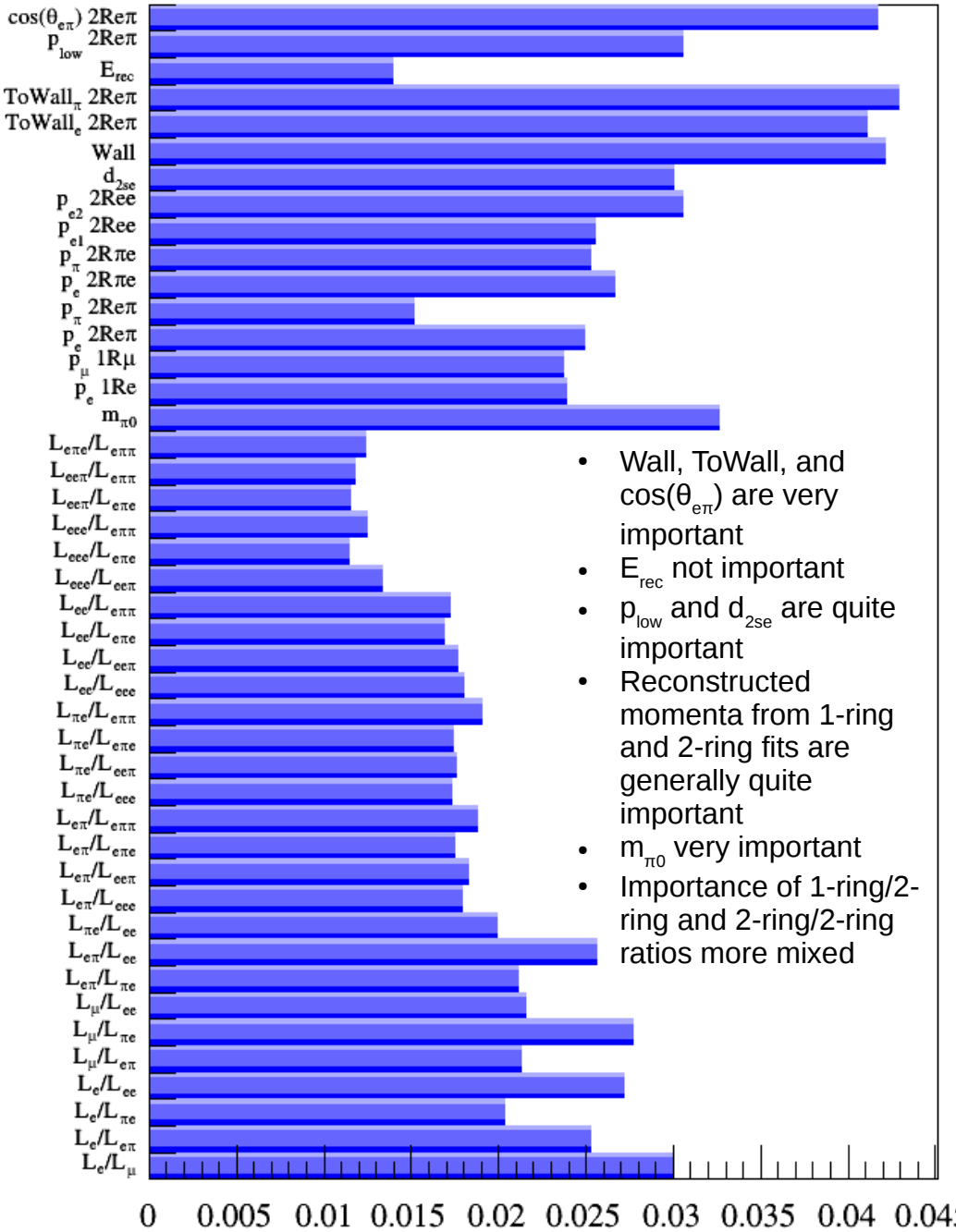
BDT Variable Importance

From 1Re 0de Training



- Wall, ToWall, and $\cos(\theta_{ee})$ are very important
- E_{rec} fairly important
- Reconstructed momenta from 1-ring and 2-ring fits are generally quite important, though mixed
- $m_{\pi 0}$ very important
- 1-ring/2-ring and 2-ring/2-ring ratios are the most important ratios

From 2Reπ 1de Training



- Wall, ToWall, and $\cos(\theta_{e\pi})$ are very important
- E_{rec} not important
- p_{low} and d_{2se} are quite important
- Reconstructed momenta from 1-ring and 2-ring fits are generally quite important
- $m_{\pi 0}$ very important
- Importance of 1-ring/2-ring and 2-ring/2-ring ratios more mixed

Hybrid Sample

- Started working on adapting Yoshida-san's hybrid $\mu\pi^+$ sample code towards an $e\pi^+$ sample
- First few steps went relatively smoothly
  - Generate list of 1-ring e-like events from atm data and from MC
  - Normalise MC to data
  - Extract e-like events from zbs files (data and MC)
  - Extract all $e\pi^+$ events from T2K MC
- Continuing to modify code step-by-step

Conclusions

- Replaced 2Reπ 0de sample with 1Re 0de sample rather than an inclusive ν_e CC sample
  - Greater statistics while maintaining decent purity
  - Larger FOM
- Hybrid $e\pi^+$ sample work is ongoing

	Sample Summary (Existing + New)				
	Sample	**osc ν_e CC**	**int ν_e CC**	**ν_μ CC**	**NC**
TN319	**ν_e CCQE**	34.84	5.40	0.17	2.77
	ν_e CC1π^+	4.61	0.76	0.11	0.25
New	**1Re 0de**	3.58	1.72	0.12	2.76
	2Reπ 1de	1.63	0.53	0.39	0.42

Backup

Selection Tables

- The following slides show the event breakdowns at three points in the selection process:
  - FCFV: After the FCFV cut is made
  - pre-BDT: After the the pre-BDT cuts are made (see slide 3)
  - post-BDT: After the BDT is trained and tested
- Three different event breakdowns are shown:
  - visible FSP: by visible final-state particle topology
    - (visible = above Cherenkov threshold + 30 MeV/c momentum)
  - NEUT mode: by true NEUT mode
  - ν type: by neutrino type
    - oscillated $\nu_e/\bar{\nu}_e$ CC, intrinsic $\nu_e/\bar{\nu}_e$ CC, $\nu_\mu/\bar{\nu}_\mu$ CC, and NC

2Reπ 0de (Exclusive) Selection

BDT training signal = $1e^{+/-}1\pi^{+/-}$

visible FSP:	$1e1\pi^{+/-}$	1e	1e other	$1\mu1\pi^{+/-}$	1μ	1μ other	$0l1\pi^{+}$	$0l1\pi^{-}$	$0l1\pi^{0}$	0lNπ	0l other		$1e1\pi^{+/-}$	other	
FCFV	4.63	45.01	8.93	8.96	41.60	32.68	7.69	12.16	83.11	17.28	15.76		4.63	273.17	
pre-BDT	1.78	4.11	2.24	2.43	22.39	5.03	6.00	10.13	63.13	6.87	11.79		1.78	134.11	
post-BDT	0.42	0.00	0.02	0.01	0.01	0.02	0.03	0.03	0.02	0.03	0.00		0.42	0.17	
NEUT mode:	ν_e $CC1\pi^{+}$	ν_e CCQE	ν_e CCNπ	ν_e CCDIS	ν_e CCother	$\bar{\nu}_e$ CC	ν_μ CC	NC					ν_e $CC1\pi^{+}$	other	
FCFV	9.04	39.19	2.29	1.12	4.10	2.82	83.29	135.95					9.04	268.76	
pre-BDT	2.64	3.54	0.37	0.09	1.21	0.26	29.89	97.87					2.64	133.25	
post-BDT	0.38	0.01	0.02	0.00	0.01	0.02	0.04	0.10					0.38	0.21	
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	83.29	135.95									38.06	239.69	2.28
pre-BDT	5.95	2.17	29.89	97.87									5.95	129.94	0.51
post-BDT	0.31	0.14	0.04	0.10									0.31	0.28	0.41

ν_e CC 0de (Inclusive) Selection

BDT training signal = $\nu_e/\bar{\nu}_e$ CC

visible FSP:	1e1π$^{+/-}$	1e	1e other	1μ1π$^{+/-}$	1μ	1μ other	0l1π^{+}	0l1π^{-}	0l1π^{0}	0lNπ	0l other		1e1π$^{+/-}$	other	
FCFV	4.63	45.01	8.93	8.96	41.60	32.68	7.69	12.16	83.11	17.28	15.76		4.63	272.98	
pre-BDT	1.78	4.11	2.24	2.43	22.39	5.03	6.00	10.13	63.13	6.87	11.79		1.78	134.12	
post-BDT	1.25	3.50	1.54	0.15	0.16	0.72	0.41	0.44	3.51	1.63	0.86		1.25	12.93	
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					ν_e CC1π^{+}	other	
FCFV	9.04	39.19	2.29	1.12	4.10	2.82	83.29	135.95					9.04	268.58	
pre-BDT	2.64	3.54	0.37	0.09	1.21	0.26	29.89	97.87					2.64	133.26	
post-BDT	1.85	3.10	0.27	0.06	0.80	0.21	1.03	6.86					1.85	12.33	
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	83.29	135.95									38.06	239.74	2.28
pre-BDT	5.95	2.17	29.89	97.87									5.95	129.95	0.51
post-BDT	4.58	1.71	1.03	6.86									4.58	9.60	1.22

1Re 0de Selection

BDT training signal = $1e^{+/-}$

visible FSP:	$1e1\pi^{+/-}$	1e	1e other	$1\mu1\pi^{+/-}$	1μ	1μ other	$0l1\pi^{+}$	$0l1\pi^{-}$	$0l1\pi^{0}$	0lNπ	0l other		$1e^{+/-}$	other	
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	
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	
post-BDT	0.24	4.88	0.19	0.01	0.06	0.05	0.04	0.08	2.34	0.13	0.17		4.88	3.30	
NEUT mode:	ν_e $CC1\pi^{+}$	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	
FCFV	9.04	39.19	2.29	1.12	4.10	2.82	83.28	135.95					40.68	237.13	
pre-BDT	3.77	5.98	0.68	0.13	2.13	0.57	35.67	118.57					6.23	161.24	
post-BDT	0.61	4.20	0.05	0.01	0.16	0.27	0.12	2.76					4.40	3.77	
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	3.58	1.72	0.12	2.76									3.58	4.60	1.25

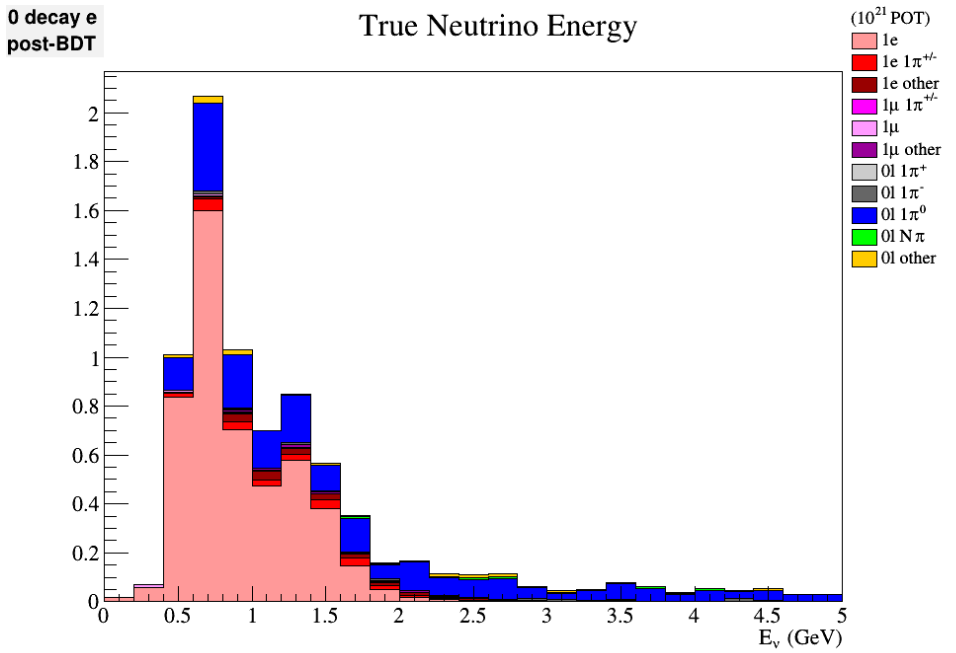
2Reπ 1de Selection

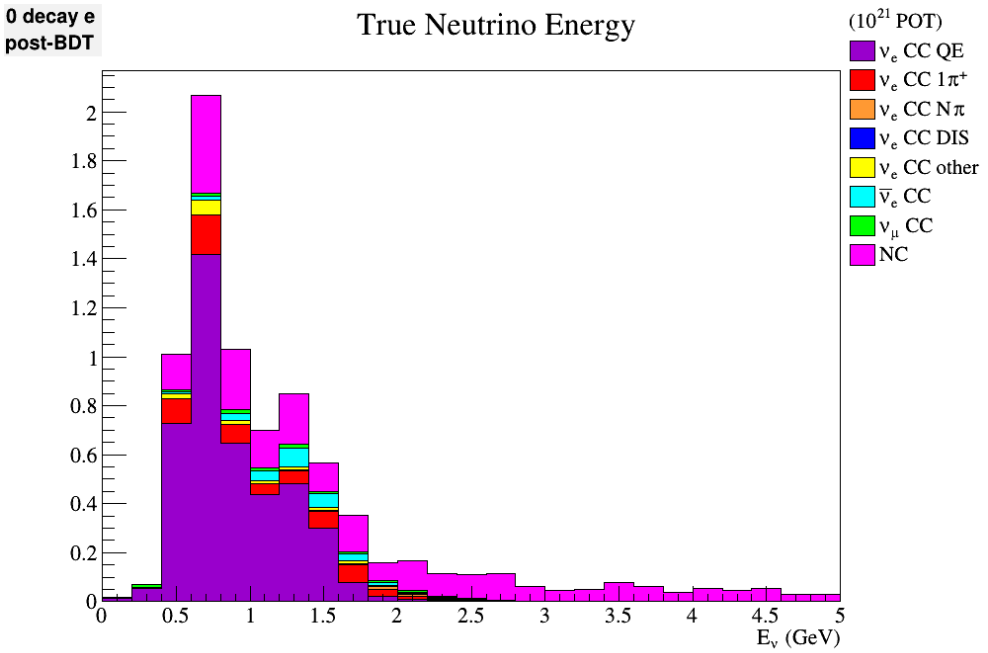
BDT training signal = $1e^{+/-}1\pi^{+/-}$

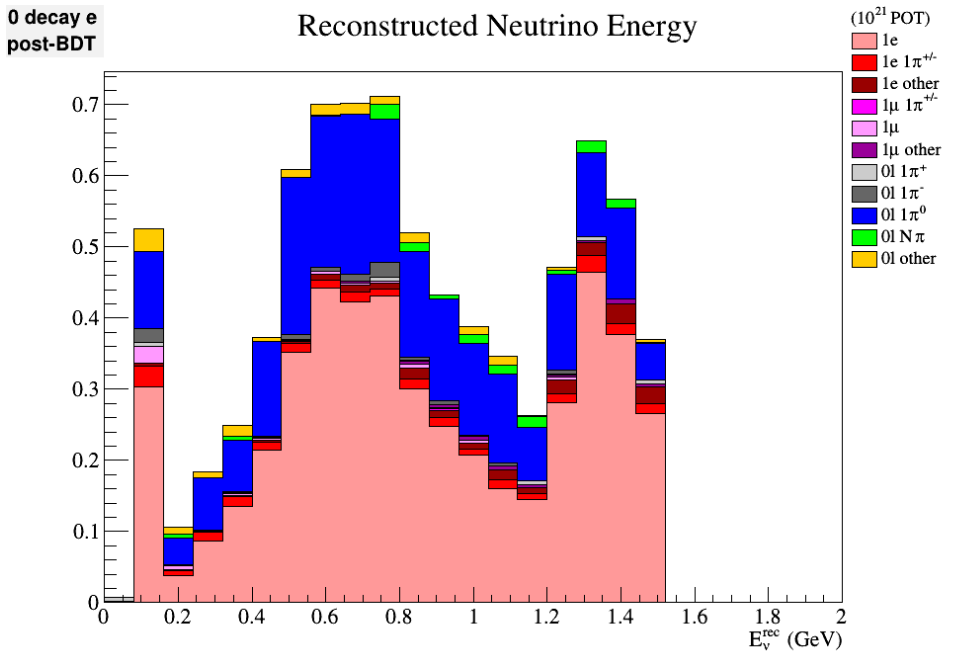
visible FSP:	$1e1\pi^{+/-}$	1e	1e other	$1\mu1\pi^{+/-}$	1μ	1μ other	$0l1\pi^{+}$	$0l1\pi^{-}$	$0l1\pi^{0}$	0lNπ	0l other		$1e^{+/-}1\pi^{+/-}$	other	
FCFV	6.95	4.64	3.81	32.01	132.51	82.41	11.12	3.61	4.65	15.28	5.14		6.95	295.10	
pre-BDT	3.24	0.65	0.67	13.62	93.68	19.37	9.77	2.63	2.70	6.82	4.05		3.24	153.95	
post-BDT	1.95	0.13	0.08	0.09	0.02	0.28	0.08	0.04	0.06	0.13	0.11		1.95	1.02	
NEUT mode:	ν_e $CC1\pi^{+}$	ν_e CCQE	ν_e CCNπ	ν_e CCDIS	ν_e CCother	$\bar{\nu}_e$ CC	ν_μ CC	NC					$\nu_e/\bar{\nu}_e$ $CC1\pi^{+}$	other	
FCFV	10.57	0.52	2.31	1.21	0.54	0.26	246.94	39.72					10.62	291.44	
pre-BDT	3.71	0.09	0.47	0.14	0.13	0.03	126.72	25.92					3.72	153.47	
post-BDT	2.01	0.02	0.08	0.00	0.03	0.01	0.39	0.42					2.02	0.95	
ν type:	osc ν_e CC	int ν_e CC	ν_μ CC	NC									osc $\nu_e/\bar{\nu}_e$ CC	other	FOM
FCFV	7.86	7.54	246.94	39.72									7.86	294.20	0.45
pre-BDT	3.06	1.50	126.72	25.92									3.06	154.13	0.24
post-BDT	1.63	0.53	0.39	0.42									1.63	1.34	0.95

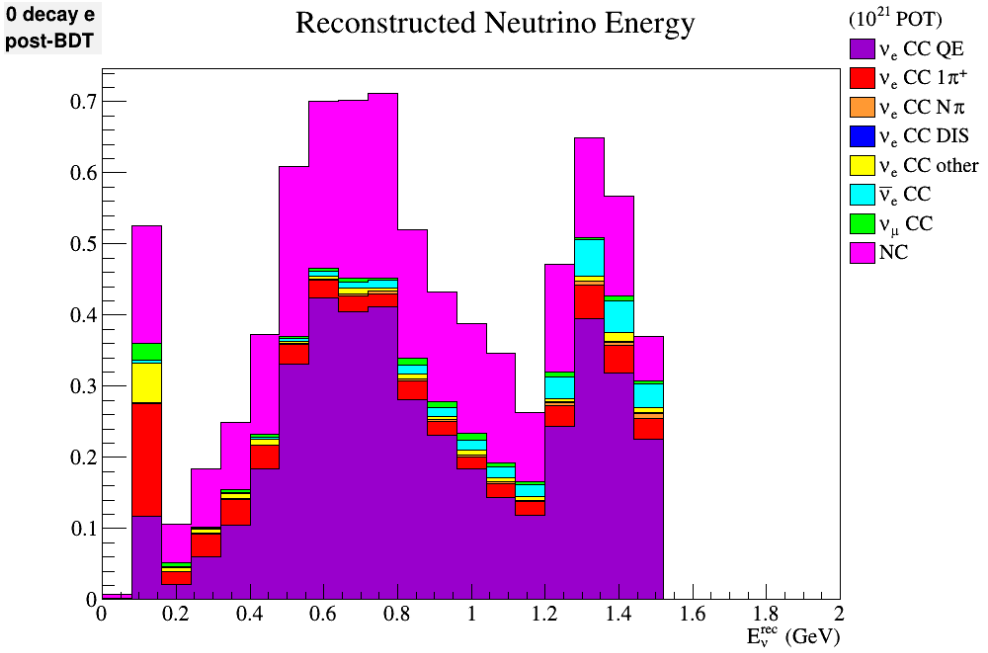
1Re 0de Selection Plots

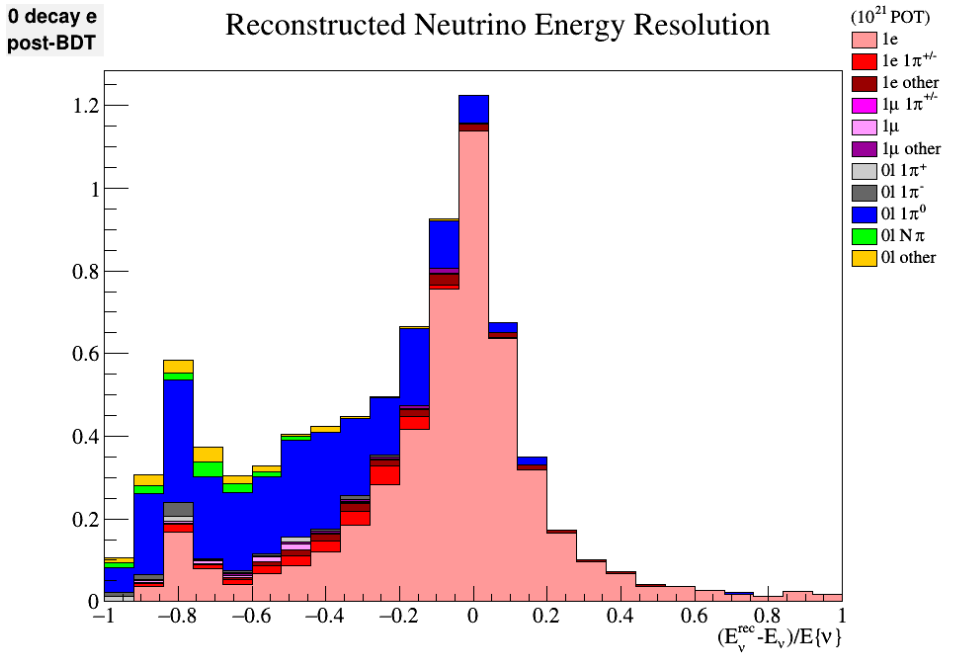
- The following slides contain plots of the 1Re 0de selection

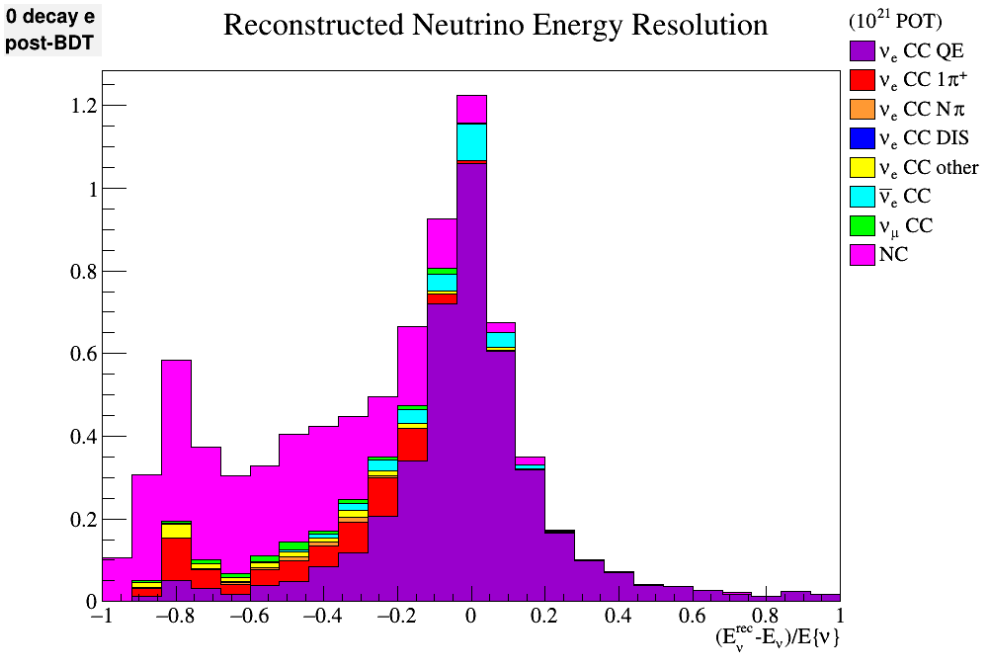

0 decay e
post-BDT
True Neutrino Energy
(10^21 POT)
1e
1e 1π+/-
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
E_ν (GeV)

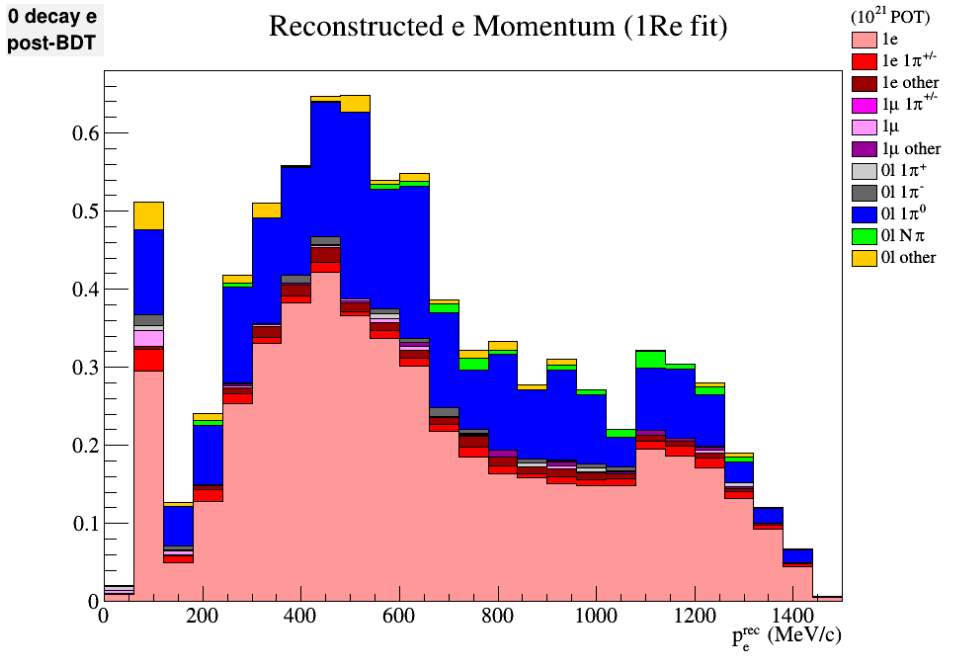

0 decay e
post-BDT
True Neutrino Energy
(10^21 POT)
ν_e CC QE
ν_e CC 1π+
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
E_ν (GeV)

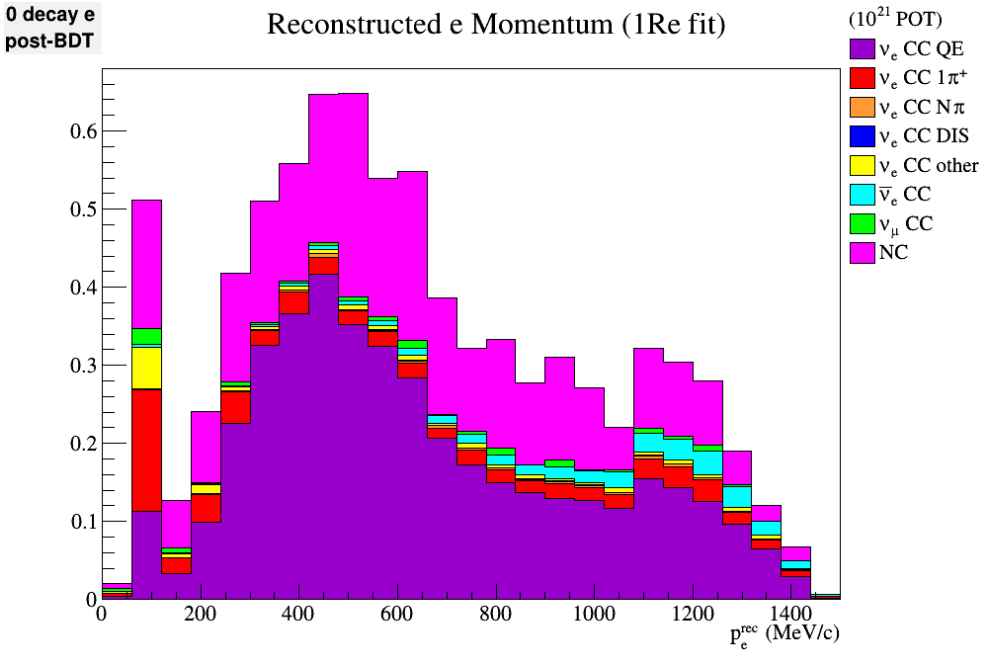

0 decay e
post-BDT
Reconstructed Neutrino Energy
(10^21 POT)
1e
1e 1π+/-
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
E_ν^rec (GeV)

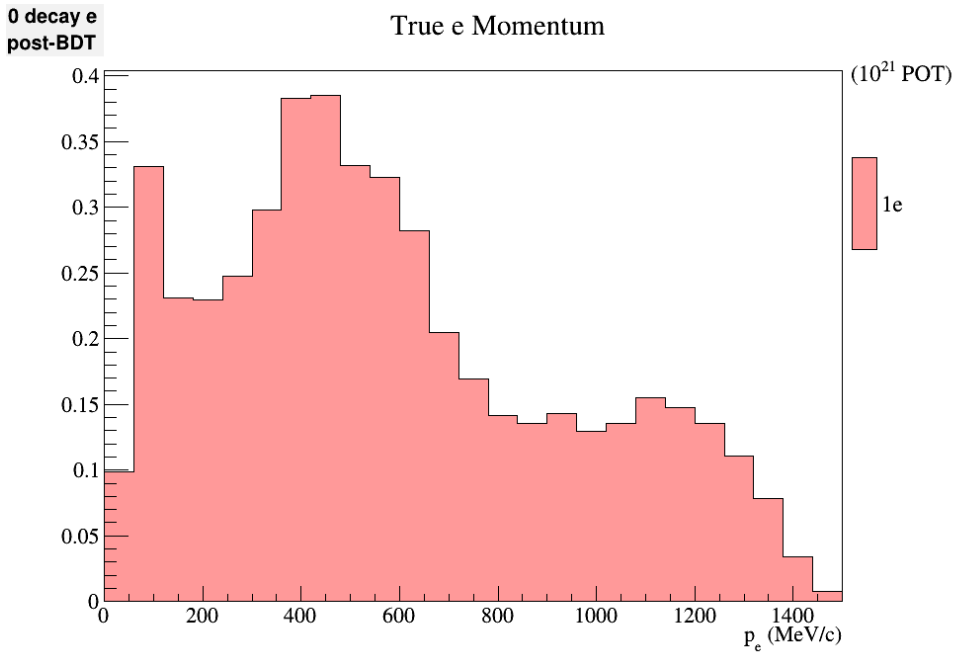

0 decay e
post-BDT
Reconstructed Neutrino Energy
(10^21 POT)
ν_e CC QE
ν_e CC 1π+
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
E_ν^rec (GeV)

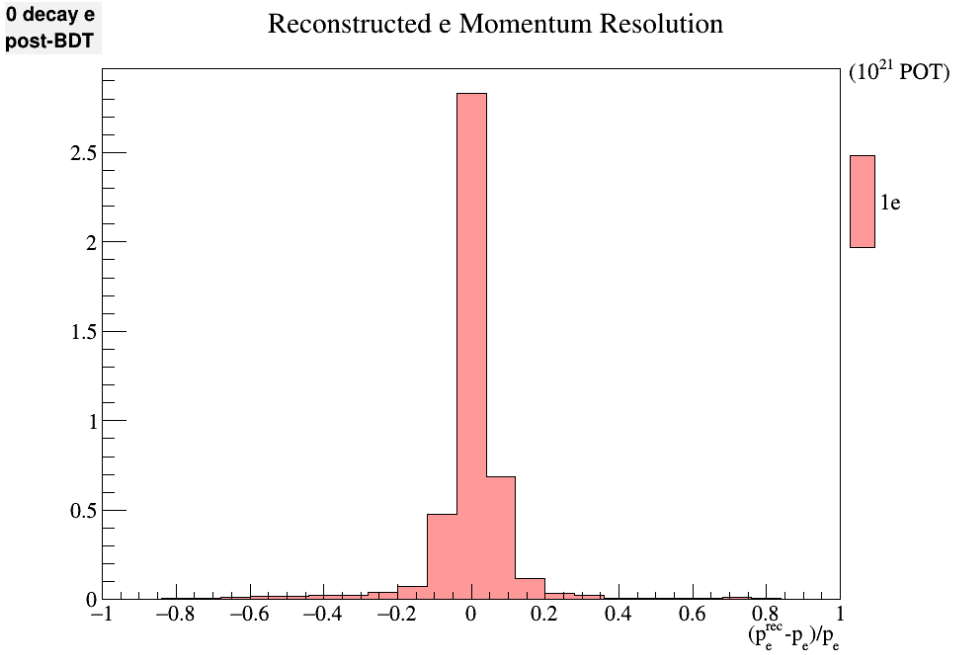

0 decay e
post-BDT
Reconstructed Neutrino Energy Resolution
(10^21 POT)
1e
1e 1π+/-
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
(E_ν^rec -E_ν)/E{ν}

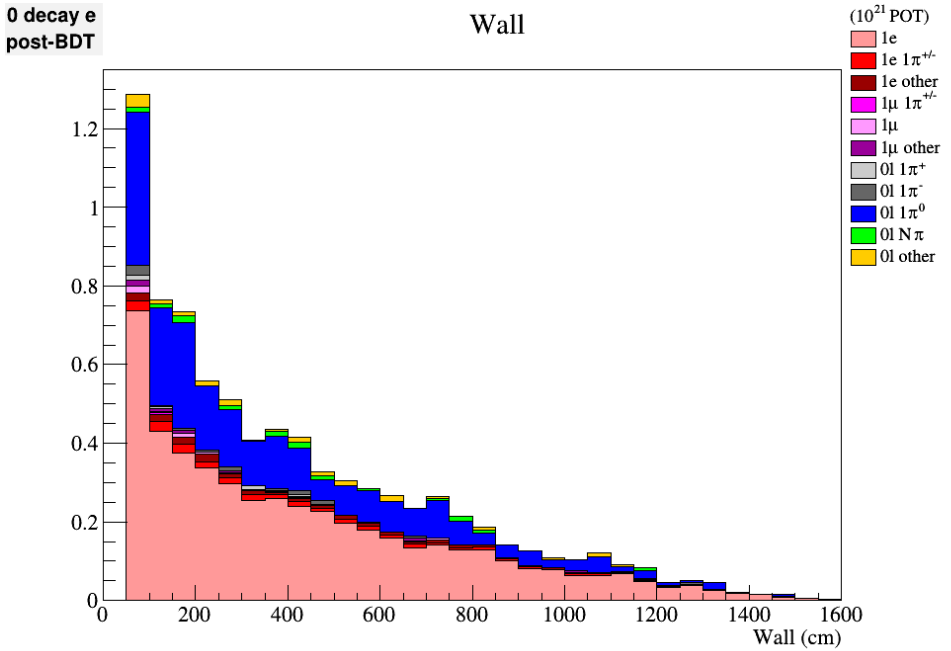

0 decay e
post-BDT
Reconstructed Neutrino Energy Resolution
(10^21 POT)
ν_e CC QE
ν_e CC 1π+
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
(E_ν^rec -E_ν)/E{ν}

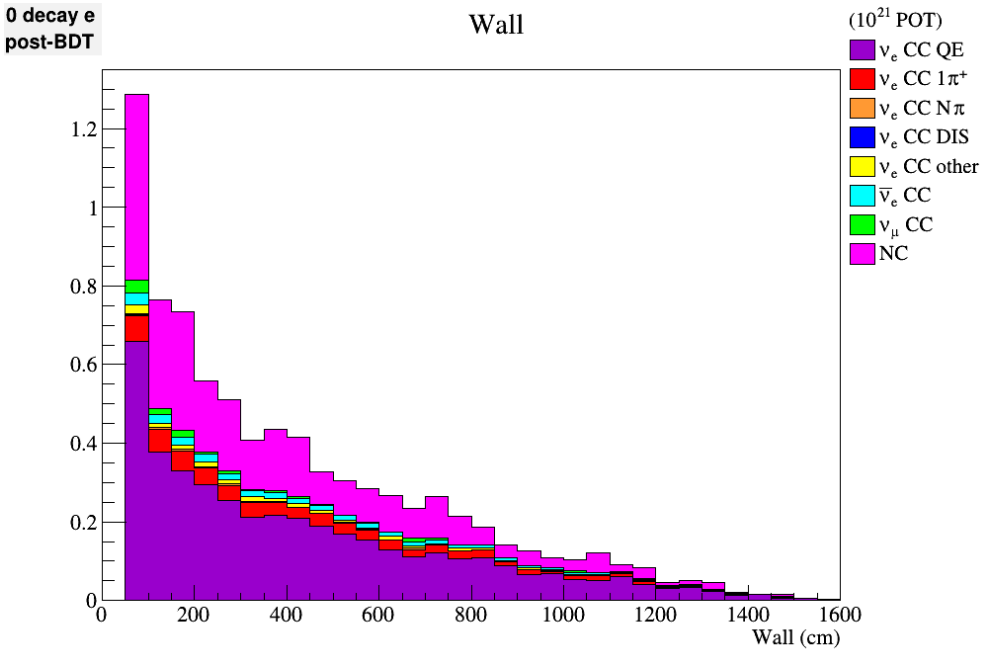

0 decay e
post-BDT
Reconstructed e Momentum (1Re fit)
(10^21 POT)
1e
1e 1π+/-
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
p_e^rec (MeV/c)

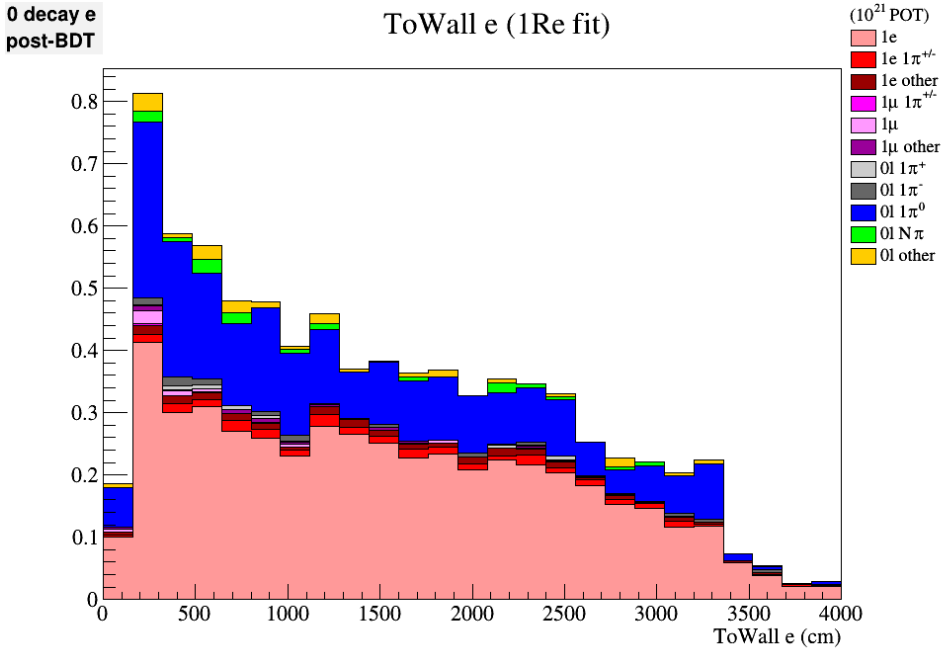

0 decay e
post-BDT
Reconstructed e Momentum (1Re fit)
(10^21 POT)
ν_e CC QE
ν_e CC 1π+
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
p_e^rec (MeV/c)

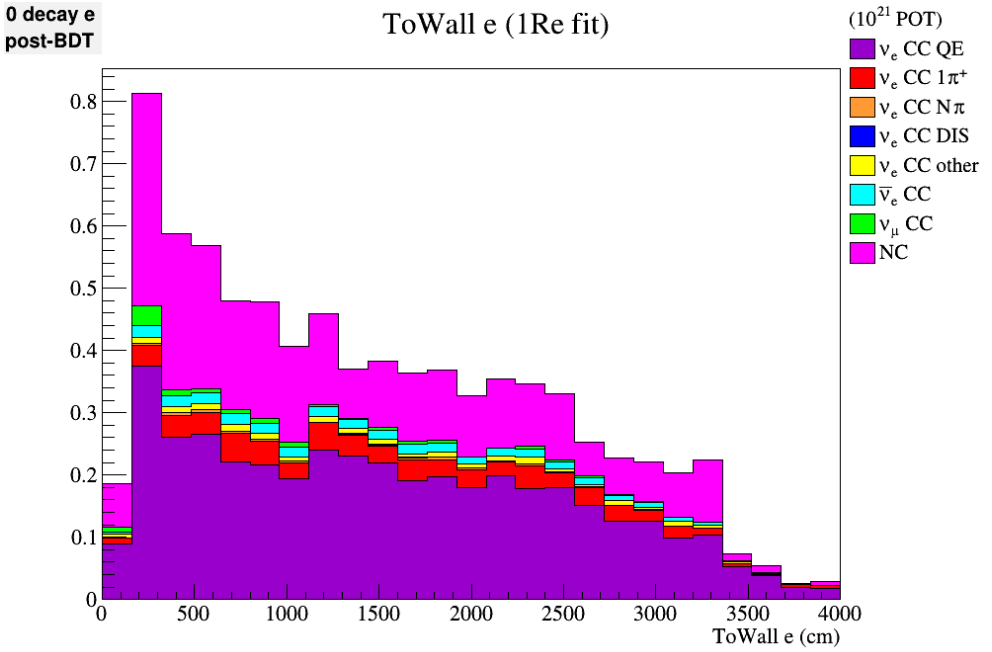

0 decay e
post-BDT
True e Momentum
(10^21 POT)
1e
p_e (MeV/c)


0 decay e
post-BDT
Reconstructed e Momentum Resolution
(10^21 POT)
1e
(p_e^rec-p_e)/p_e

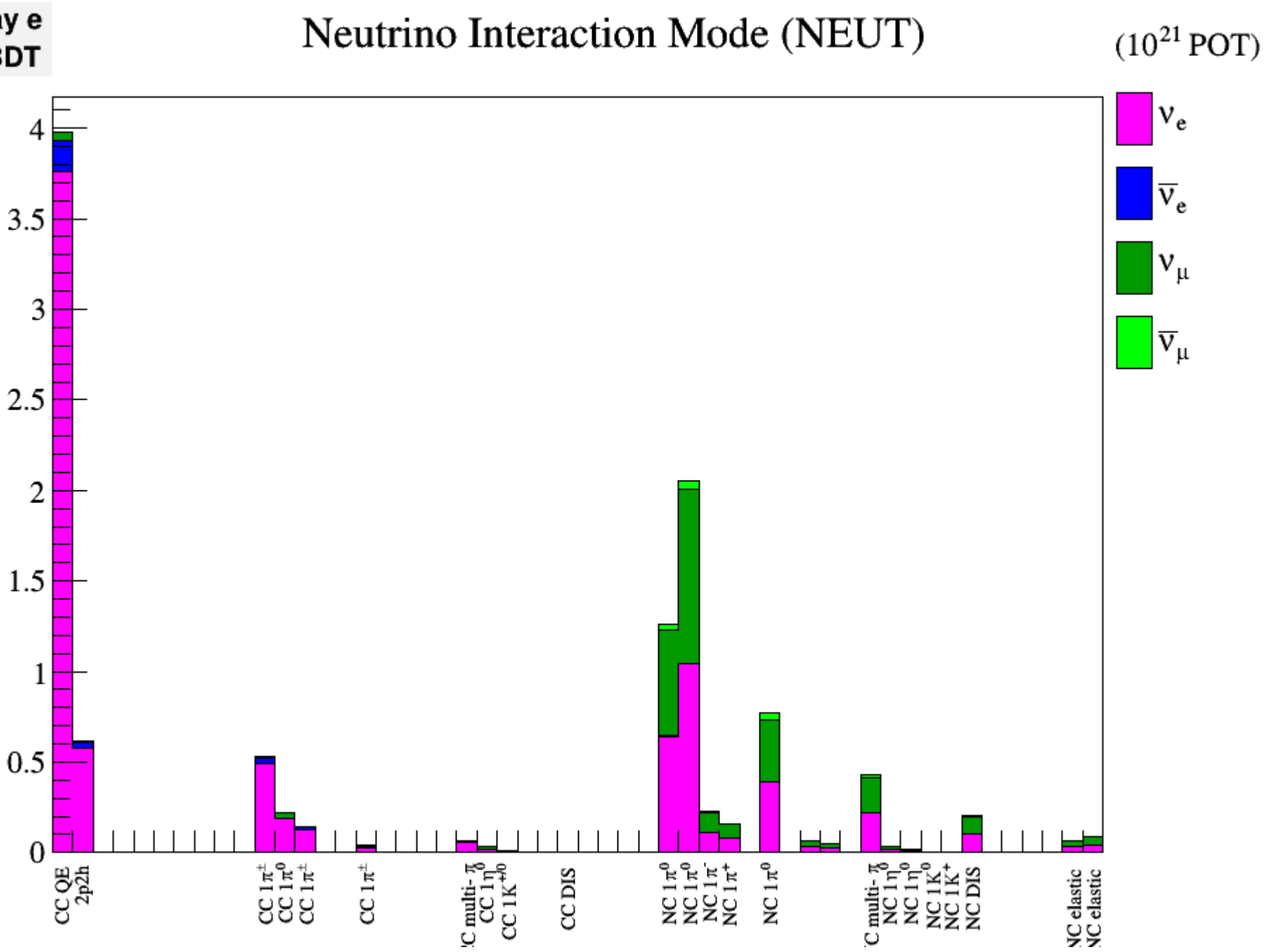

0 decay e
post-BDT
Wall
(10^21 POT)
1e
1e 1π+/-
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
Wall (cm)


0 decay e
post-BDT
Wall
(10^21 POT)
νe CC QE
νe CC 1π+
νe CC Nπ
νe CC DIS
νe CC other
ν̄e CC
νμ CC
NC
Wall (cm)


0 decay e
post-BDT
ToWall e (1Re fit)
(10^21 POT)
1e
1e 1π+/-
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
ToWall e (cm)

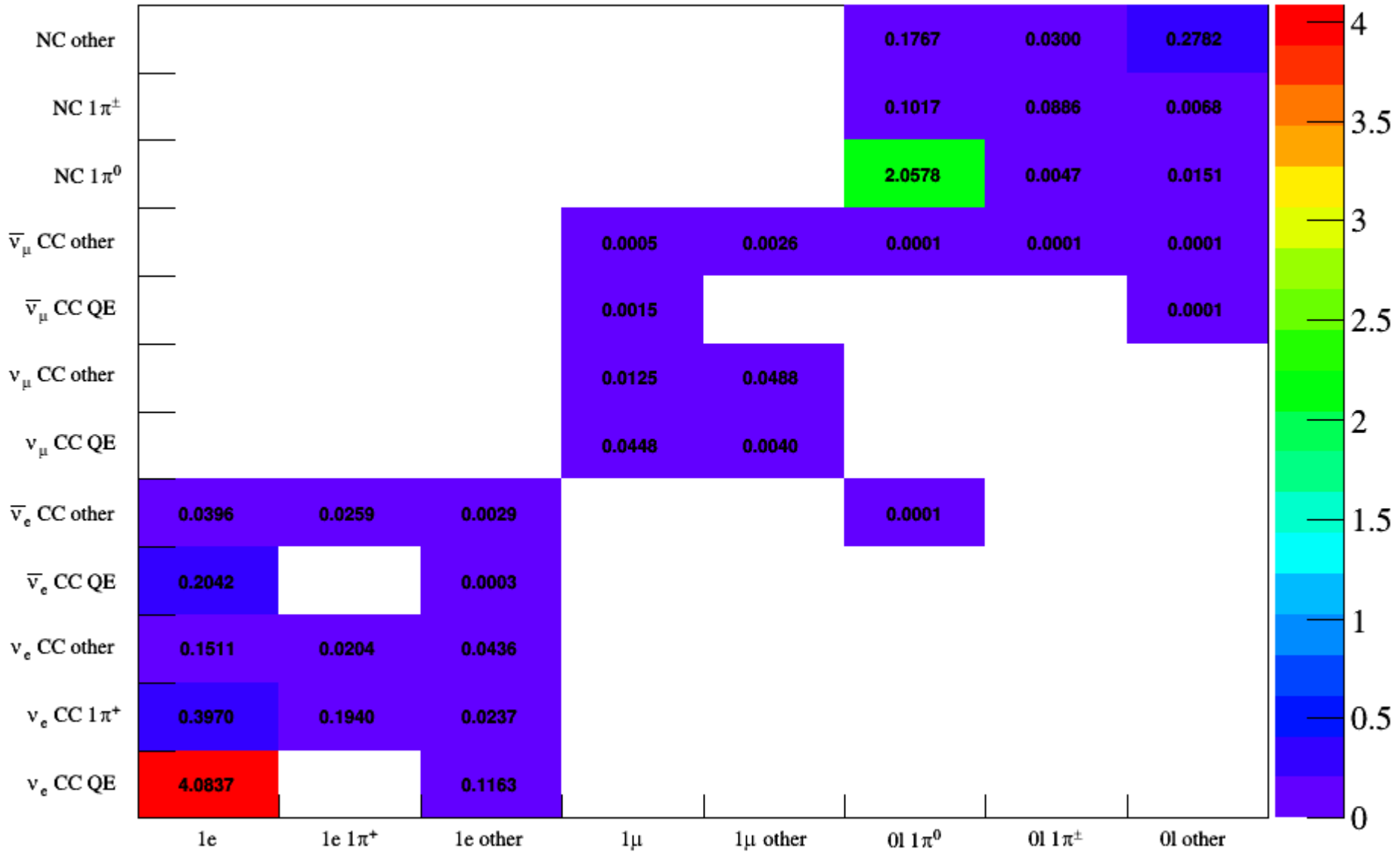

0 decay e
post-BDT
ToWall e (1Re fit)
(10^21 POT)
νe CC QE
νe CC 1π+
νe CC Nπ
νe CC DIS
νe CC other
ν̄e CC
νμ CC
NC
ToWall e (cm)

0 decay e
post-BDT



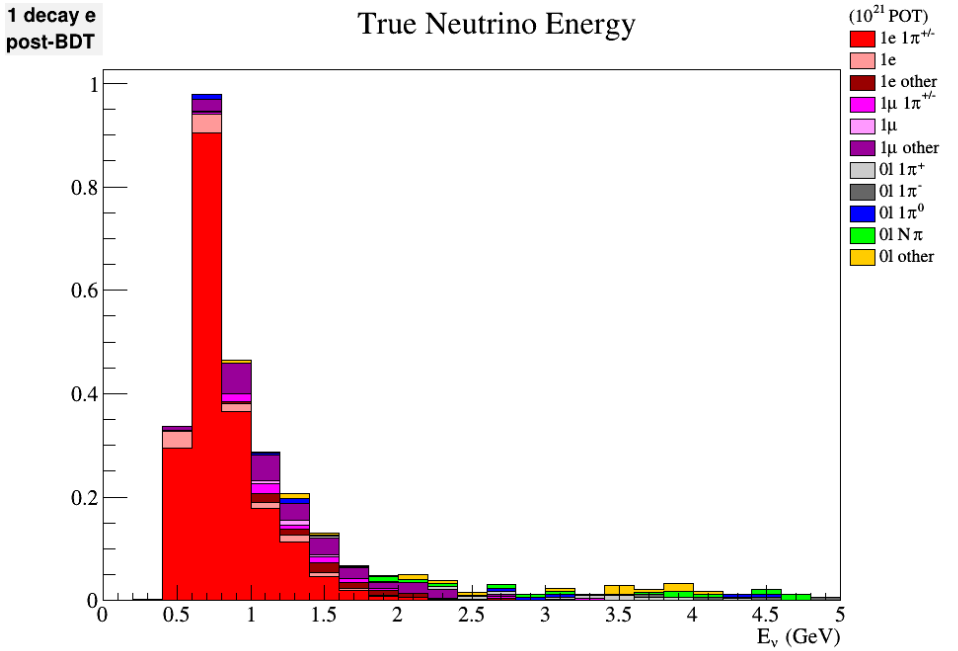
0 decay e post-BDT

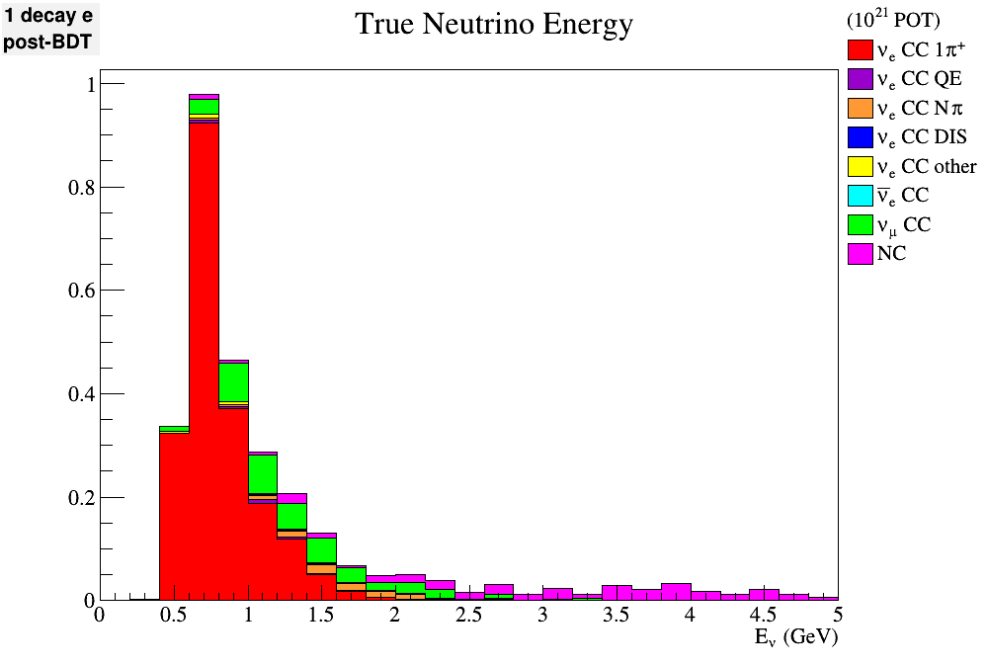
NEUT Mode vs. Visible Final State Particles

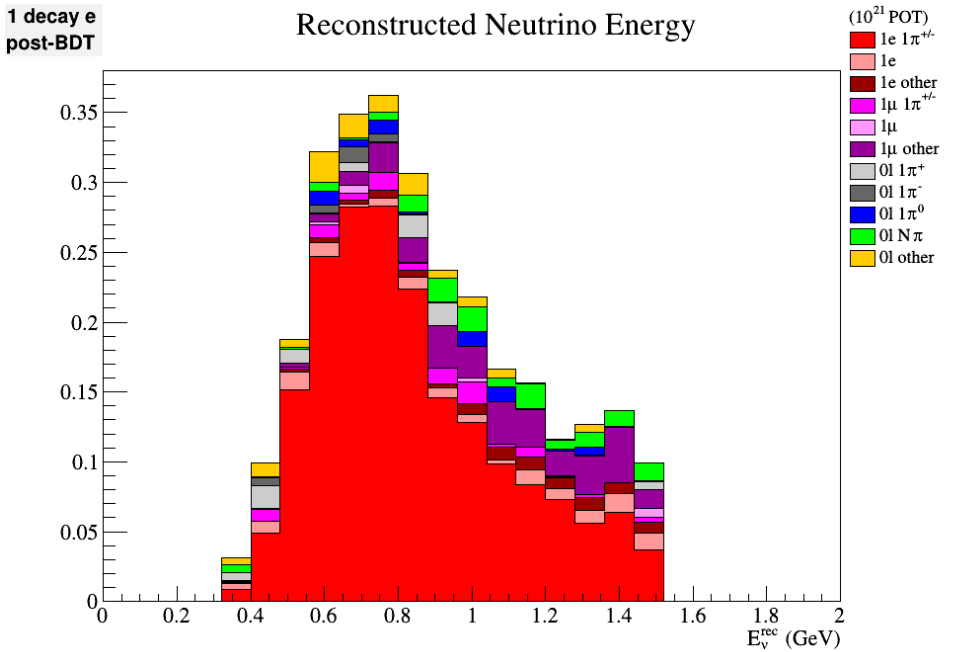


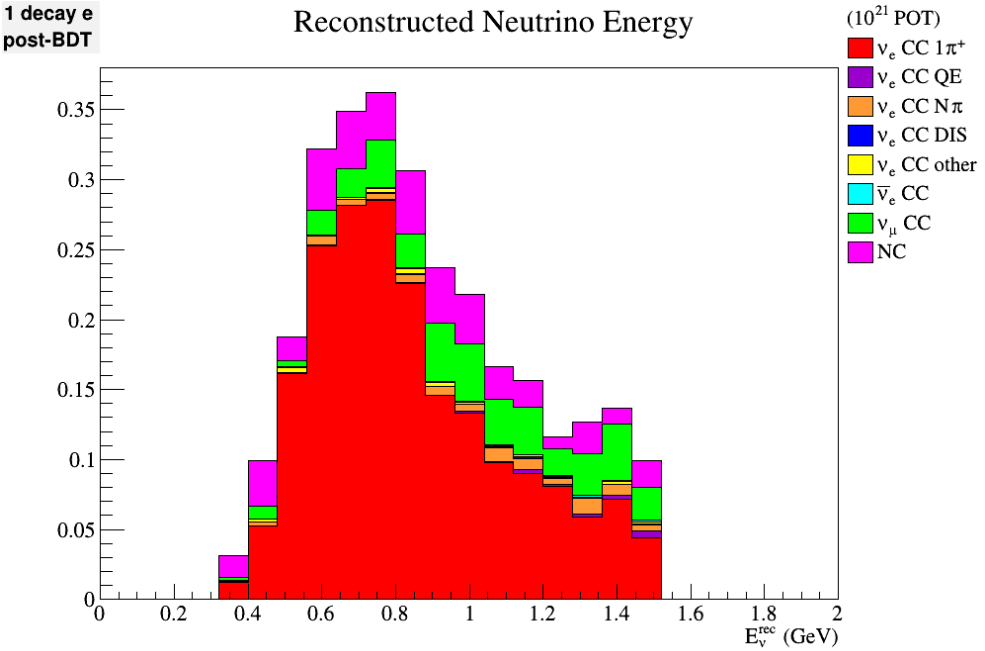
2Reπ 1de Selection

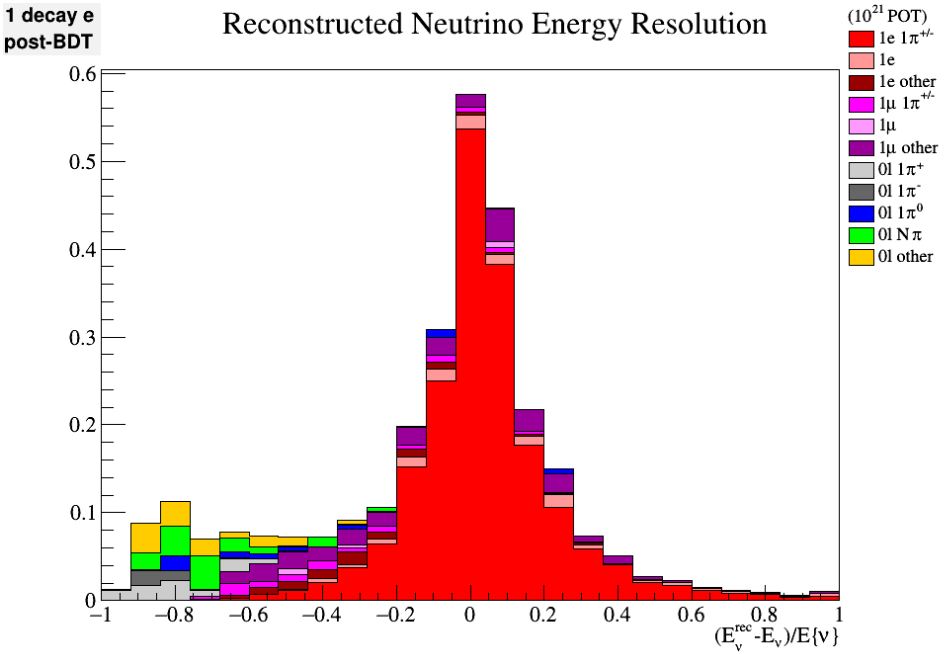
- The following slides contain plots of the 2Reπ 1de selection

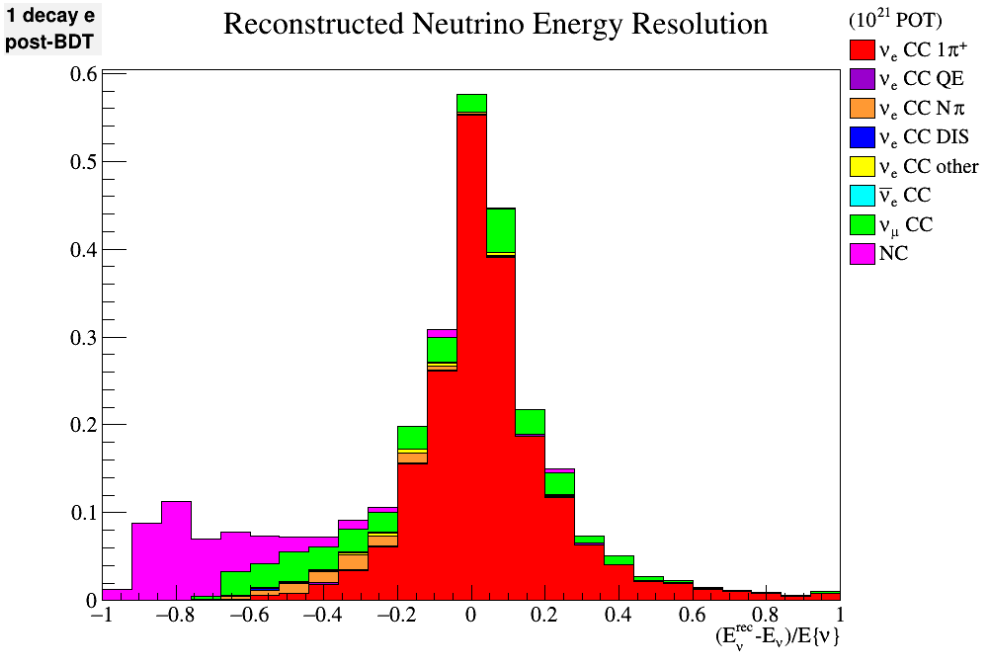

1 decay e
post-BDT
True Neutrino Energy
(10^{21} POT)
1e $1\pi^{+/-}$
1e
1e other
1μ $1\pi^{+/-}$
1μ
1μ other
0l $1\pi^{+}$
0l $1\pi^{-}$
0l $1\pi^{0}$
0l N π
0l other
E_ν (GeV)

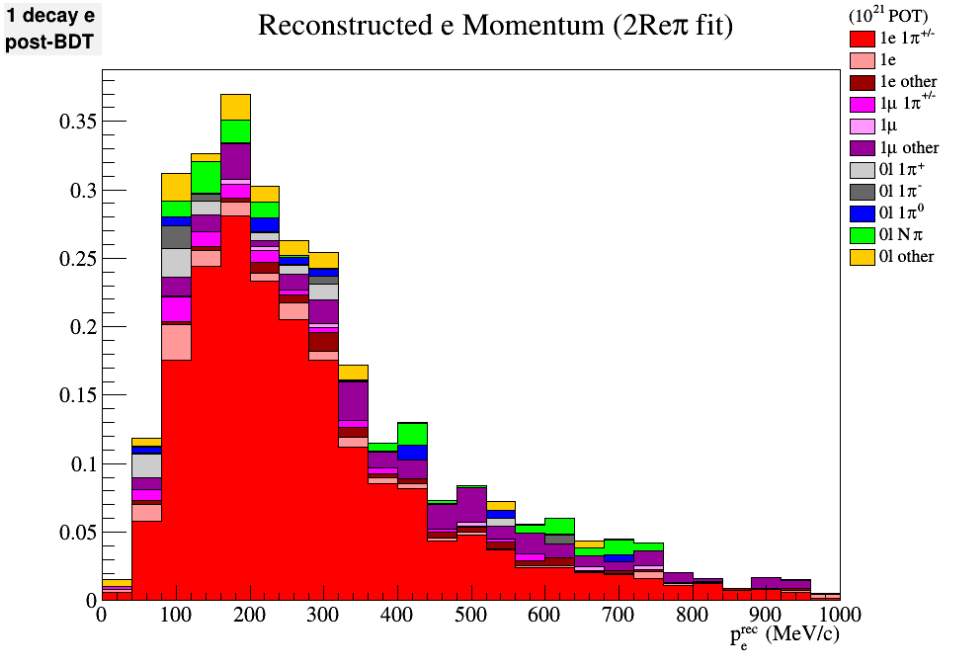

1 decay e
post-BDT
True Neutrino Energy
(10^{21} POT)
ν_e CC $1\pi^{+}$
ν_e CC QE
ν_e CC N π
ν_e CC DIS
ν_e CC other
$\bar{\nu}_e$ CC
ν_μ CC
NC
E_ν (GeV)

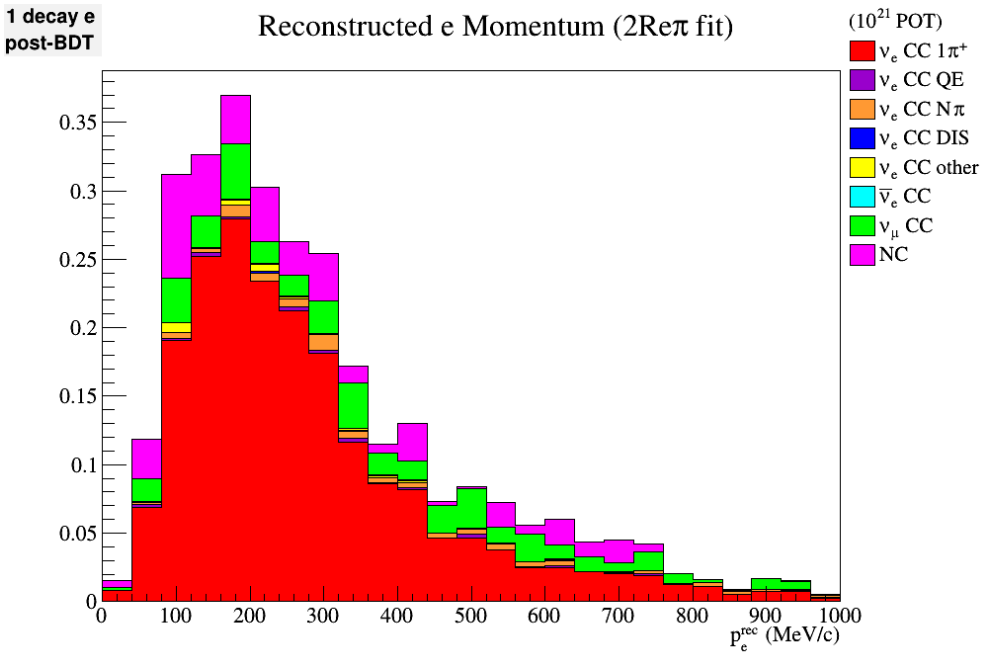

1 decay e
post-BDT
Reconstructed Neutrino Energy
(10^{21} POT)
1e $1\pi^{+/-}$
1e
1e other
1μ $1\pi^{+/-}$
1μ
1μ other
0l $1\pi^{+}$
0l $1\pi^{-}$
0l $1\pi^{0}$
0l N π
0l other
E_ν^{rec} (GeV)

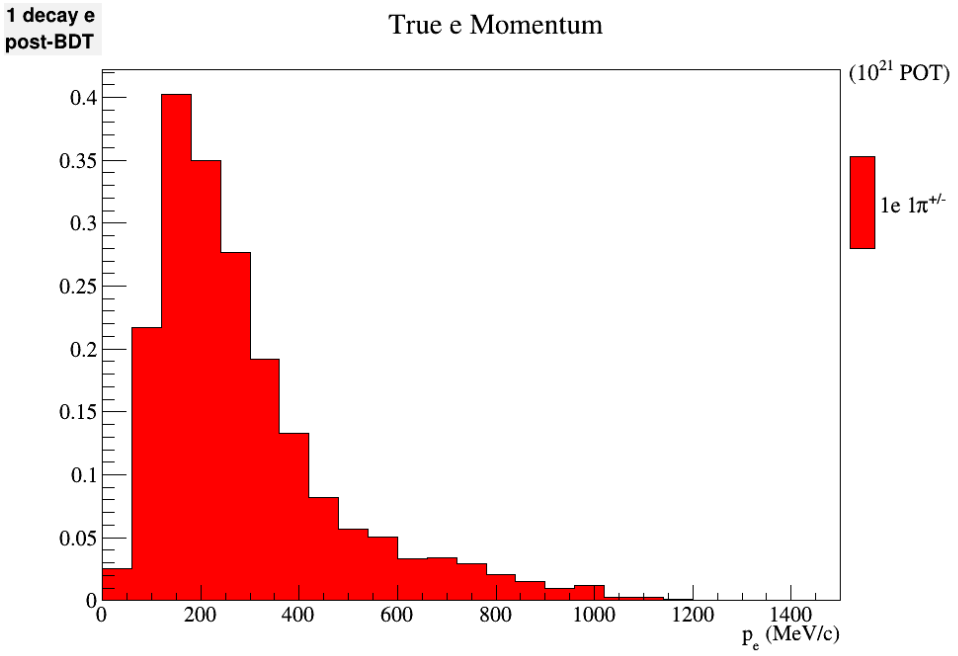

1 decay e
post-BDT
Reconstructed Neutrino Energy
(10^{21} POT)
ν_e CC $1\pi^{+}$
ν_e CC QE
ν_e CC N π
ν_e CC DIS
ν_e CC other
$\bar{\nu}_e$ CC
ν_μ CC
NC
E_ν^{rec} (GeV)

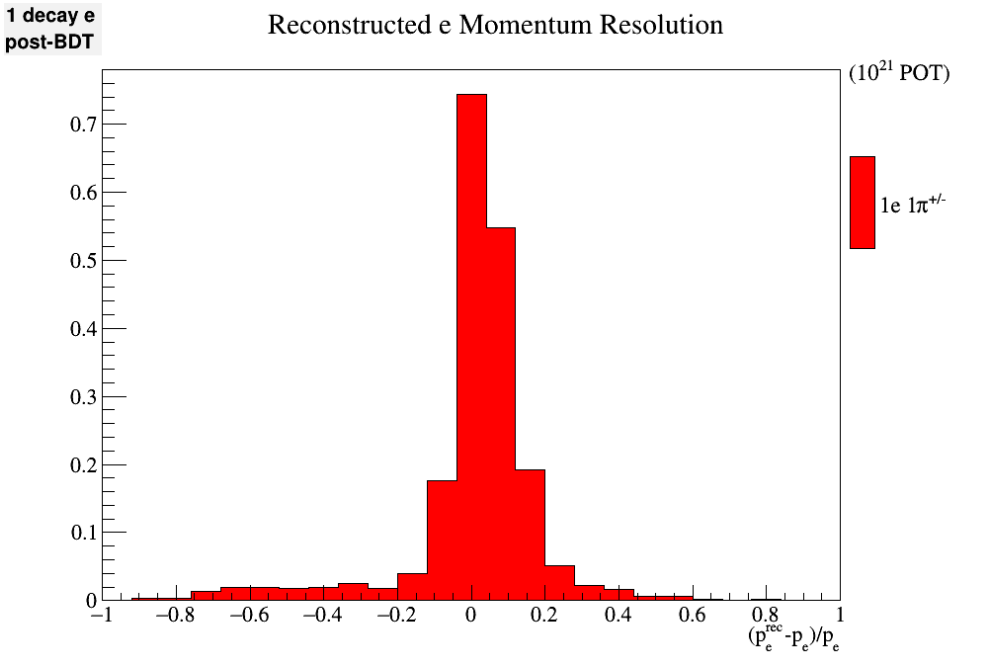

1 decay e
post-BDT
Reconstructed Neutrino Energy Resolution
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
0.6
0.5
0.4
0.3
0.2
0.1
0
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
(E_ν^rec-E_ν)/E{ν}

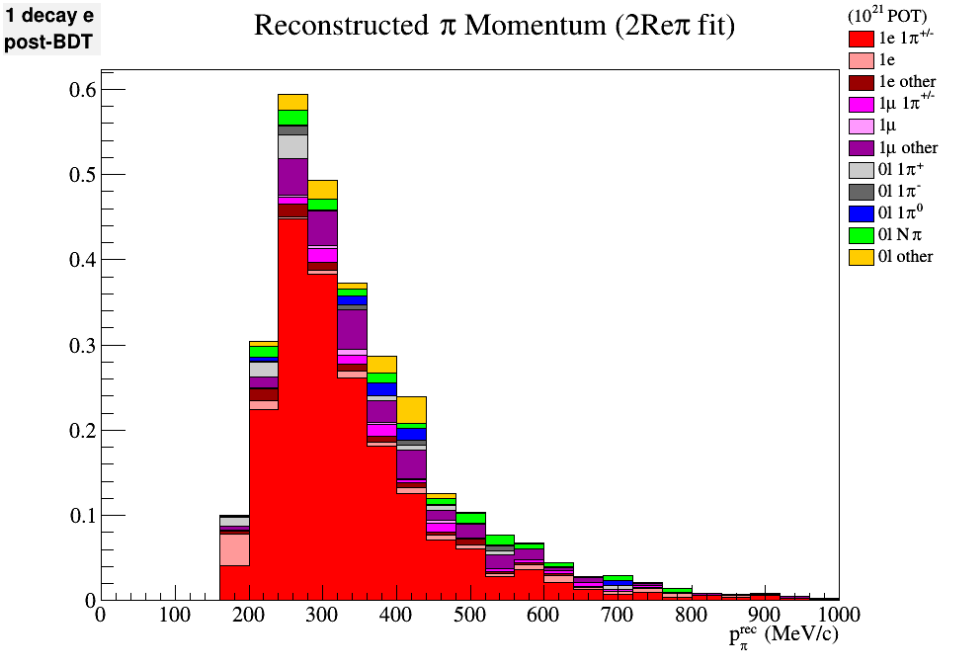

1 decay e
post-BDT
Reconstructed Neutrino Energy Resolution
(10^21 POT)
ν_e CC 1π+
ν_e CC QE
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
0.6
0.5
0.4
0.3
0.2
0.1
0
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
(E_ν^rec-E_ν)/E{ν}

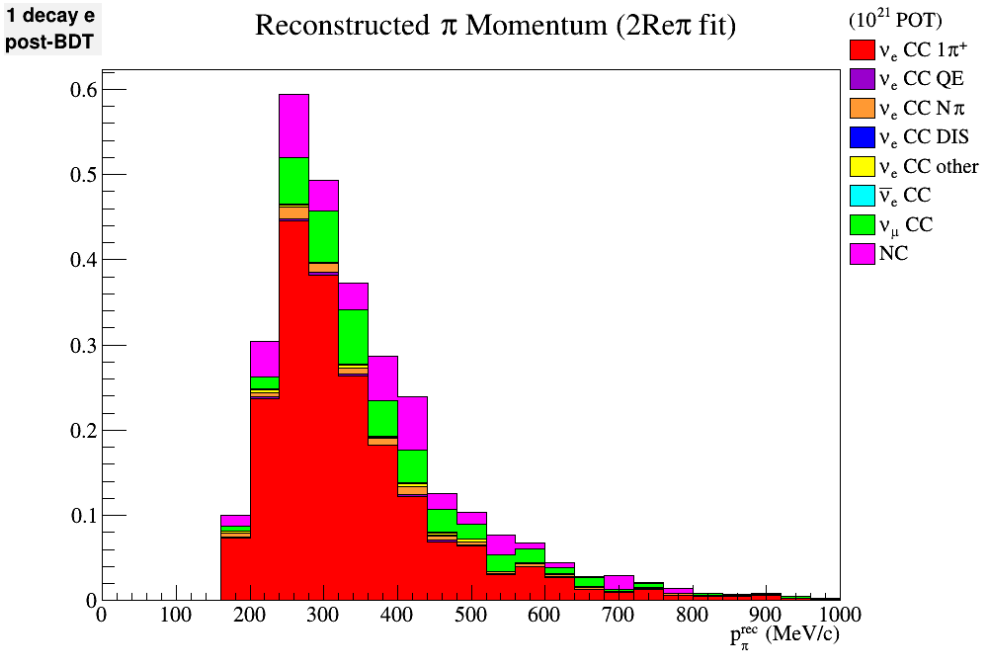

1 decay e
post-BDT
Reconstructed e Momentum (2Reπ fit)
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
p_e^rec (MeV/c)

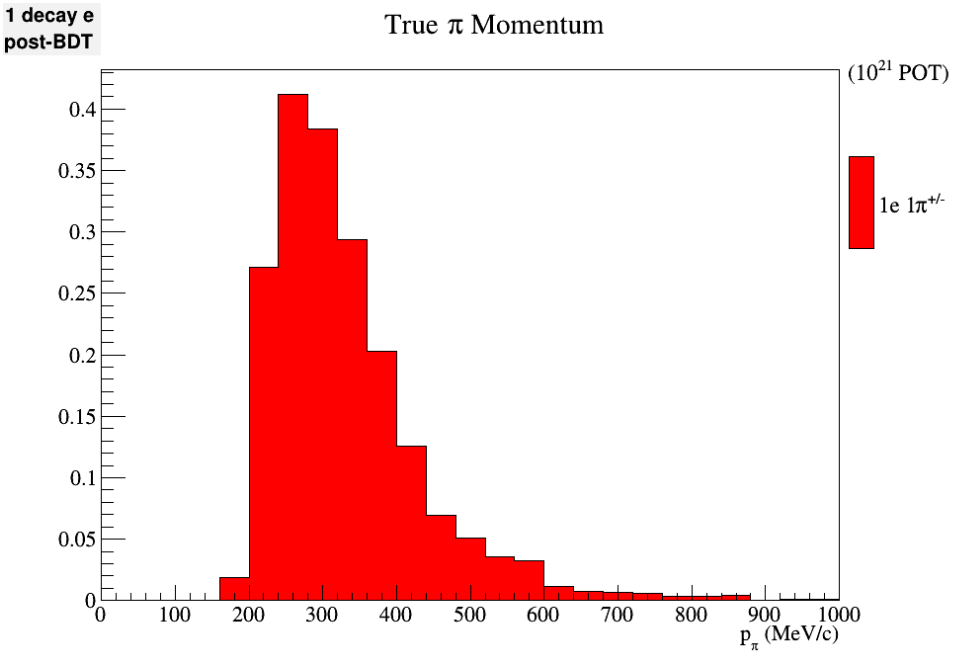

1 decay e
post-BDT
Reconstructed e Momentum (2Reπ fit)
(10^21 POT)
ν_e CC 1π+
ν_e CC QE
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
p_e^rec (MeV/c)

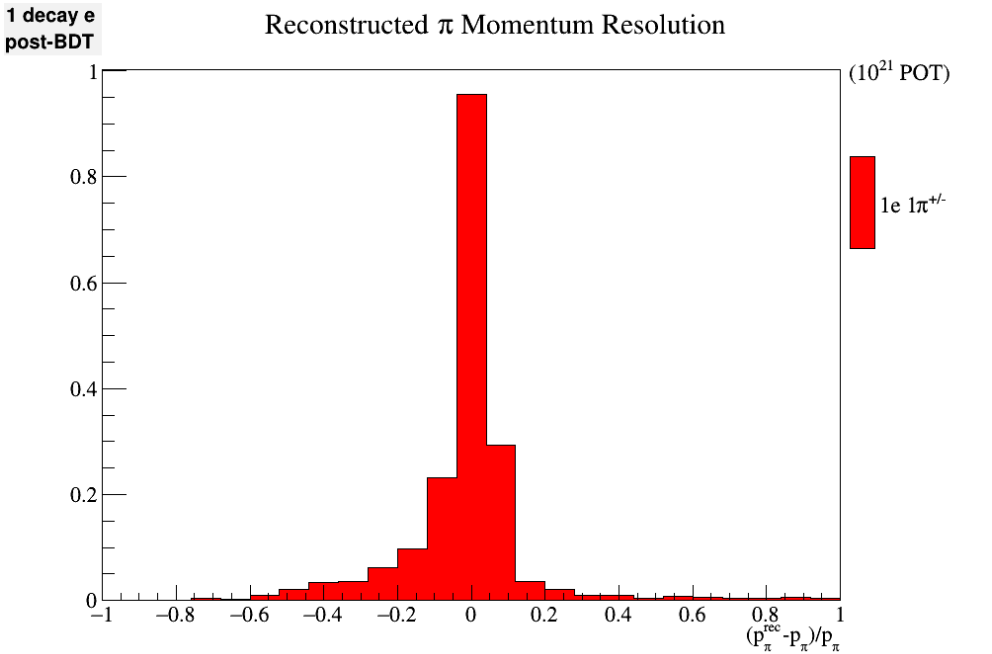

1 decay e
post-BDT
True e Momentum
(10^21 POT)
1e 1π+/-
p_e (MeV/c)

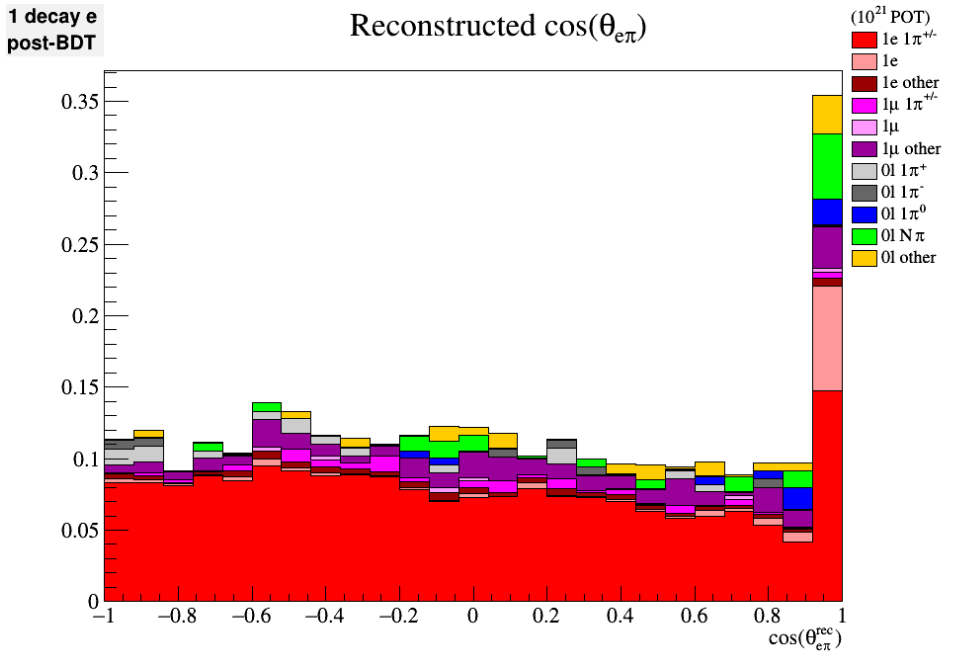

1 decay e
post-BDT
Reconstructed e Momentum Resolution
(10^21 POT)
1e 1π+/-
(p_e^rec-p_e)/p_e

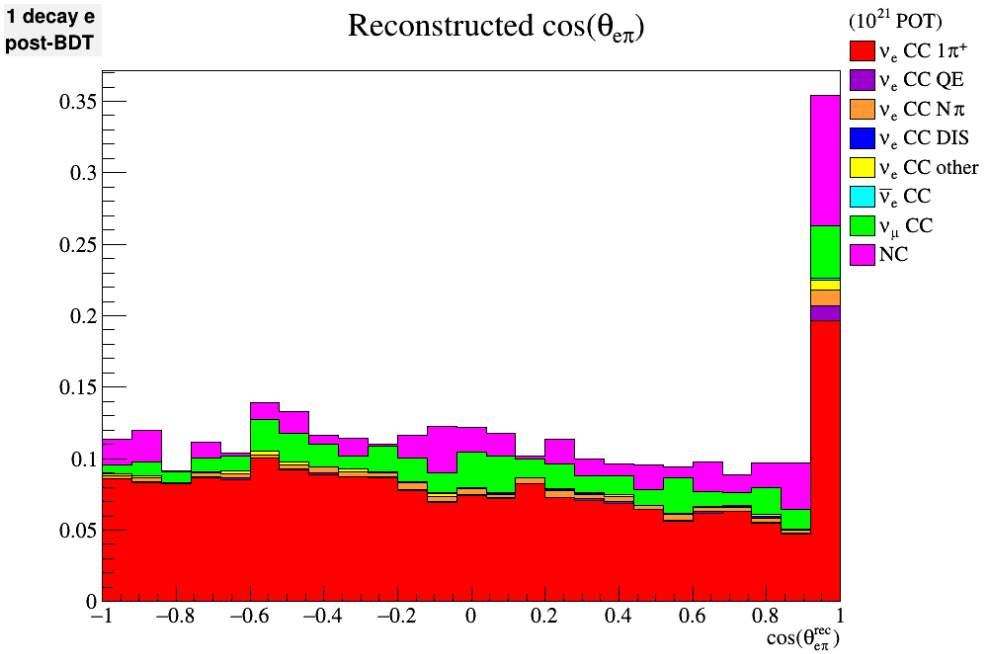

1 decay e
post-BDT
Reconstructed π Momentum (2Reπ fit)
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
p_π^rec (MeV/c)

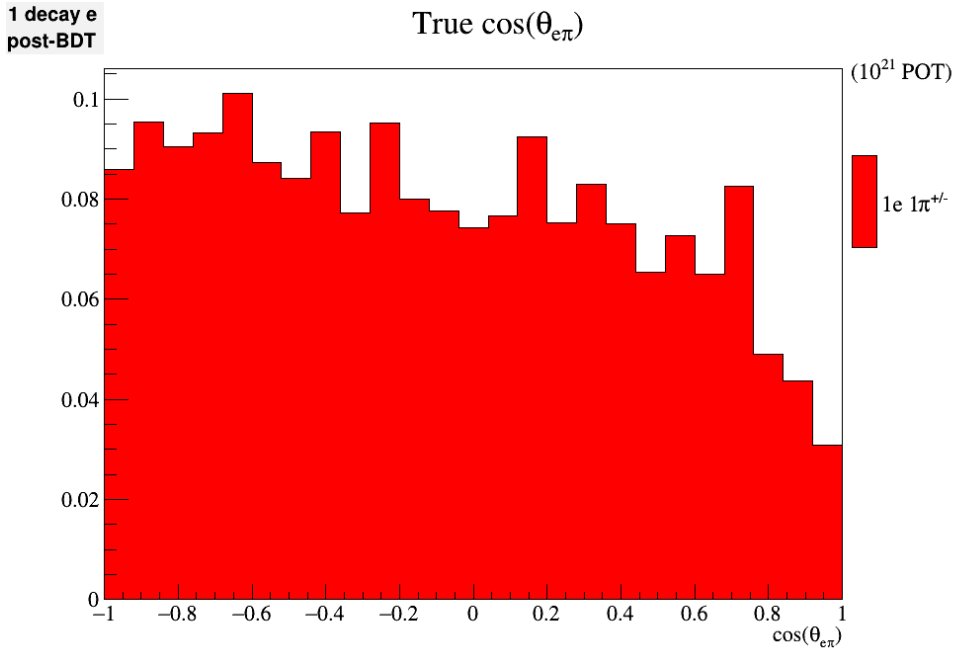

1 decay e
post-BDT
Reconstructed π Momentum (2Reπ fit)
(10^21 POT)
ν_e CC 1π+
ν_e CC QE
ν_e CC Nπ
ν_e CC DIS
ν_e CC other
ν̄_e CC
ν_μ CC
NC
p_π^rec (MeV/c)

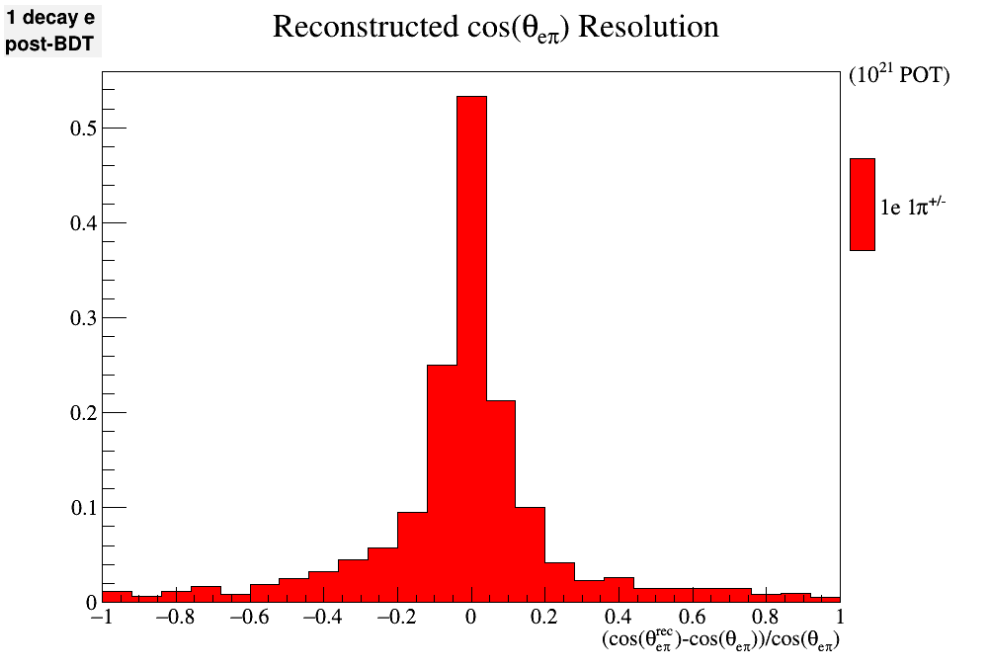

1 decay e
post-BDT
True π Momentum
(10^21 POT)
1e 1π+/-
p_π (MeV/c)

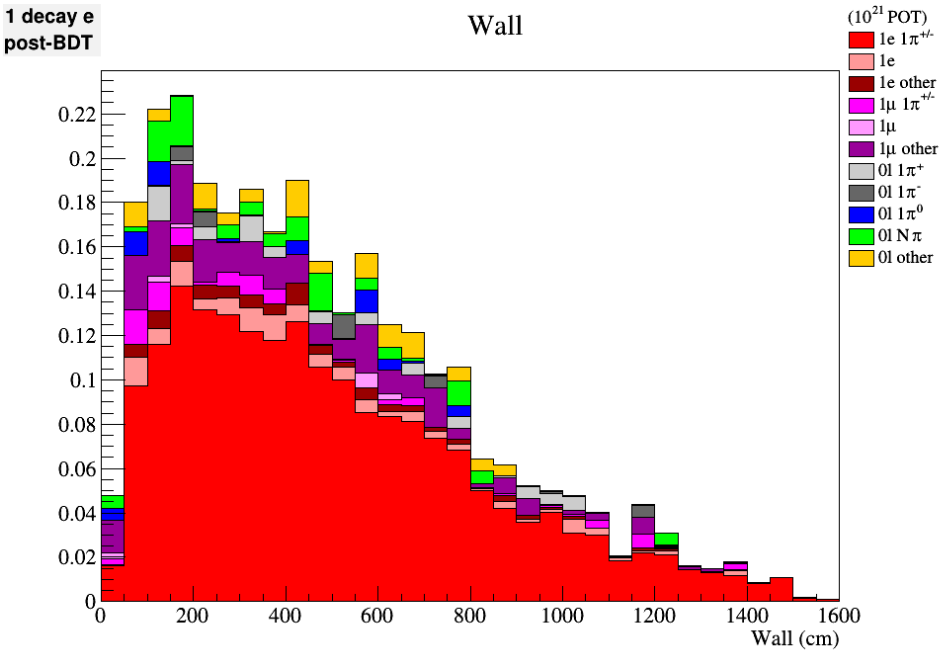

1 decay e
post-BDT
Reconstructed π Momentum Resolution
(10^21 POT)
1e 1π+/-
(p_π^rec - p_π)/p_π

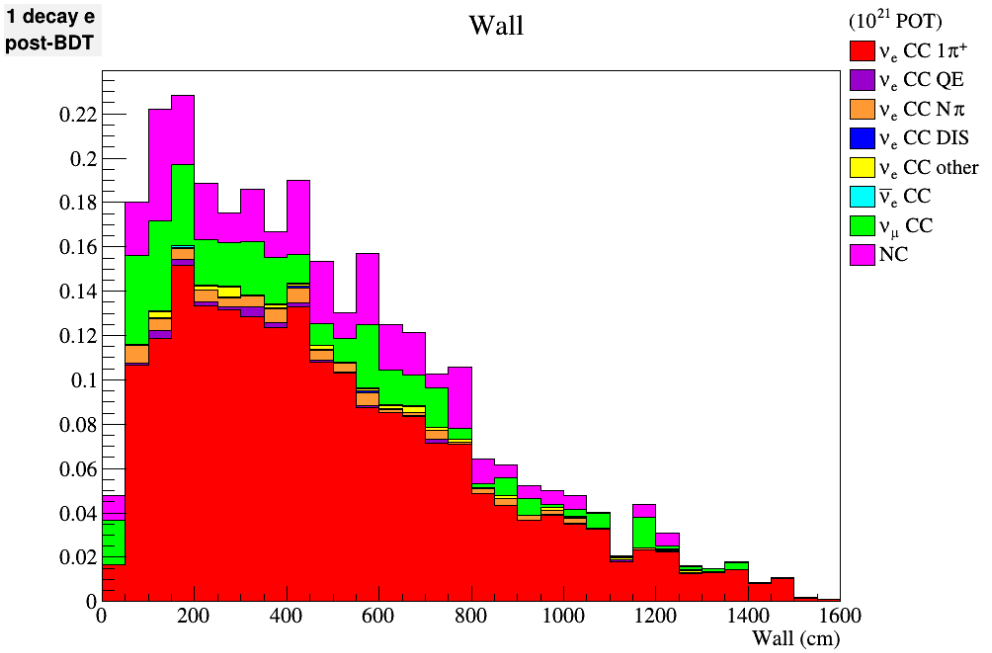

1 decay e
post-BDT
Reconstructed cos(θeπ)
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l N π
0l other
cos(θeπrec)

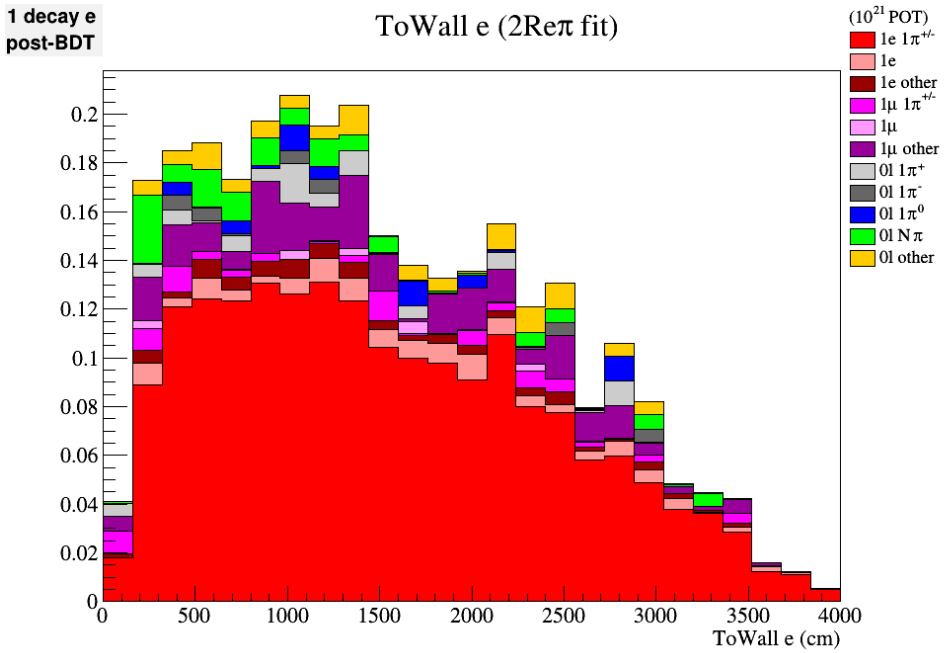

1 decay e
post-BDT
Reconstructed cos(θeπ)
(10^21 POT)
νe CC 1π+
νe CC QE
νe CC N π
νe CC DIS
νe CC other
ν̄e CC
νμ CC
NC
cos(θeπrec)

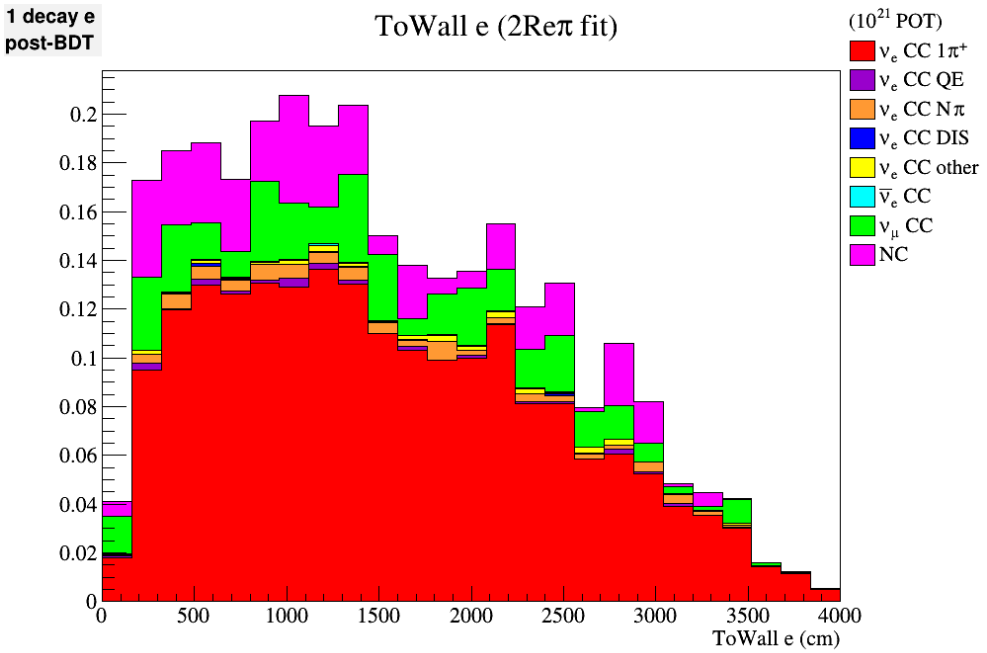

1 decay e
post-BDT
True cos(θeπ)
(10^21 POT)
1e 1π+/-
cos(θeπ)

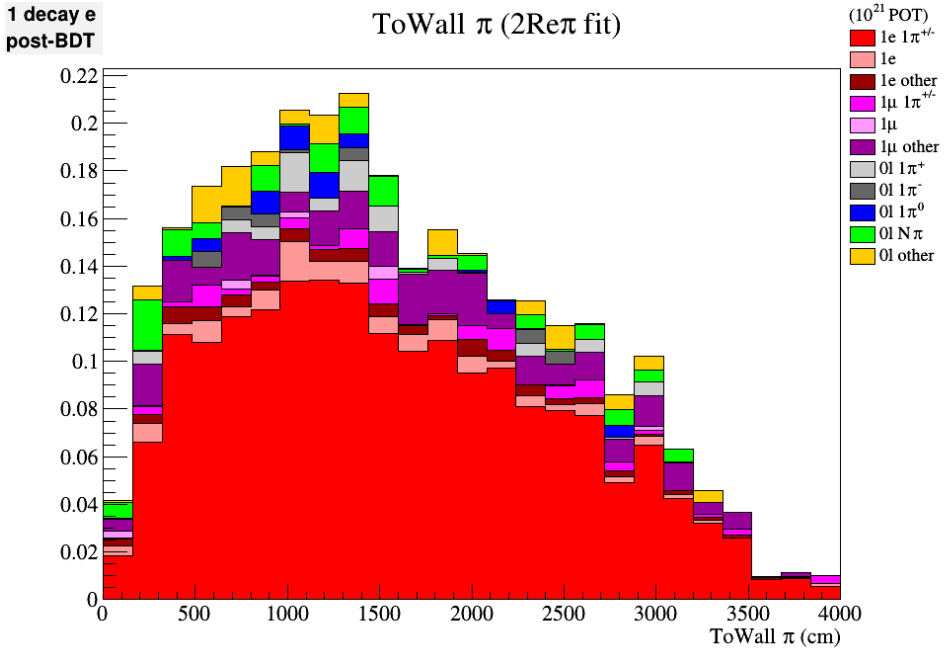

1 decay e
post-BDT
Reconstructed cos(θeπ) Resolution
(10^21 POT)
1e 1π+/-
(cos(θeπrec)-cos(θeπ))/cos(θeπ)

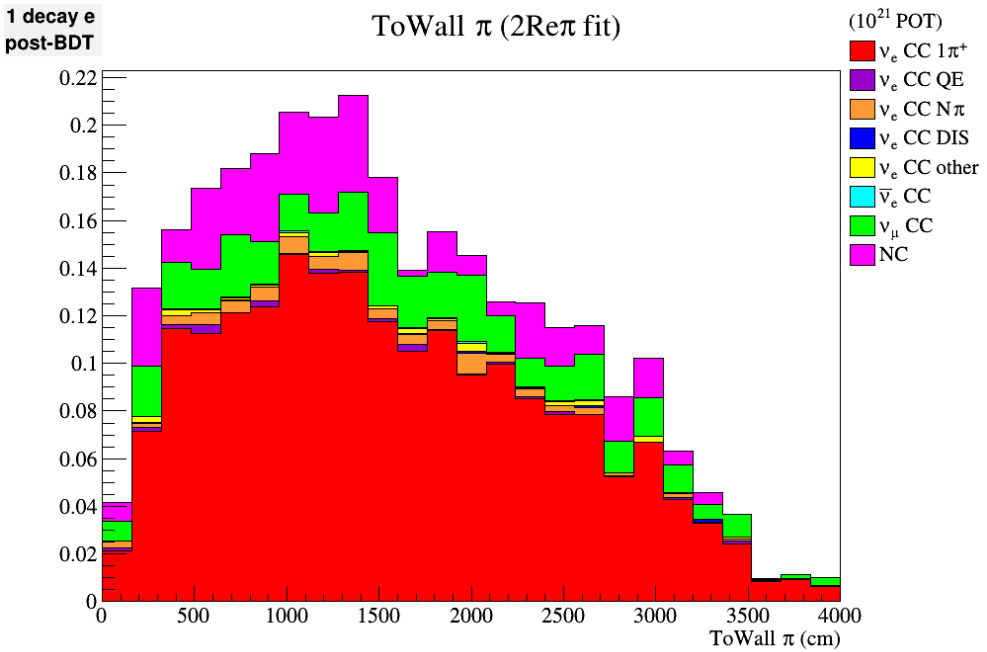

1 decay e
post-BDT
Wall
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
1200
1400
1600
Wall (cm)


1 decay e
post-BDT
Wall
(10^21 POT)
νe CC 1π+
νe CC QE
νe CC Nπ
νe CC DIS
νe CC other
ν̄e CC
νμ CC
NC
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
1200
1400
1600
Wall (cm)

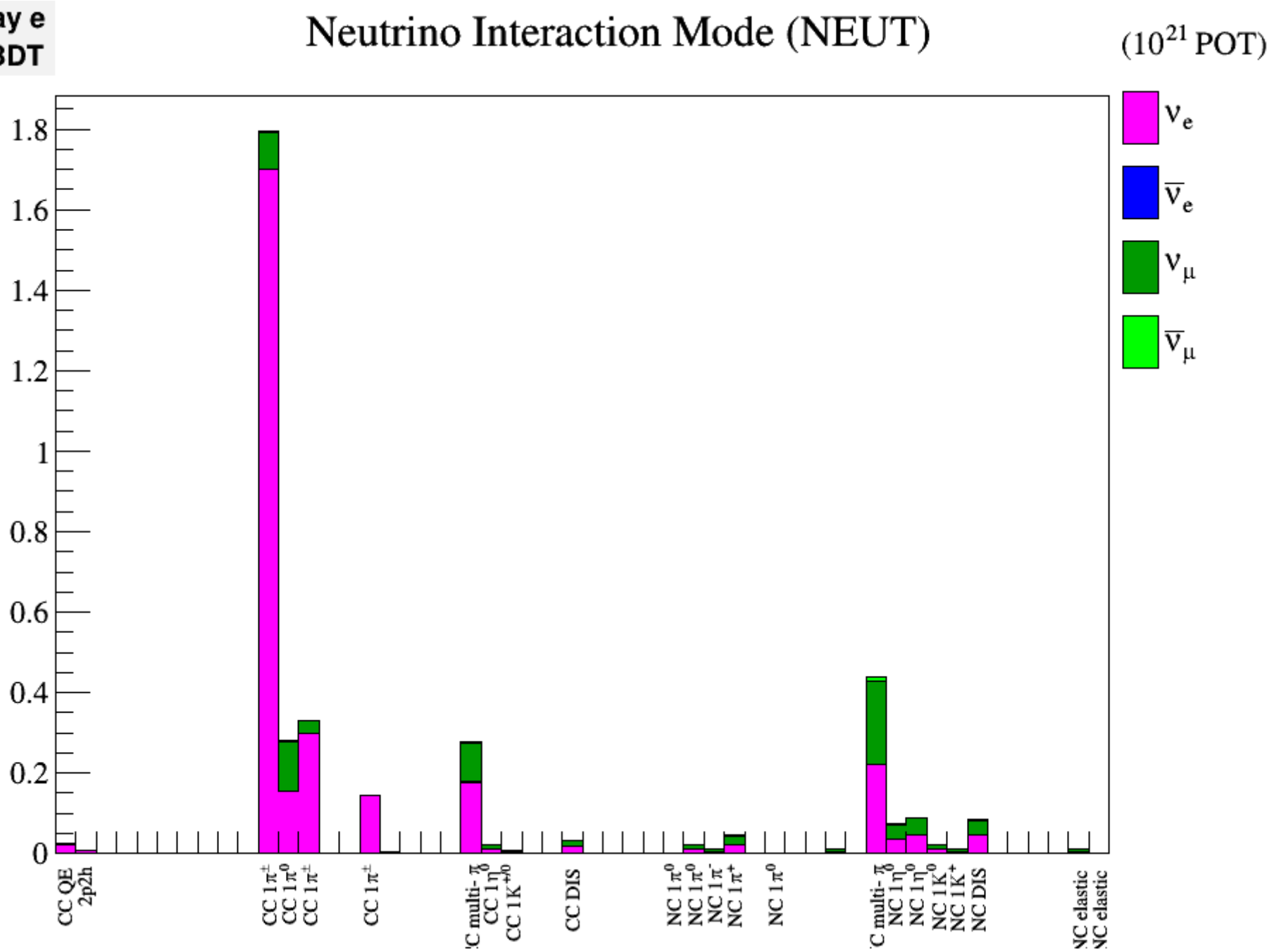

1 decay e
post-BDT
ToWall e (2Reπ fit)
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
ToWall e (cm)


1 decay e
post-BDT
ToWall e (2Reπ fit)
(10^21 POT)
νe CC 1π+
νe CC QE
νe CC Nπ
νe CC DIS
νe CC other
ν̄e CC
νμ CC
NC
ToWall e (cm)


1 decay e
post-BDT
ToWall π (2Reπ fit)
(10^21 POT)
1e 1π+/-
1e
1e other
1μ 1π+/-
1μ
1μ other
0l 1π+
0l 1π-
0l 1π0
0l Nπ
0l other
ToWall π (cm)


1 decay e
post-BDT
ToWall π (2Reπ fit)
(10^21 POT)
νe CC 1π+
νe CC QE
νe CC Nπ
νe CC DIS
νe CC other
ν̄e CC
νμ CC
NC
ToWall π (cm)

1 decay e post-BDT



1 decay e post-BDT

NEUT Mode vs. Visible Final State Particles