

Progress Update

Trevor Towstego
UofT Neutrino/DM Meeting
February 28, 2018

Cut Optimization: Grid Search

- Cut optimization against FOM using N-dimensional grid search
 - Example shown uses 11 grid points per cut (+1 point for case where cut is not used)
 - 1.5 GeV cut included in baseline
- 2Re π** (7 variables)
- $p_e - p_\pi$ low (-1000,-500)
 - $p_e - p_\pi$ high (500,1000)
 - p_{low} (20,70)
 - $m_{e\pi}$: (200,300) low, (310,410) high
- vs
- $nll_{2Re\pi} - nll_{2Ree}$: (-100,-50) low, (-75,-25) high
- 2Re π 1de** (3 variables)
- $p_e - p_\pi$ low (-1000,-500)
 - $p_e - p_\pi$ high (500,1000)
 - $d2se$ (150,200)

Grid Search Summary

<p>2Reπ Max: (0,5,6,7,6,8,0) Max FOM = 0.697</p>	<p>2Reπ1de Max: (10,8,4) Max FOM = 1.149</p>
<p>p_e-p_{π} low not used p_e-p_{π} high = 700 p_{low} = 45 m_{eπ} low = 260 m_{eπ} high = 360 nll_{2Reπ}-nll_{2Ree} low = -65 nll_{2Reπ}-nll_{2Ree} high not used</p>	<p>p_e-p_{π} low = -550 p_e-p_{π} high = 850 d2se = 180</p>

BL+E_{rec}: 0.638

BL+E_{rec}: 1.124

Grid Search Cutflow

(neutrino beam mode, normal mass hierarchy, $\delta_{CP}=0$, 10^{21} POT)

Sample	cut	$\nu_\mu/\bar{\nu}_\mu$ CC	intrinsic $\nu_e/\bar{\nu}_e$ CC	osc $\nu_e/\bar{\nu}_e$ CC	$\nu_\mu/\bar{\nu}_\mu$ NC	$\nu_e/\bar{\nu}_e$ NC	Signal	Background	Purity	FOM
2Reπ	baseline+E _{rec}	0.21	0.55	1.31	2.00	0.13	1.31	2.89	0.31	0.638
	$p_e - p_\pi < 700 \text{ MeV}$	0.21	0.55	1.31	1.99	0.13	1.31	2.87	0.31	0.639
	$p_{\text{low}} > 45 \text{ MeV}$	0.18	0.54	1.29	1.53	0.08	1.29	2.33	0.36	0.677
	$m_{e\pi} < 260 \text{ MeV}$ $> 360 \text{ MeV} \parallel$ $n _{2\text{Re}\pi} - n _{2\text{Ree}} < -65$	0.17	0.53	1.25	1.21	0.06	1.25	1.98	0.39	0.697
2Reπ1de	baseline+E _{rec}	0.71	0.85	2.58	1.04	0.09	2.58	2.70	0.49	1.124
	$-550 < p_e - p_\pi < 850$	0.67	0.84	2.55	0.91	0.08	2.55	2.49	0.51	1.135
	d2se < 180	0.53	0.80	2.50	0.83	0.07	2.50	2.23	0.53	1.149

Event breakdown: $2\text{Re}\pi$

(neutrino beam mode, normal mass hierarchy, $\delta_{\text{CP}}=0$, 10^{21} POT)

cut	$\nu_e/\bar{\nu}_e$ NC $1\pi^+$	$\nu_e/\bar{\nu}_e$ NC $1\pi^-$	$\nu_e/\bar{\nu}_e$ NC $1\pi^0$	$\nu_e/\bar{\nu}_e$ NC $N\pi$	$\nu_e/\bar{\nu}_e$ NC 0π	$\nu_\mu/\bar{\nu}_\mu$ NC $1\pi^+$	$\nu_\mu/\bar{\nu}_\mu$ NC $1\pi^-$	$\nu_\mu/\bar{\nu}_\mu$ NC $1\pi^0$	$\nu_\mu/\bar{\nu}_\mu$ NC $N\pi$	$\nu_\mu/\bar{\nu}_\mu$ NC 0π
baseline+ E_{rec}	0.02	0.03	0.04	0.01	0.04	0.21	0.28	0.89	0.18	0.44
$p_e - p_\pi < 700\text{MeV}$	0.02	0.03	0.04	0.01	0.04	0.21	0.28	0.89	0.17	0.44
$p_{\text{low}} > 45\text{MeV}$	0.01	0.01	0.04	0.01	0.01	0.13	0.15	0.89	0.16	0.20
$m_{\text{ent}} < 260\text{MeV}$ $> 360\text{MeV} \parallel n _{2\text{Re}\pi} -$ $n _{2\text{Ree}} < -65$	0.01	0.01	0.02	0.01	0.01	0.13	0.14	0.62	0.15	0.17

cut	$\nu_e/\bar{\nu}_e$ CC $1\pi^{+/-}$	$\nu_e/\bar{\nu}_e$ CCQE	$\nu_e/\bar{\nu}_e$ CCother	$\nu_\mu/\bar{\nu}_\mu$ CC $1\pi^{+/-}$	$\nu_\mu/\bar{\nu}_\mu$ CCQE	$\nu_\mu/\bar{\nu}_\mu$ CCother	$\nu_e/\bar{\nu}_e$ CC $1\pi^{+/-}$	Other	Purity
baseline+ E_{rec}	1.27	0.38	0.22	0.06	0.05	0.10	1.27	2.93	0.30
$p_e - p_\pi < 700\text{MeV}$	1.26	0.38	0.21	0.06	0.05	0.09	1.26	2.92	0.30
$p_{\text{low}} > 45\text{MeV}$	1.24	0.37	0.21	0.05	0.04	0.09	1.24	2.38	0.34
$m_{\text{ent}} < 260\text{MeV}$ $> 360\text{MeV} \parallel n _{2\text{Re}\pi} -$ $n _{2\text{Ree}} < -65$	1.23	0.36	0.20	0.05	0.04	0.09	1.23	2.01	0.38

Event breakdown: 2Re π 1de

(neutrino beam mode, normal mass hierarchy, $\delta_{CP}=0$, 10^{21} POT)

cut	$\nu_e/\bar{\nu}_e$ NC 1 π^+	$\nu_e/\bar{\nu}_e$ NC 1 π^-	$\nu_e/\bar{\nu}_e$ NC 1 π^0	$\nu_e/\bar{\nu}_e$ NC N π	$\nu_e/\bar{\nu}_e$ NC 0 π	$\nu_\mu/\bar{\nu}_\mu$ NC 1 π^+	$\nu_\mu/\bar{\nu}_\mu$ NC 1 π^-	$\nu_\mu/\bar{\nu}_\mu$ NC 1 π^0	$\nu_\mu/\bar{\nu}_\mu$ NC N π	$\nu_\mu/\bar{\nu}_\mu$ NC 0 π
baseline+E _{rec}	0.03	0.01	0.00	0.02	0.03	0.39	0.10	0.05	0.19	0.31
-550<p _e -p _{π} <850	0.02	0.01	0.00	0.02	0.03	0.32	0.08	0.05	0.17	0.30
d2se<180	0.02	0.01	0.00	0.02	0.03	0.29	0.07	0.05	0.16	0.25

cut	$\nu_e/\bar{\nu}_e$ CC1 $\pi^{+/-}$	$\nu_e/\bar{\nu}_e$ CCQE	$\nu_e/\bar{\nu}_e$ CCother	$\nu_\mu/\bar{\nu}_\mu$ CC1 $\pi^{+/-}$	$\nu_\mu/\bar{\nu}_\mu$ CCQE	$\nu_\mu/\bar{\nu}_\mu$ CCother	$\nu_e/\bar{\nu}_e$ CC1 $\pi^{+/-}$	Other	Purity
baseline+E _{rec}	3.21	0.02	0.20	0.28	0.03	0.40	3.21	2.07	0.61
-550<p _e -p _{π} <850	3.16	0.02	0.20	0.25	0.03	0.38	3.16	1.88	0.63
d2se<180	3.09	0.02	0.19	0.22	0.02	0.29	3.09	1.64	0.65

Some tweaking + first look at wall

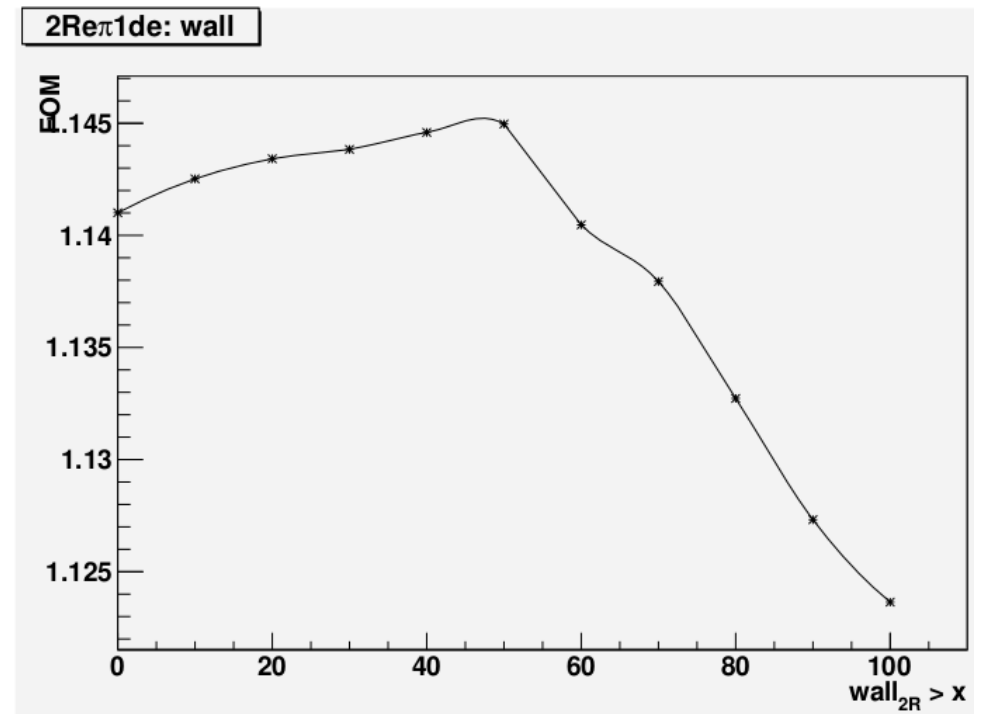
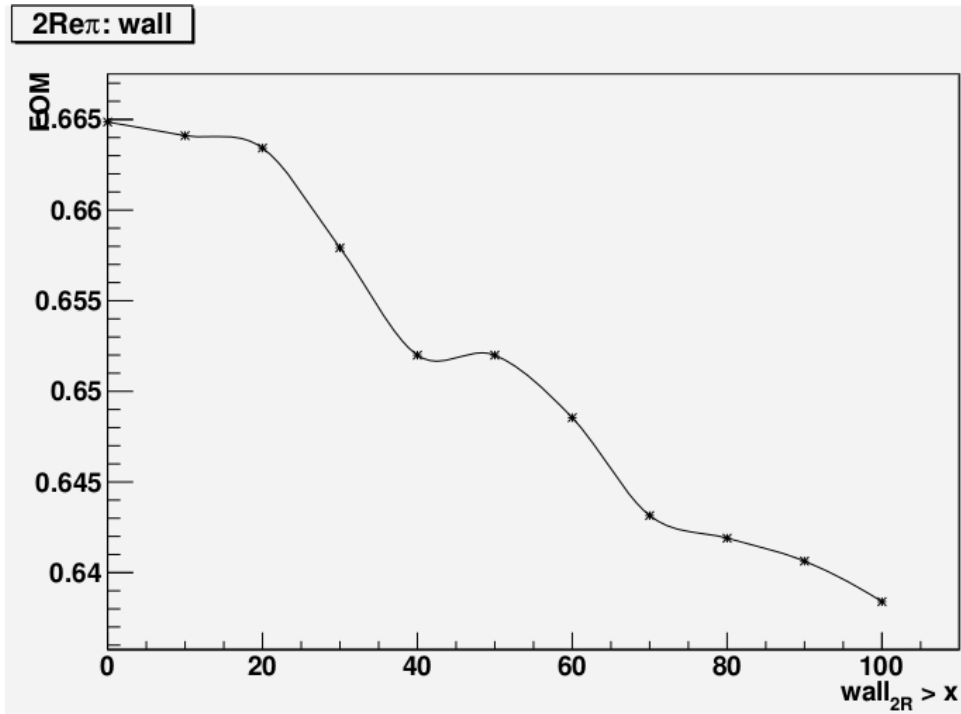
BL+E_{rec}: 0.638

2Reπ	2Reπ1de
Max: (0,0,7,7,7,6,8)	Max: (4,5,3,3)
Max FOM = 0.712	Max FOM = 1.196
wall not used	wall = 30
p_e-p_{π} low not used	p_e-p_{π} low = -300
p_e-p_{π} high = 800	p_e-p_{π} high = 350
p_{low} = 50	
m_{eπ} low = 260	
m_{eπ} high = 360	
nll_{2Reπ}-nll_{2Ree} low = -65	d2se = 160

BL+E_{rec}: 1.124

wall: (0 cm, 100 cm) in steps of 10 cm

Baseline + Wall cuts



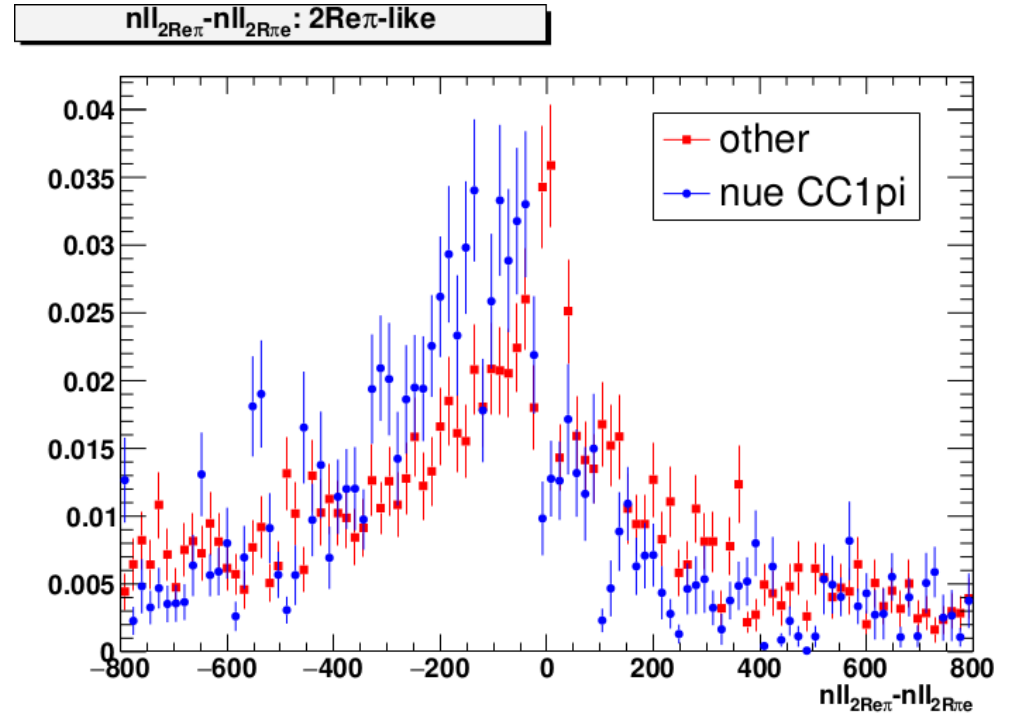
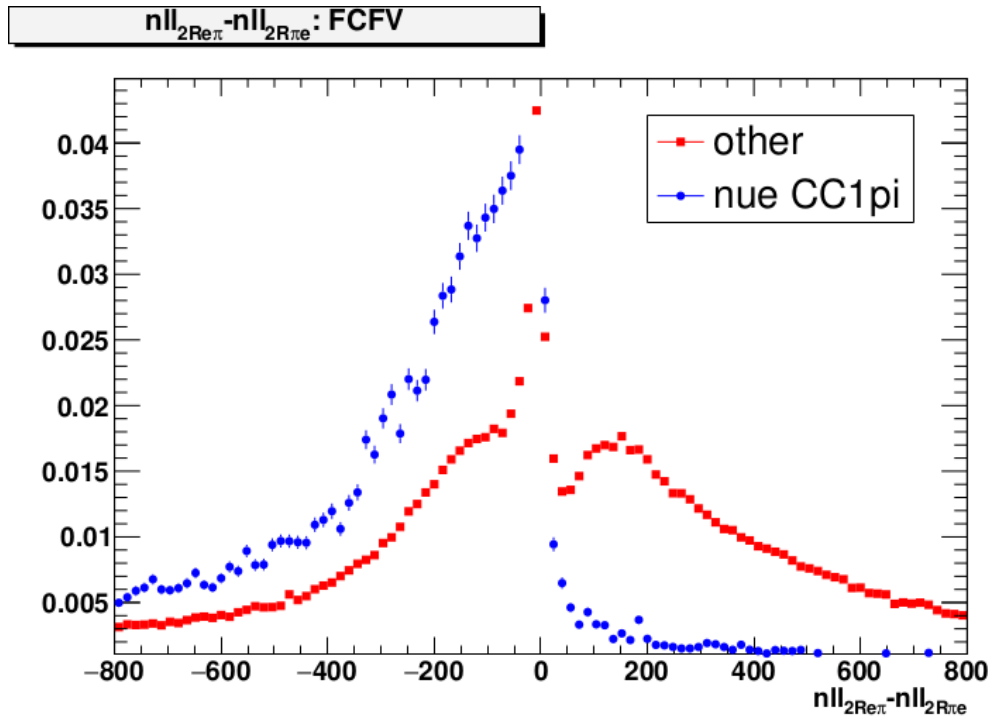
Cutflow

Sample	cut	$\nu_\mu/\bar{\nu}_\mu$ CC	intrinsic $\nu_e/\bar{\nu}_e$ CC	osc $\nu_e/\bar{\nu}_e$ CC	$\nu_\mu/\bar{\nu}_\mu$ NC	$\nu_e/\bar{\nu}_e$ NC	Signal	Background	Purity	FOM
2Reπ	baseline+E _{rec} (no wall)	0.67	0.71	1.57	2.50	0.15	1.57	4.03	0.28	0.665
	wall>0cm	0.67	0.71	1.57	2.50	0.15	1.57	4.03	0.28	0.665
	p _e -p _{π} <800MeV	0.67	0.70	1.57	2.49	0.15	1.57	4.01	0.28	0.666
	p _{low} >45MeV	0.54	0.69	1.54	1.96	0.10	1.54	3.30	0.32	0.698
	m _{eπ} <260MeV >360MeV n _{2Reπ} -n _{2Ree} <-65	0.50	0.67	1.48	1.58	0.08	1.48	2.84	0.34	0.712
2Reπ1de	baseline+E _{rec} (no wall)	1.11	0.95	2.84	1.23	0.10	2.84	3.40	0.46	1.137
	wall>30cm	1.00	0.94	2.80	1.16	0.09	2.80	3.19	0.47	1.144
	-300<p _e -p _{π} <350	0.75	0.74	2.51	0.51	0.05	2.51	2.04	0.55	1.177
	d2se<160	0.57	0.70	2.44	0.42	0.04	2.44	1.72	0.59	1.196

Likelihood Ratios

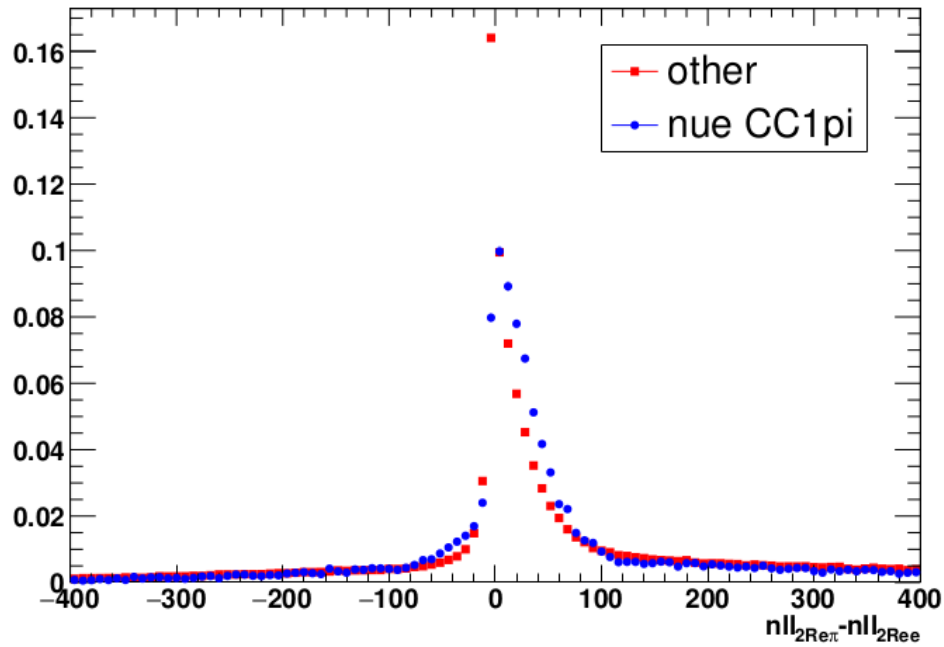
- Look at likelihood ratios of various 2-ring fits both before and after $2R_{e\pi}$ -like cut
 - $2R_{e\pi}$
 - $2R_{\pi e}$
 - $2R_{ee}$
- Wanted to look at $2R_{ep}$ and $2R_{pe}$ fits as well, but these all had $nll = 0$
- In following plots, $\nu_e CC 1\pi$ is defined by visible particles

$2\text{Re}\pi$ vs $2\text{R}\pi e$

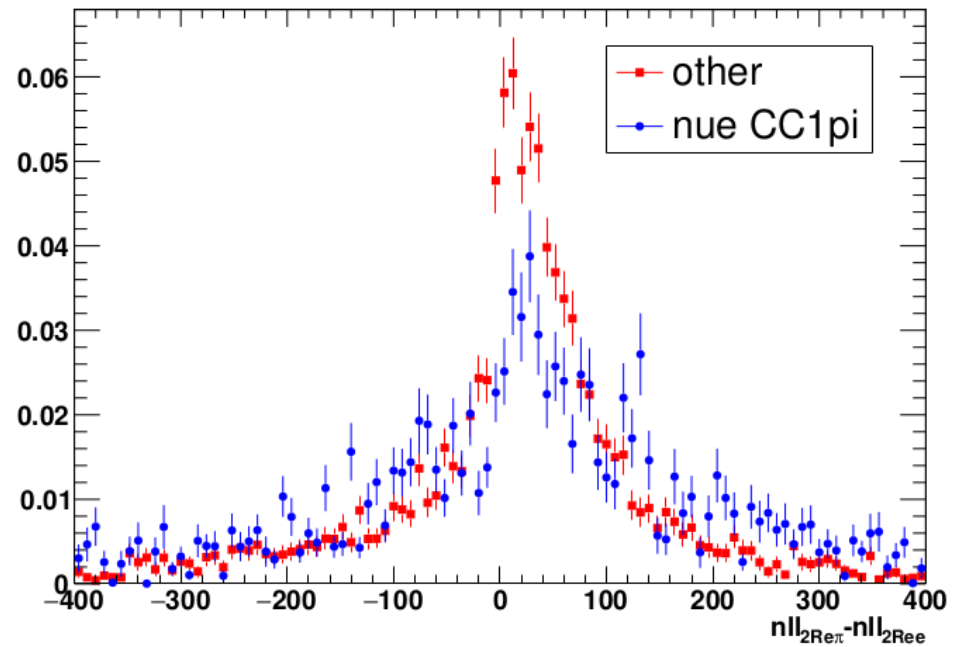


2Re π vs 2Ree

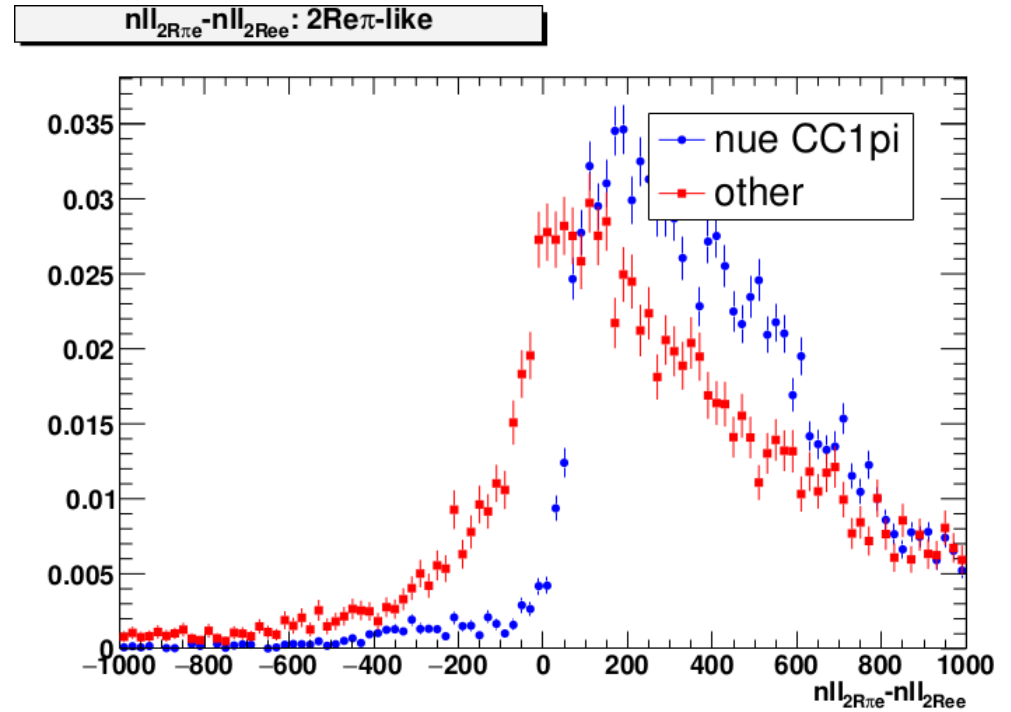
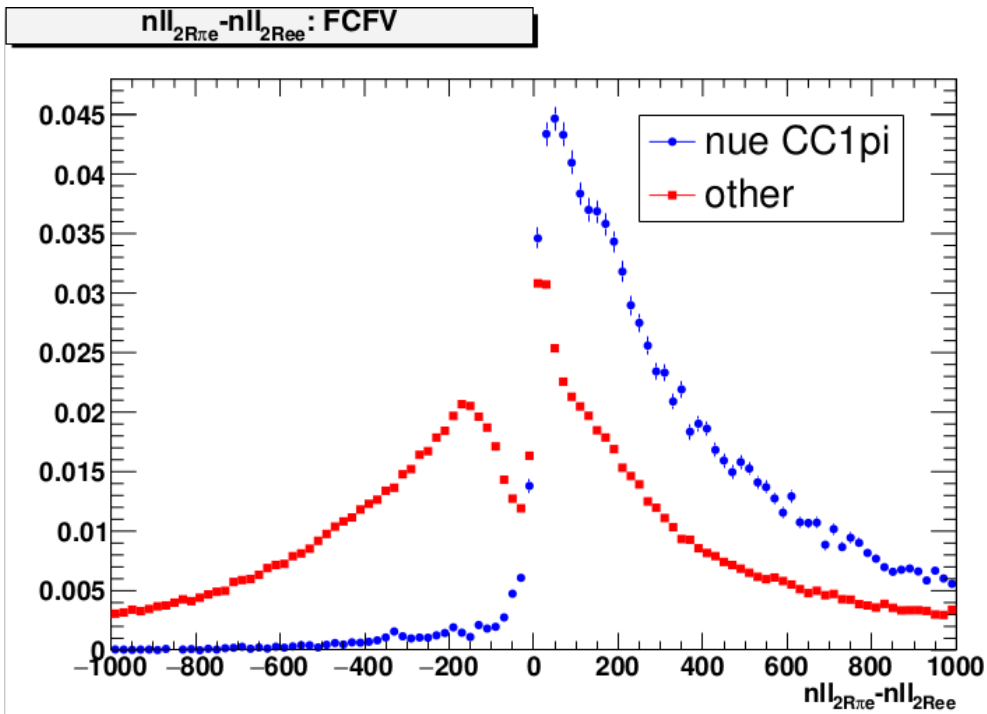
$nll_{2Re\pi} - nll_{2Ree}$: FCFV



$nll_{2Re\pi} - nll_{2Ree}$: 2Re π -like



2R π e vs 2Ree



Event Display

- Want to look at $\text{NC}1\pi^0$ events in event display
 - better understand why these are being reconstructed as $e\pi$ -like events
- Tried to look at T2K-SK MC zbs files using superscan:

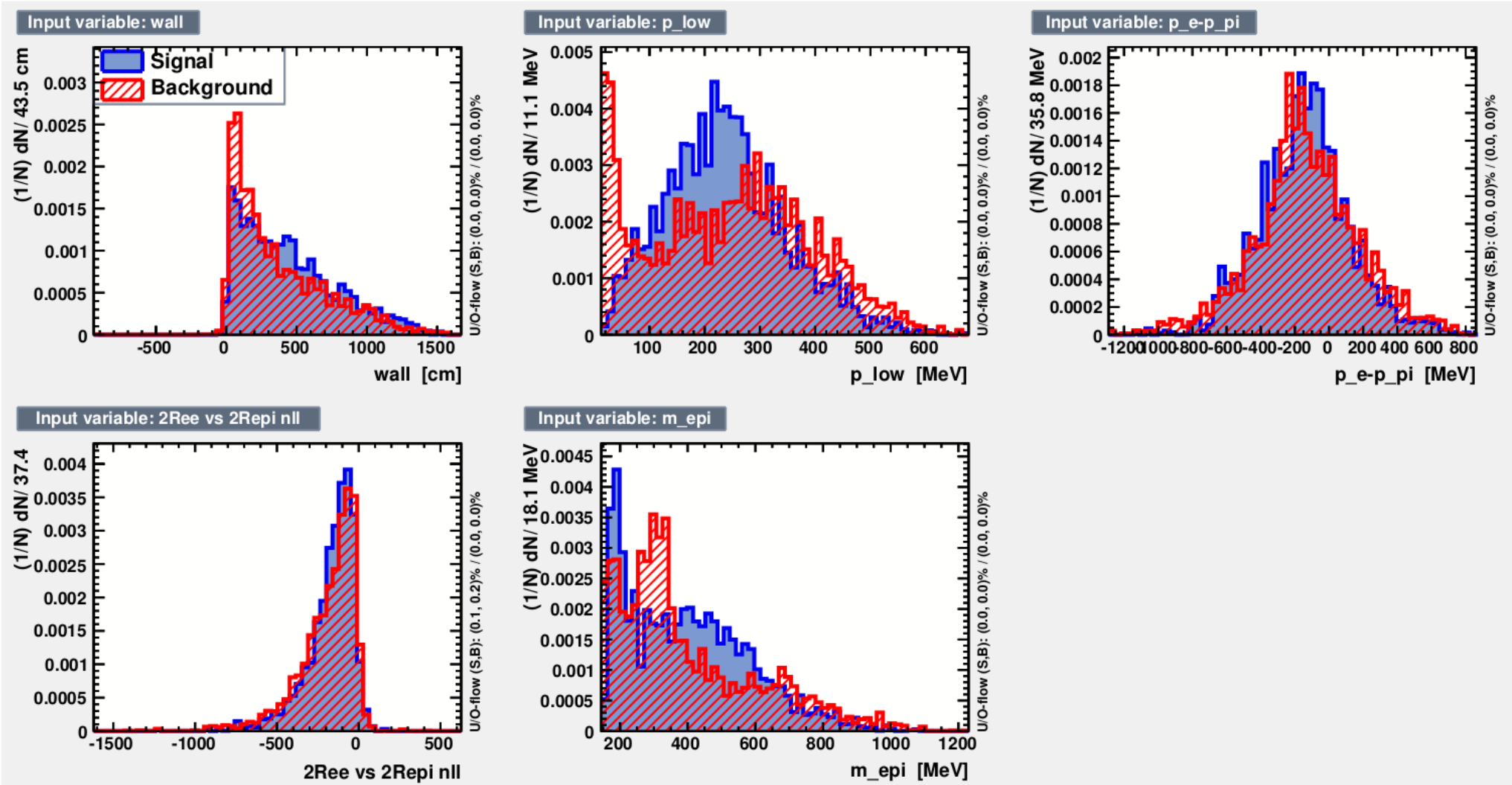
```
$ superscan -f numu_x_numu.h2o.sk.flux13a.neut_532_ap14a.000.000_fQv4r0.zbs
```

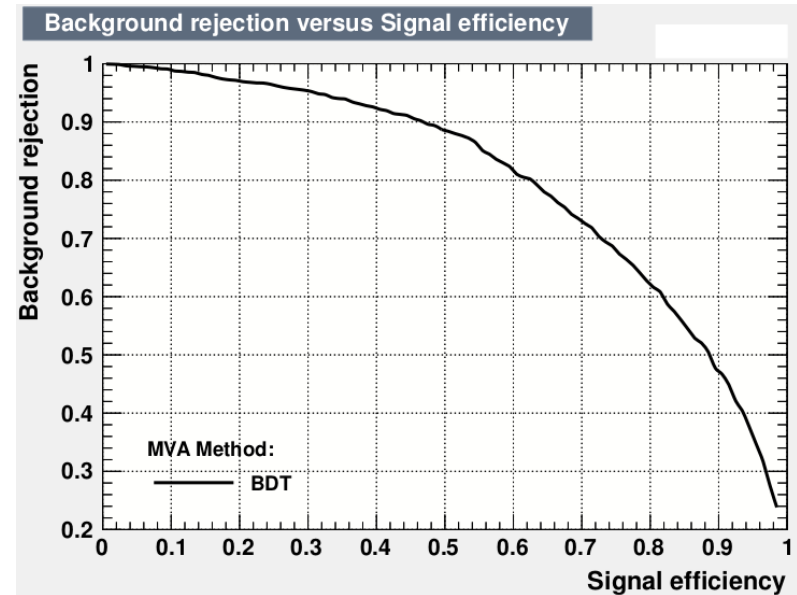
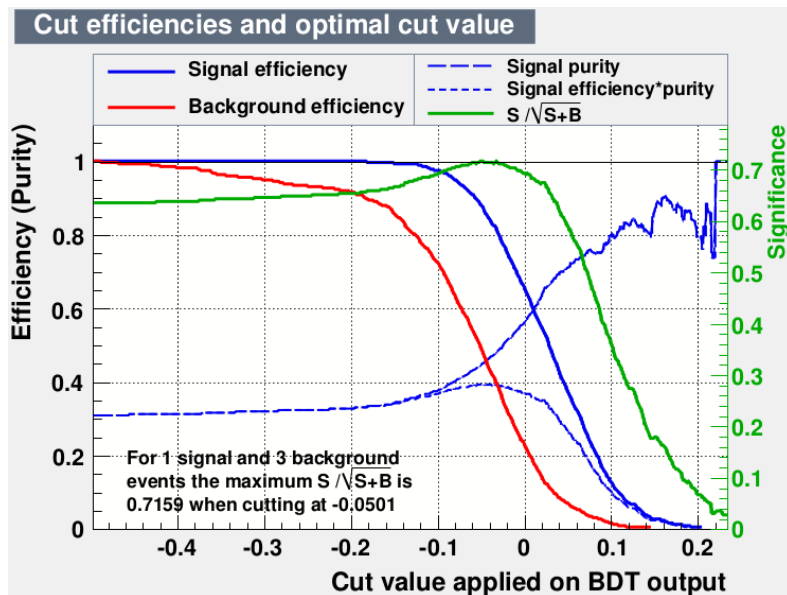
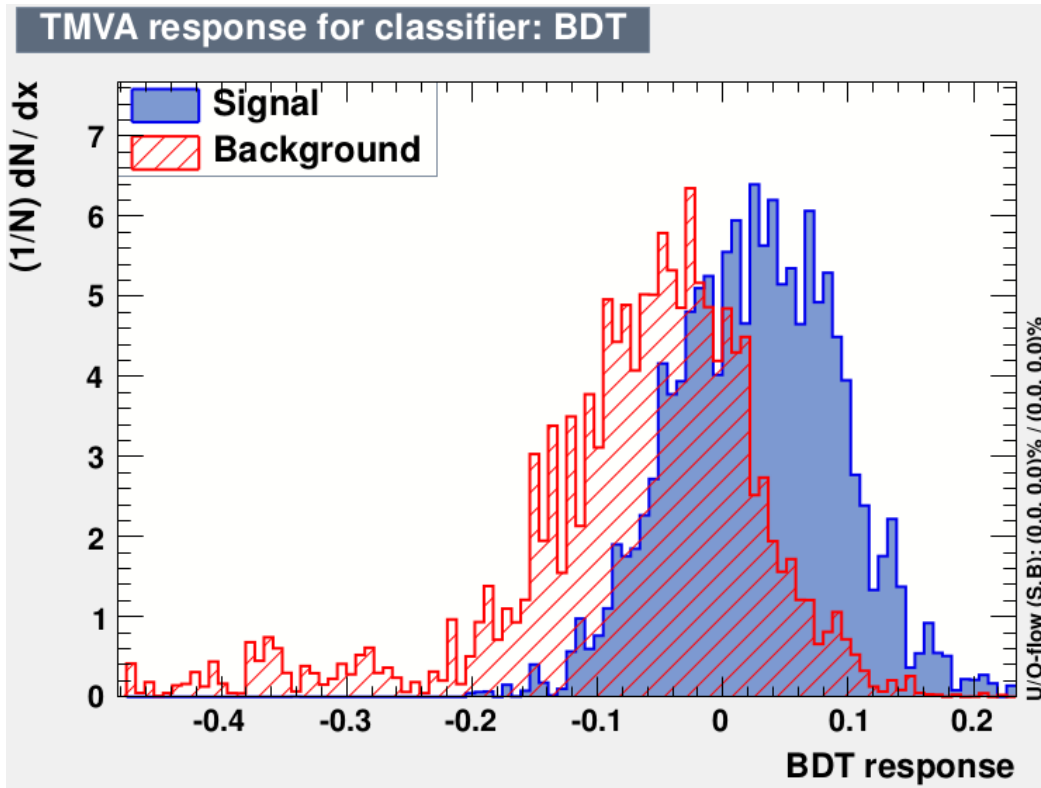
 - superscan loads, window forms, but then it crashes
 - are these files supposed to be able to be opened using superscan?
- Tried my own installation of the SK software on neut cluster, as well as one of Shimpei's installations on sukap

TMVA

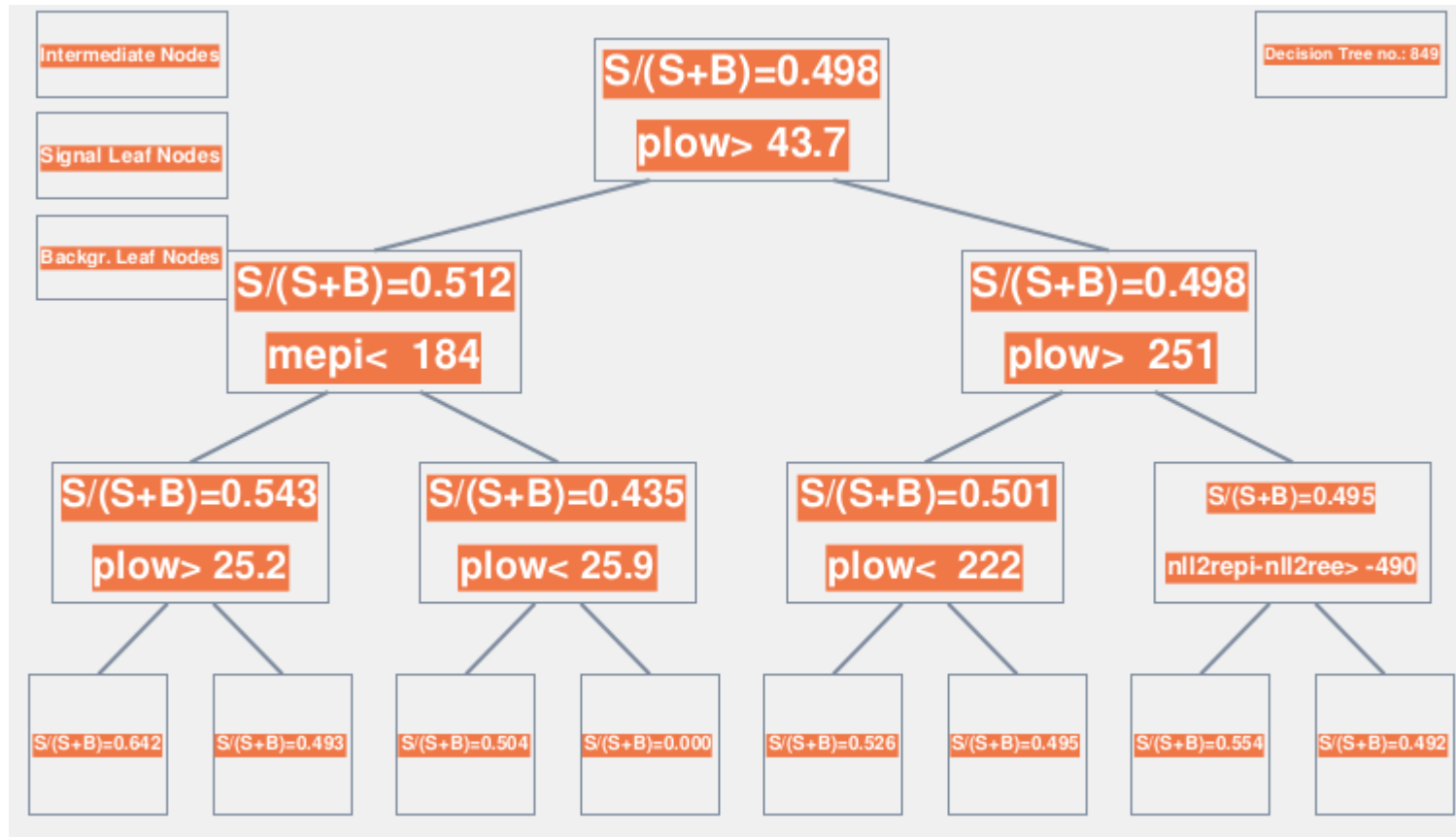
- Some complications regarding rectangular cut optimization in TMVA:
 - Assumes signal is “clustered” along all user-supplied variables, and so only optimizes for cuts of the form $(\min < x < \max)$
 - This doesn't work when the background is clustered rather than the signal
 - In general, seem to be getting strange results using TMVA's rectangular cut optimization... still investigating
- In the meantime, I've gotten some more promising results using BDTs and NNs

Boosted Decision Tree

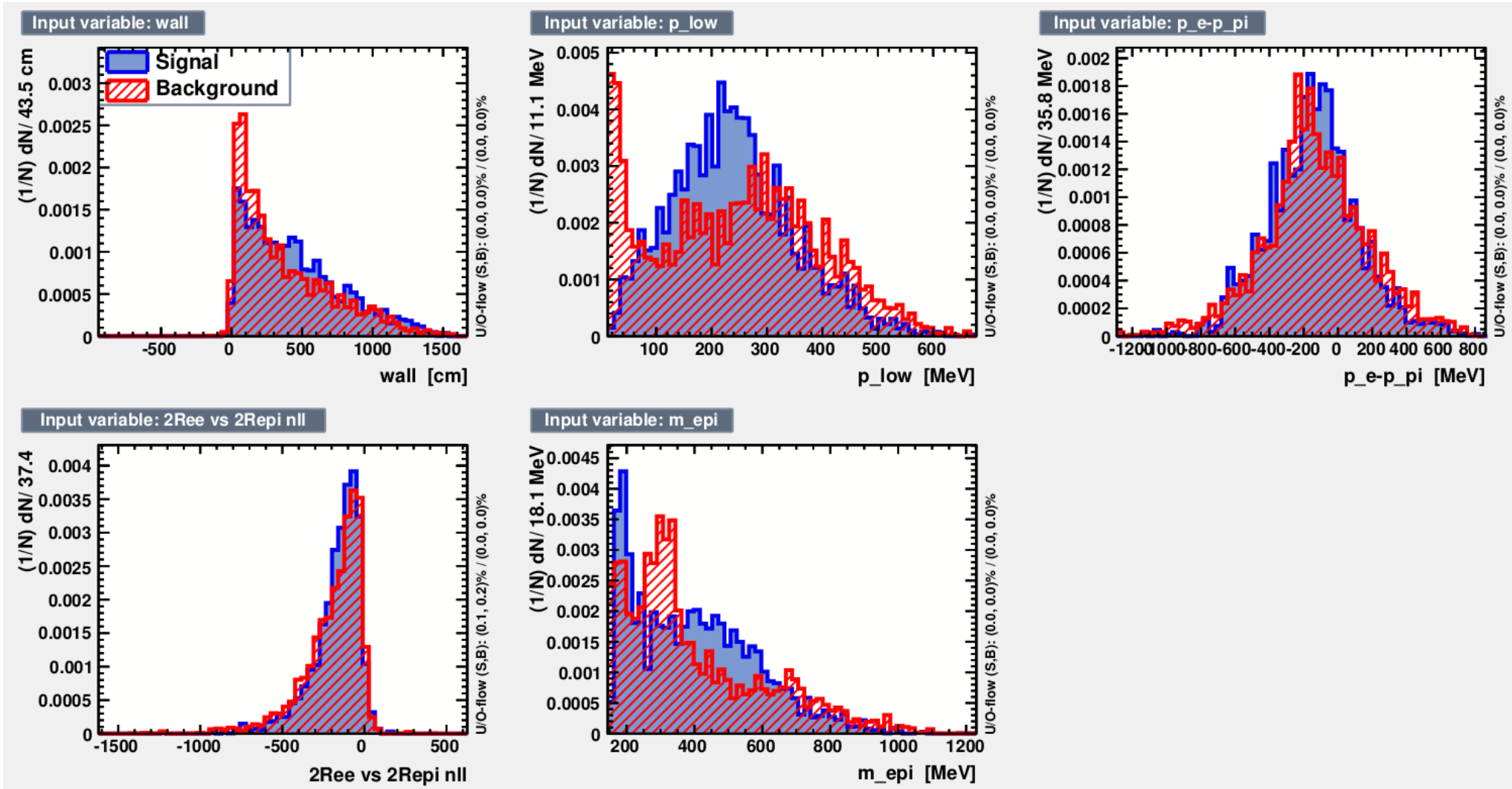


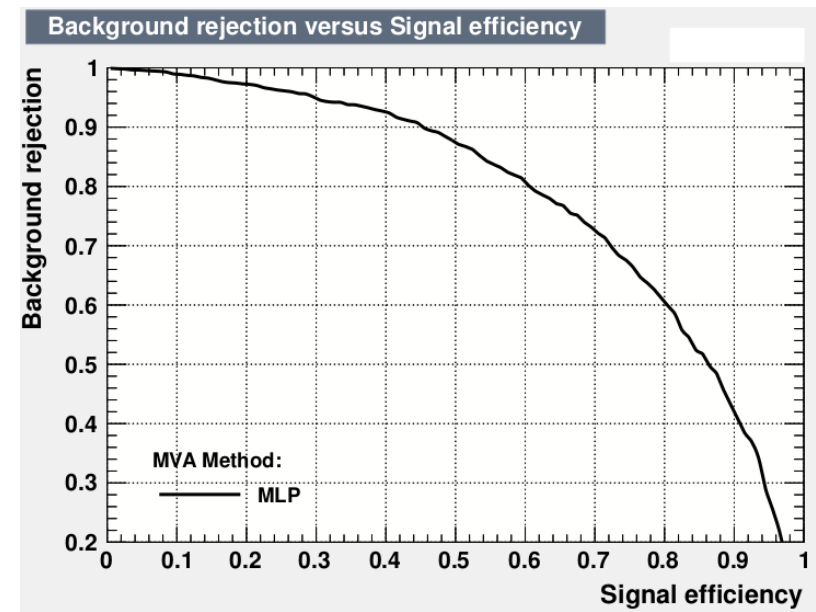
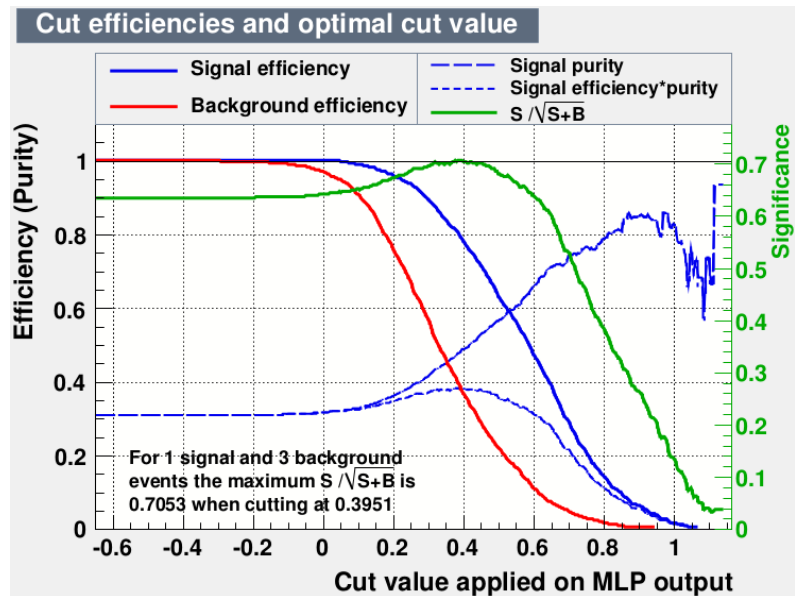
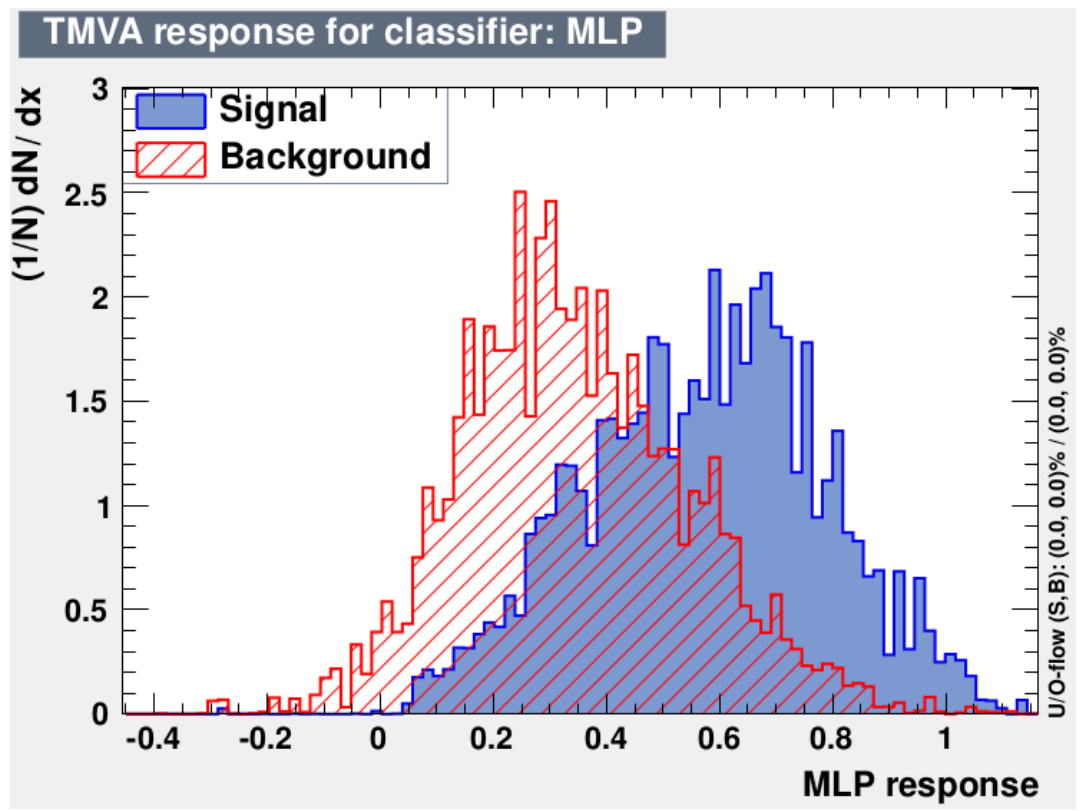


An example decision tree (one of 850)

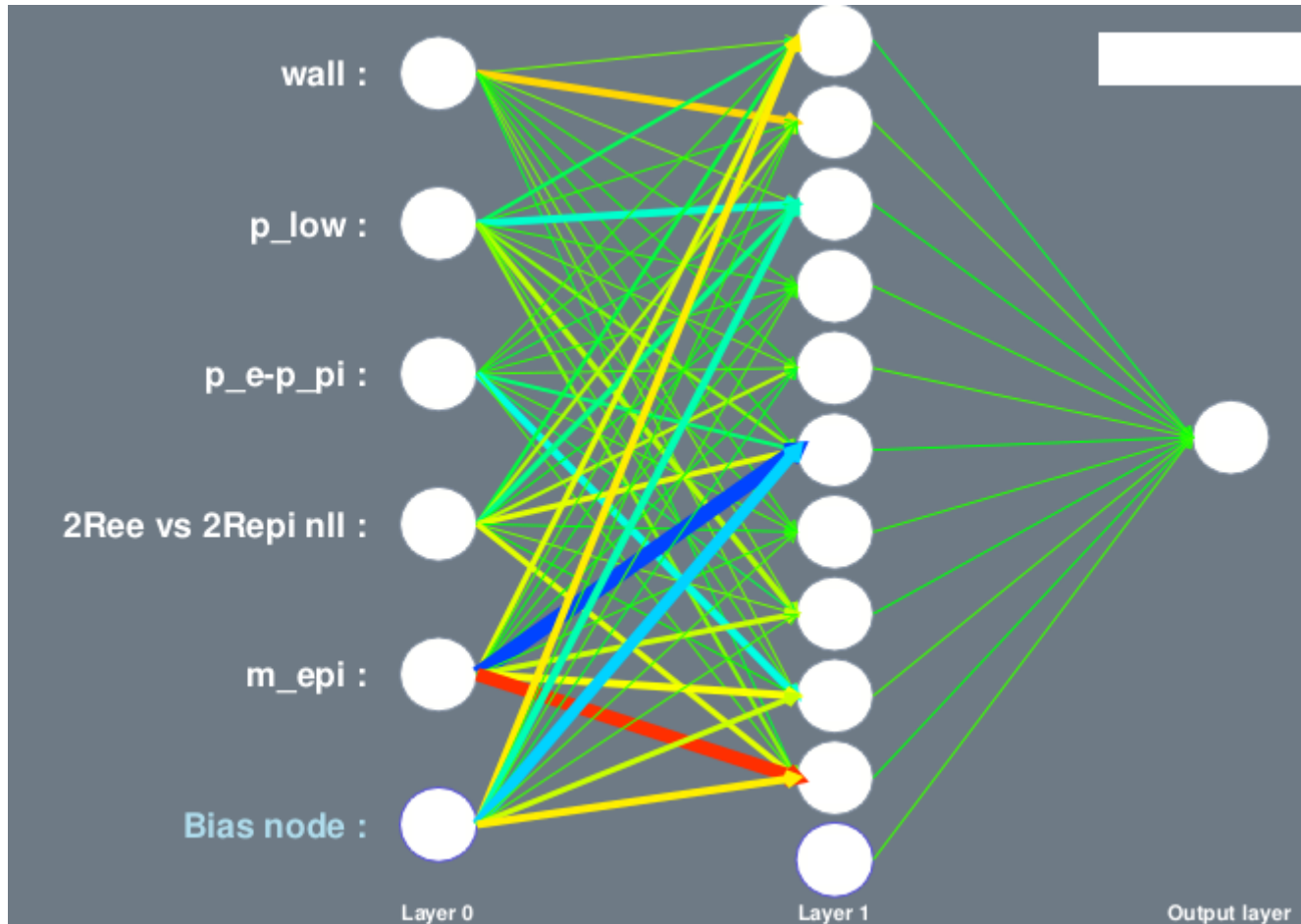


Neural Network





Neural Network Visualization



Other things on the to-do list

- Investigate events where a proton is above Cherenkov threshold (suggested by Mike)