

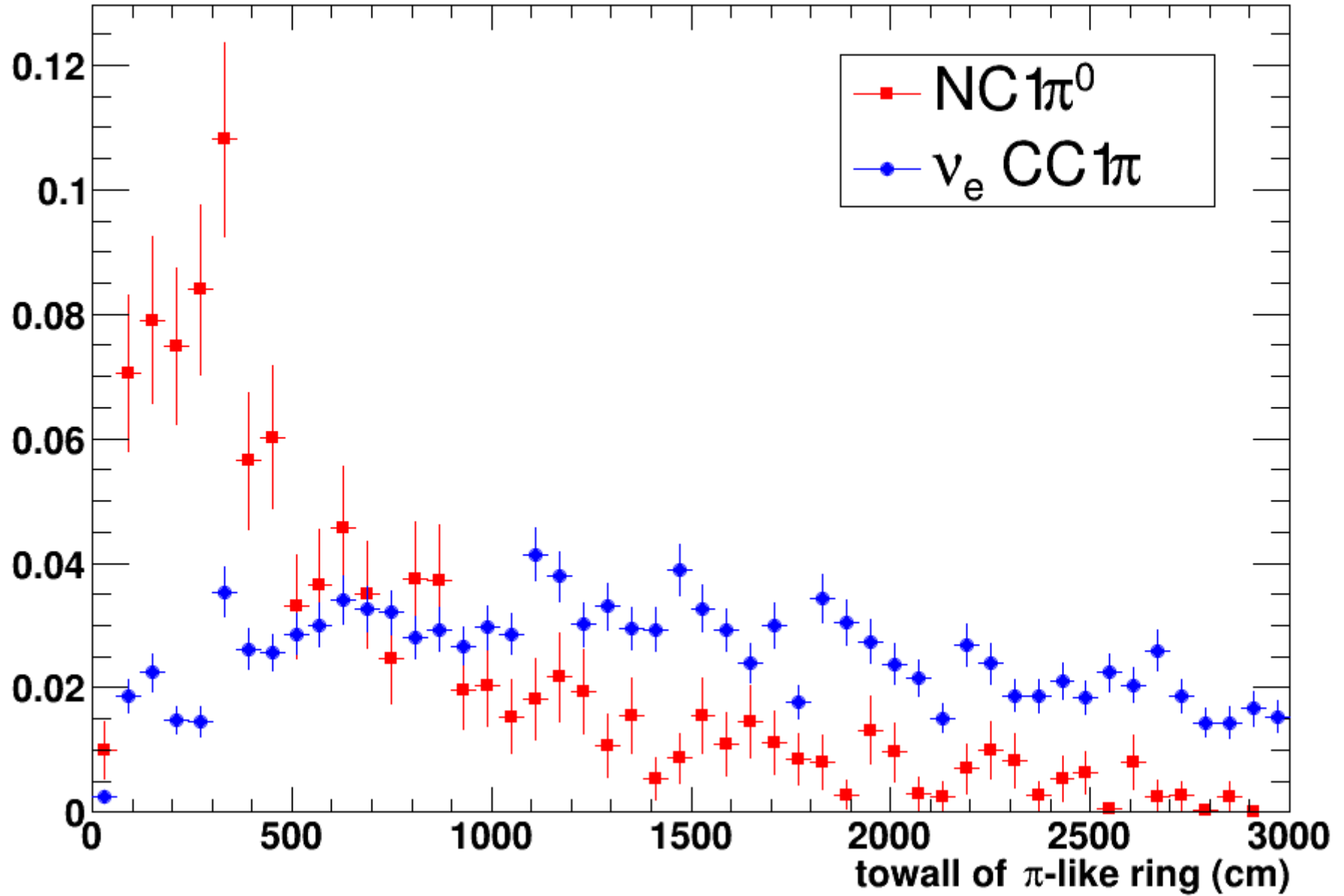
# Progress Update

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UofT Neutrino/DM Meeting  
April 12, 2018

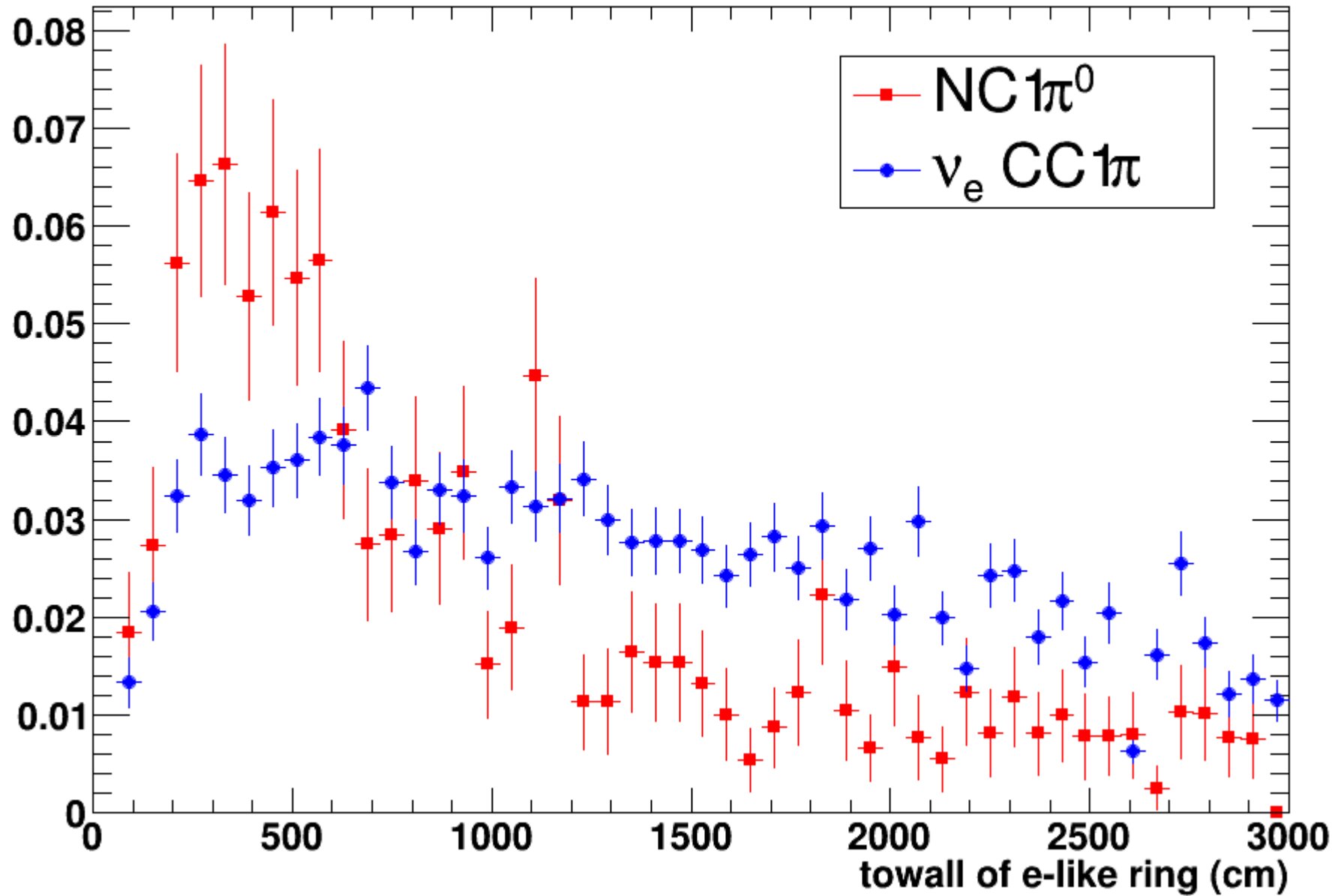
# NC $1\pi^0$ Investigation

- Looked at towall of  $\pi$  and reconstructed  $\pi^0$  mass using fitQun
- Took a look at towall of e as well
- All events are after baseline+ $E_{\text{rec}}$  cuts

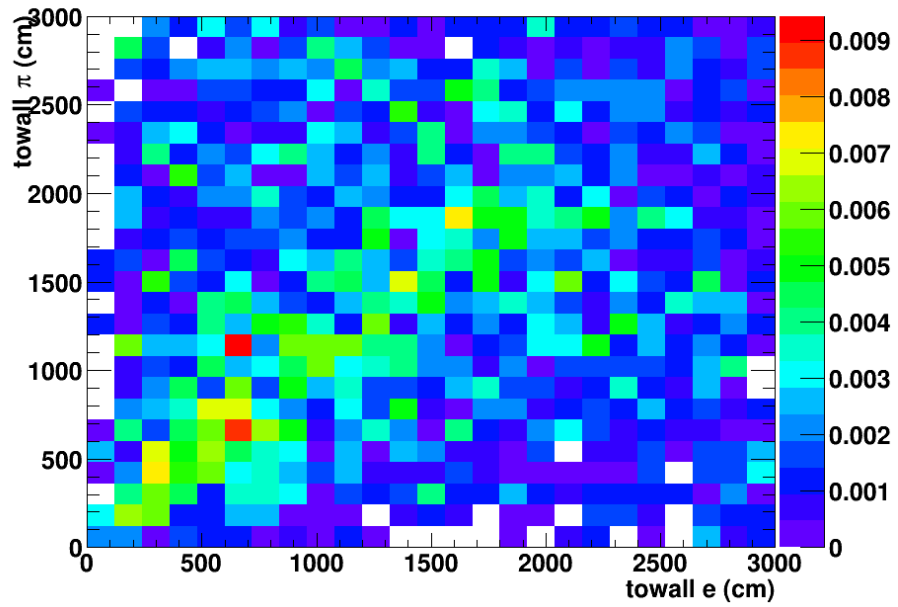
towall of  $\pi$ -like ring:  $2\text{Re } \pi$



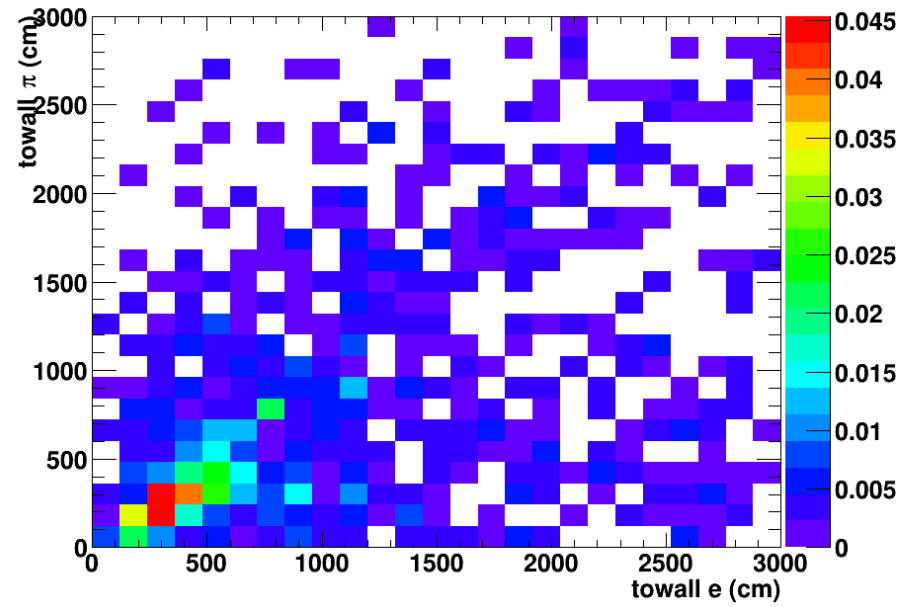
towall of e-like ring:  $2Re \pi$



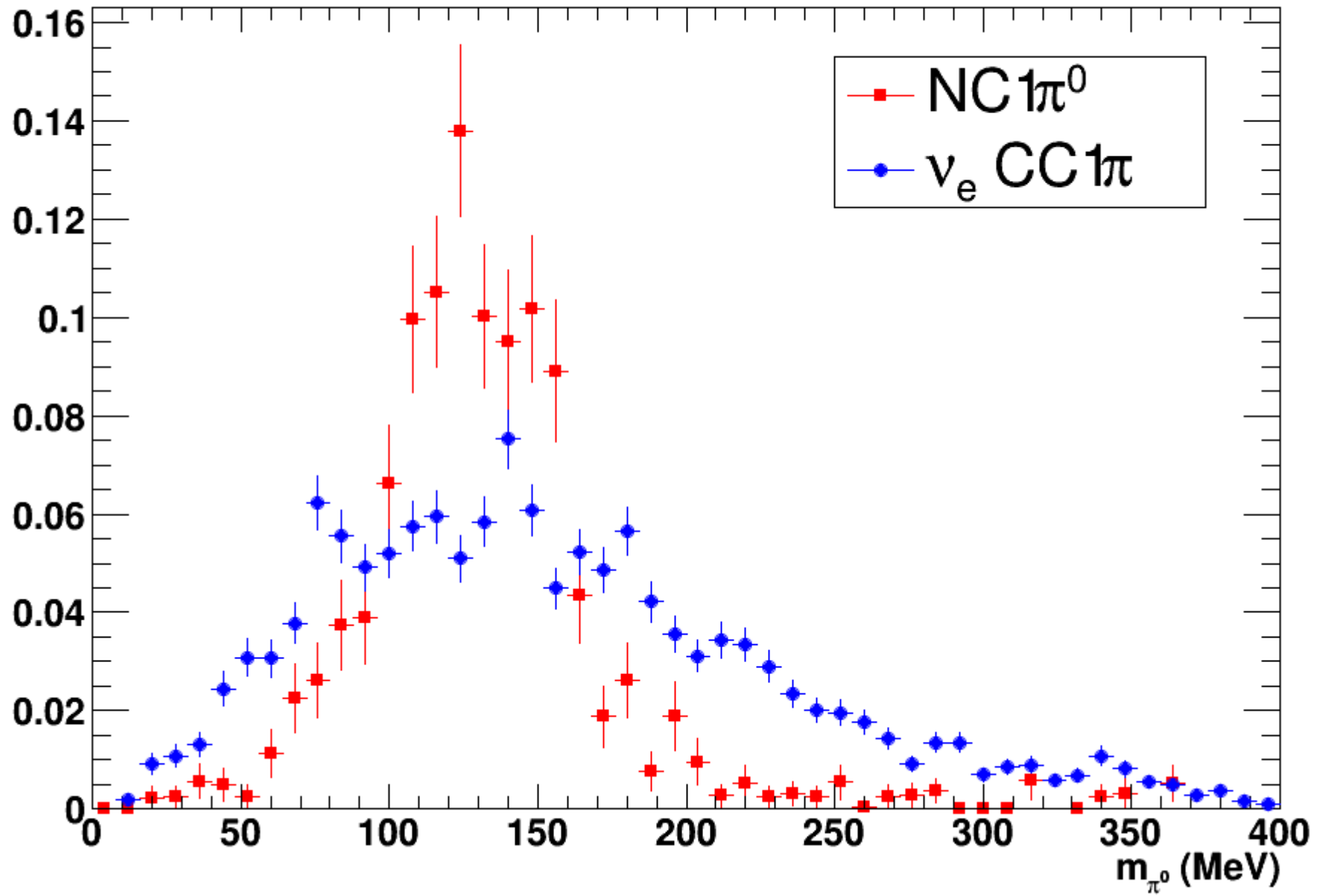
towall  $\pi$  vs. towall e: 2Repi  $\nu_e$  CC1 $\pi$



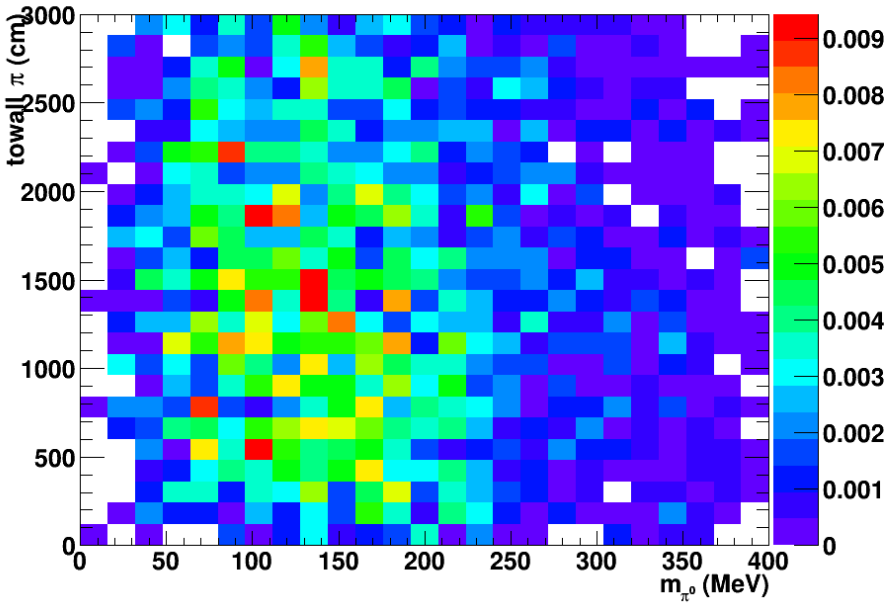
towall  $\pi$  vs. towall e: 2Repi NC 1  $\pi^0$



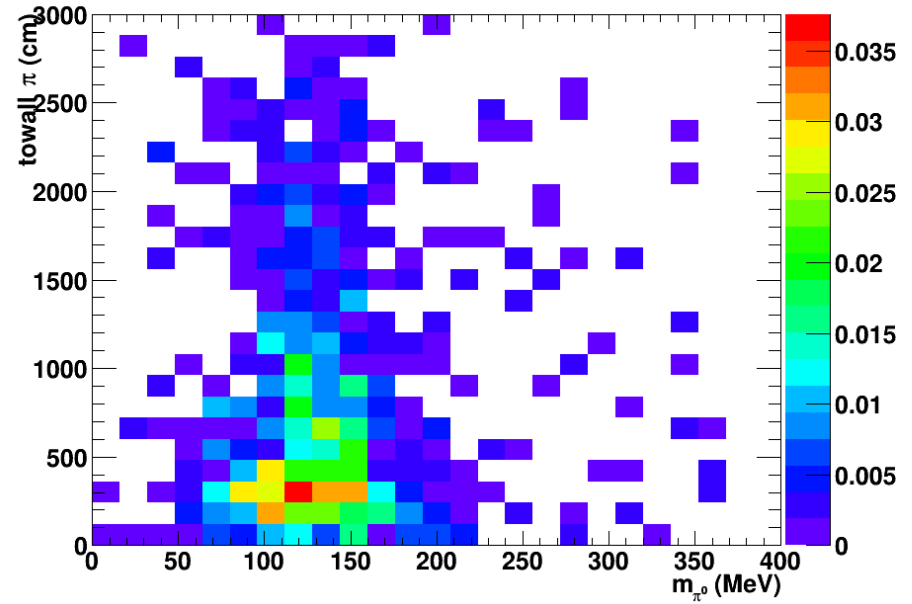
fqpi0mass[0]: 2Re  $\pi$



towall  $\pi$  vs.  $m_{\pi^0}$ : 2Repi  $\nu_e$  CC1 $\pi$



towall  $\pi$  vs.  $m_{\pi^0}$ : 2Repi NC 1 $\pi^0$



# Grid Search Implementation

<p><b>2Re<math>\pi</math></b></p> <p><b>Max: (6,10,7,3)</b></p> <p><b>Max FOM = 0.710</b></p> <hr/> <p><b><math>p_{\text{low}} = 50</math></b></p> <p><b>towall <math>\pi = 450</math></b></p> <p><b><math>m_{\pi^0} \text{ low} = 80</math></b></p> <p><b><math>m_{\pi^0} \text{ high} = 160</math></b></p>	<p><b>2Re<math>\pi</math>1de</b></p> <p><b>Max: (7,2,2)</b></p> <p><b>Max FOM = 1.197</b></p> <hr/> <p><b><math>p_e - p_\pi \text{ low} = -290</math></b></p> <p><b><math>p_e - p_\pi \text{ high} = 310</math></b></p> <p><b>d2se = 162</b></p>
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baseline: 0.652  
prev. grid: 0.706

baseline: 1.145  
prev. grid: 1.195

- Removed  $p_e - p_\pi$  cut in 2Re $\pi$  sample (had minimal effect)
- Refined 2Re $\pi$ 1de search to a smaller range



# Grid Search Cut Flow

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
<b>2Re<math>\pi</math></b>	baseline+E <sub>rec</sub>	0.47	0.63	1.44	2.24	0.13	1.44	3.47	0.29	0.652
	p <sub>low</sub> >50MeV	0.38	0.62	1.42	1.74	0.09	1.42	2.82	0.33	0.687
	m <sub><math>\pi^0</math></sub> <80    m <sub><math>\pi^0</math></sub> >160    toward <sub><math>\pi</math></sub> >450	<b>0.30</b>	<b>0.60</b>	<b>1.35</b>	<b>1.29</b>	<b>0.07</b>	<b>1.35</b>	<b>2.26</b>	<b>0.37</b>	<b>0.710</b>
<b>2Re<math>\pi</math>1de</b>	baseline+E <sub>rec</sub>	0.91	0.92	2.75	1.11	0.09	2.75	3.03	0.48	1.145
	-290<p <sub>e</sub> - p <sub><math>\pi</math></sub> <310	0.66	0.70	2.44	0.44	0.04	2.44	1.84	0.57	1.178
	d2se<162	<b>0.51</b>	<b>0.66</b>	<b>2.37</b>	<b>0.36</b>	<b>0.03</b>	<b>2.37</b>	<b>1.55</b>	<b>0.60</b>	<b>1.197</b>

$$\text{FOM} = S/\sqrt{S+B}$$

Signal = oscillated  $\nu_e/\bar{\nu}_e$  CC events

# Grid Search Breakdown: $2\text{Re}\pi$

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
baseline+E <sub>rec</sub>	1.38	0.44	0.24	0.11	0.11	0.13
p <sub>low</sub> >50MeV	1.35	0.44	0.24	0.09	0.08	0.13
m <sub>π0</sub> <80    m <sub>π0</sub> >160    toward <sub>π</sub> >450	<b>1.30</b>	<b>0.42</b>	<b>0.22</b>	<b>0.07</b>	<b>0.05</b>	<b>0.11</b>

cut	NC 1 $\pi^+$	NC 1 $\pi^-$	NC 1 $\pi^0$	NC N $\pi$	NC 0 $\pi$
baseline+E <sub>rec</sub>	0.26	0.36	1.13	0.23	0.52
p <sub>low</sub> >50MeV	0.15	0.20	1.11	0.21	0.23
m <sub>π0</sub> <80    m <sub>π0</sub> >160    toward <sub>π</sub> >450	<b>0.14</b>	<b>0.18</b>	<b>0.73</b>	<b>0.19</b>	<b>0.20</b>

cut	$\nu_e/\bar{\nu}_e$ CC1 $\pi^{+/-}$	Other	Purity
baseline+E <sub>rec</sub>	1.38	3.54	0.28
p <sub>low</sub> >50MeV	1.35	2.89	0.32
m <sub>π0</sub> <80    m <sub>π0</sub> >160    toward <sub>π</sub> >450	<b>1.30</b>	<b>2.31</b>	<b>0.36</b>

# Prev. Grid Search Breakdown: $2\text{Re}\pi$

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
baseline	1.38	0.44	0.24	0.11	0.11	0.13
$p_e - p_\pi < 700\text{MeV}$	1.37	0.44	0.24	0.11	0.11	0.13
$p_{\text{low}} > 50\text{MeV}$	1.34	0.44	0.23	0.09	0.08	0.12
$m_{e\pi} < 260\text{MeV}$ $> 360\text{MeV} \parallel$ $n _{2\text{Re}\pi} - n _{2\text{Ree}} < -65$	<b>1.32</b>	<b>0.41</b>	<b>0.22</b>	<b>0.09</b>	<b>0.07</b>	<b>0.12</b>

cut	NC $1\pi^+$	NC $1\pi^-$	NC $1\pi^0$	NC $N\pi$	NC $0\pi$
baseline	0.26	0.36	1.13	0.23	0.52
$p_e - p_\pi < 700\text{MeV}$	0.26	0.36	1.13	0.22	0.52
$p_{\text{low}} > 50\text{MeV}$	0.15	0.20	1.11	0.21	0.23
$m_{e\pi} < 260\text{MeV}$ $> 360\text{MeV} \parallel$ $n _{2\text{Re}\pi} - n _{2\text{Ree}} < -65$	<b>0.15</b>	<b>0.19</b>	<b>0.78</b>	<b>0.20</b>	<b>0.20</b>

cut	$\nu_e/\bar{\nu}_e$ CC $1\pi^{+/-}$	Other	Purity
baseline	1.38	3.54	0.28
$p_e - p_\pi < 700\text{MeV}$	1.37	3.52	0.28
$p_{\text{low}} > 50\text{MeV}$	1.34	2.88	0.32
$m_{e\pi} < 260\text{MeV}$ $> 360\text{MeV} \parallel$ $n _{2\text{Re}\pi} - n _{2\text{Ree}} < -65$	<b>1.32</b>	<b>2.43</b>	<b>0.35</b>

# TMVA Troubles

- Found mistake in TMVA setup code

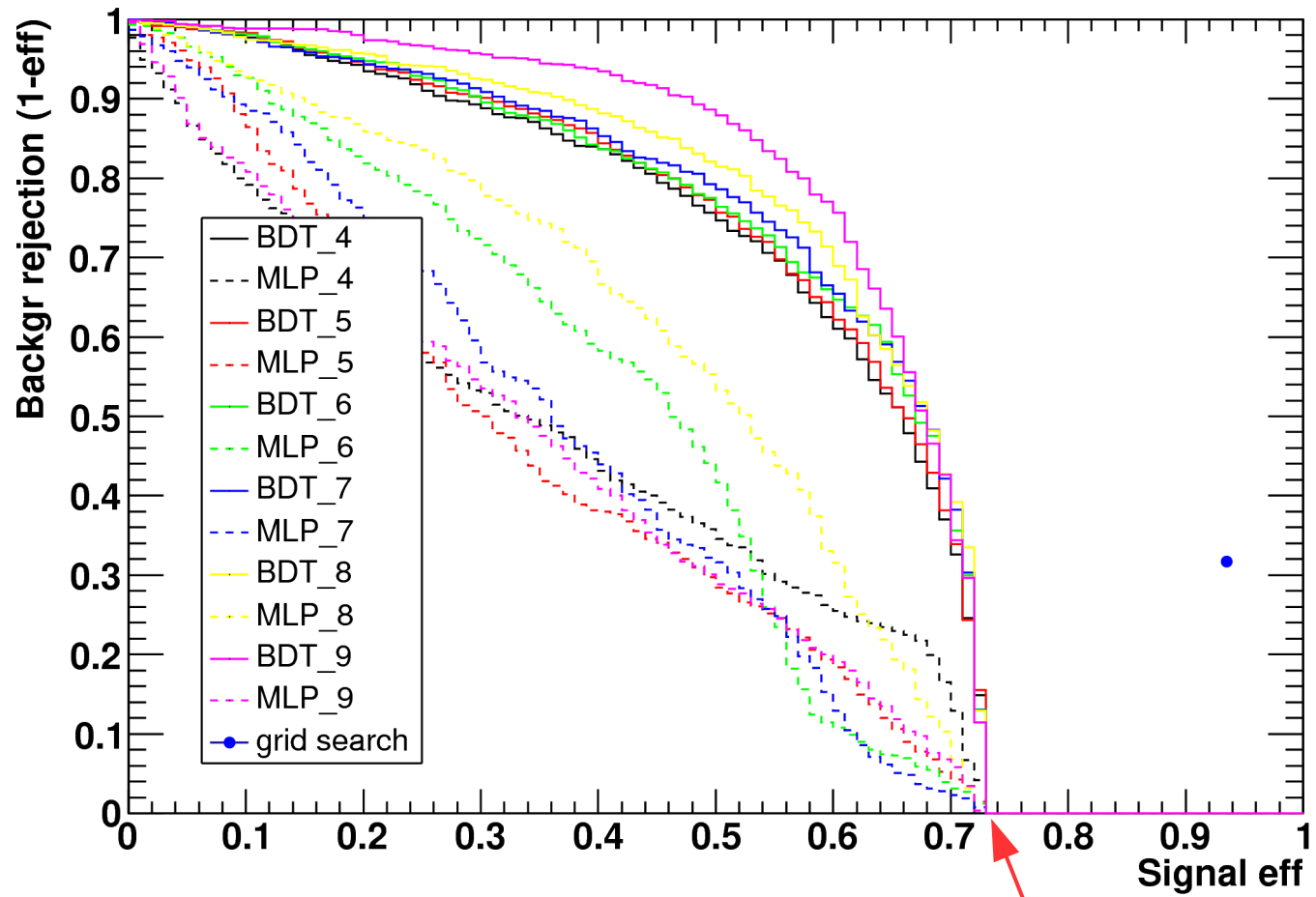
```
factory->PrepareTrainingAndTestTree( mycuts,  
mycutb, "nTrain_Signal=0:nTrain_Background=0:  
SplitMode=Random:NormMode=NumEvents:!V" );
```

- NormMode should be set to “None”
  - NumEvents normalizes the events so that the “average weight” is 1 per event
- Re-ran all previous TMVA algorithms
- Now getting strange (and very poor) results for  $2\text{Re}\pi$  sample
  - For  $2\text{Re}\pi 1\text{de}$  sample, BDT is better but MLP is worse

	2Repi	MLP		BDT	
	Cuts	Notes	FOM	Notes	FOM
4	p_low p_e-p_pi 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll m_epi	HiddenLayers= N+5	0.511	MaxDepth=3	0.588
5	p_low p_e-p_pi 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll m_epi cos(theta)	HiddenLayers= N+5	0.495	MaxDepth=3	0.593
6	p_low p_e-p_pi 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll m_epi cos(theta)	HiddenLayers= N+5,N	0.494	MaxDepth=4	0.610
7	p_low p_e p_pi 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll m_epi cos(theta)	HiddenLayers= N+5,N	0.494	MaxDepth=4	0.616
8	p_low p_e p_pi 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll m_epi cos(theta)	HiddenLayers= N+5,N,N	0.496	MaxDepth=5	0.637
9	p_low p_e p_pi 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll m_epi cos(theta) towall e towall pi	HiddenLayers= N+5,N,N	0.494	MaxDepth=5	0.683

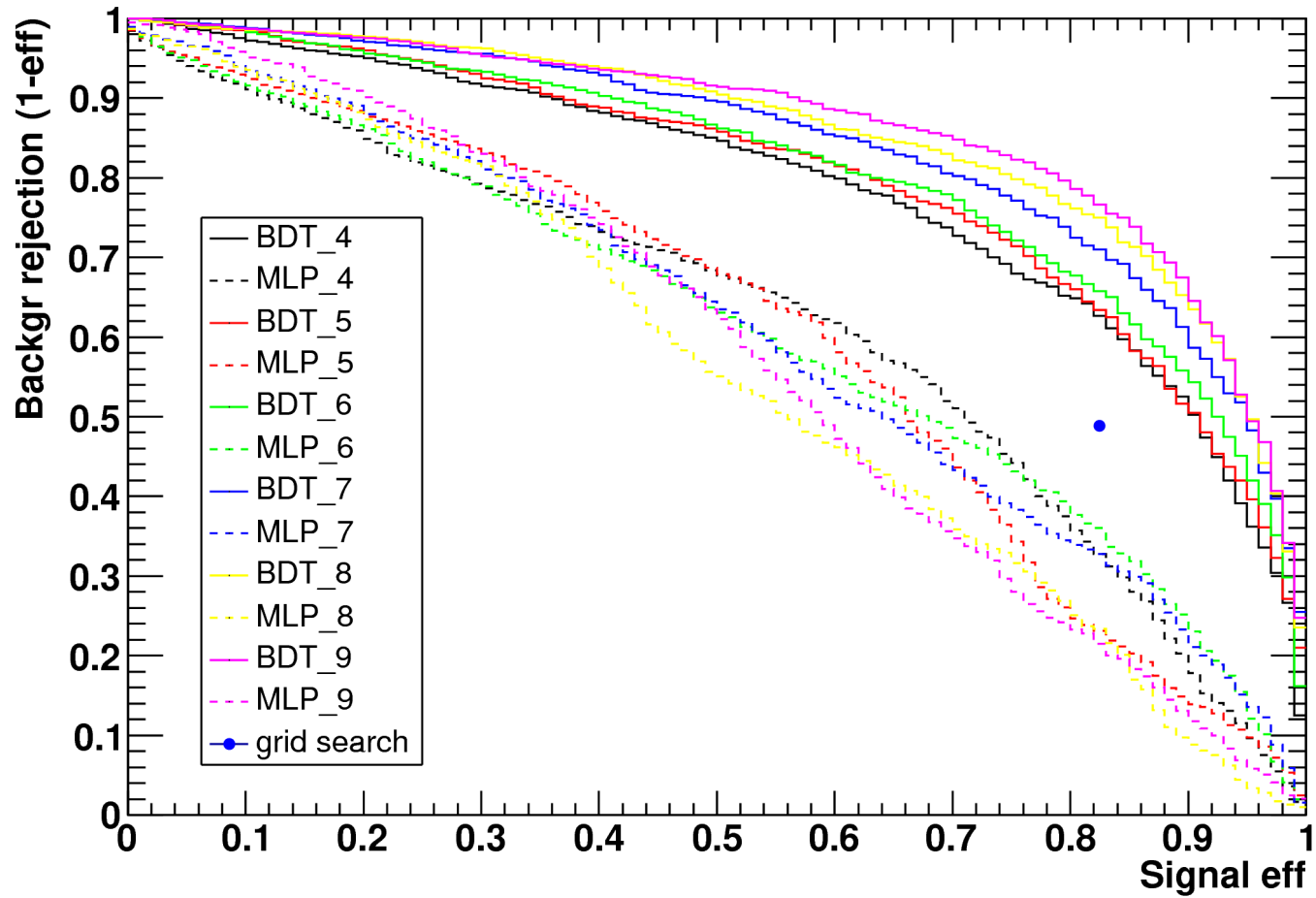
	2Repi1de	MLP		BDT	
	Cuts	Notes	FOM	Notes	FOM
	p_e-p_pi d2se 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll	HiddenLayers= N+5	1.146	MaxDepth=3	1.247
	p_e-p_pi d2se 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll cos(theta)	HiddenLayers= N+5	1.149	MaxDepth=3	1.248
	p_e-p_pi d2se 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll cos(theta)	HiddenLayers= N+5,N	1.147	MaxDepth=4	1.268
	p_e p_pi d2se 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll cos(theta)	HiddenLayers= N+5,N	1.154	MaxDepth=4	1.296
	p_e p_pi d2se 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll cos(theta)	HiddenLayers= N+5,N,N	1.145	MaxDepth=5	1.315
	p_e p_pi d2se 2Repi vs 2Rpie nll 2Rpie vs 2Ree nll cos(theta) towall e towall pi	HiddenLayers= N+5,N,N	1.148	MaxDepth=5	1.329

## 2Re $\pi$ ROC curves

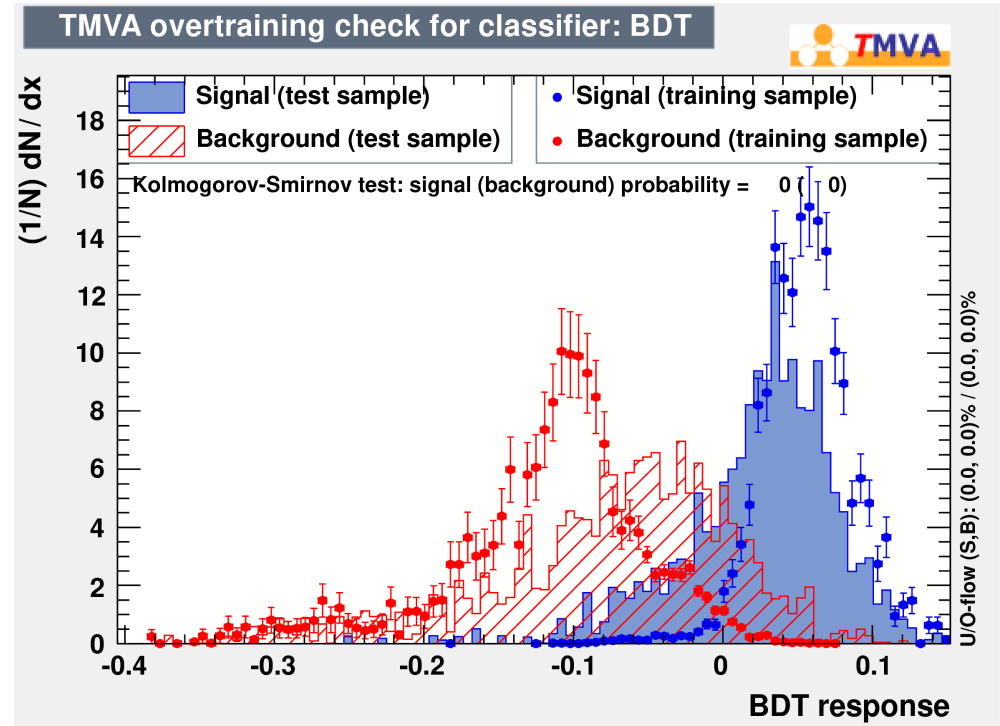
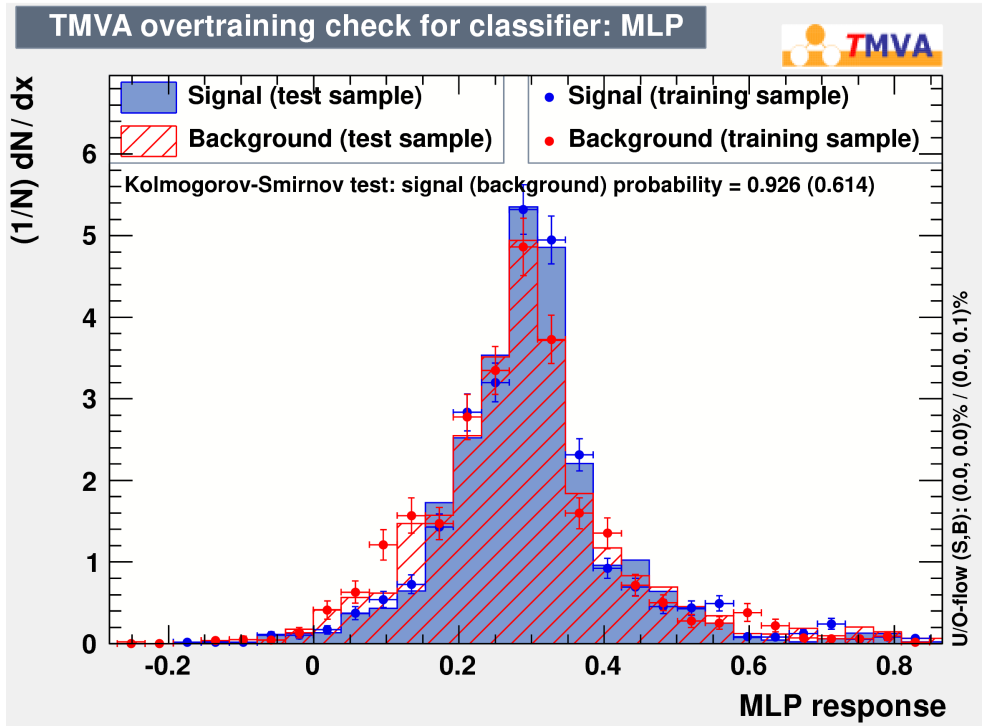


why is there a cut-off here?

### 2Re $\pi$ 1de ROC curves

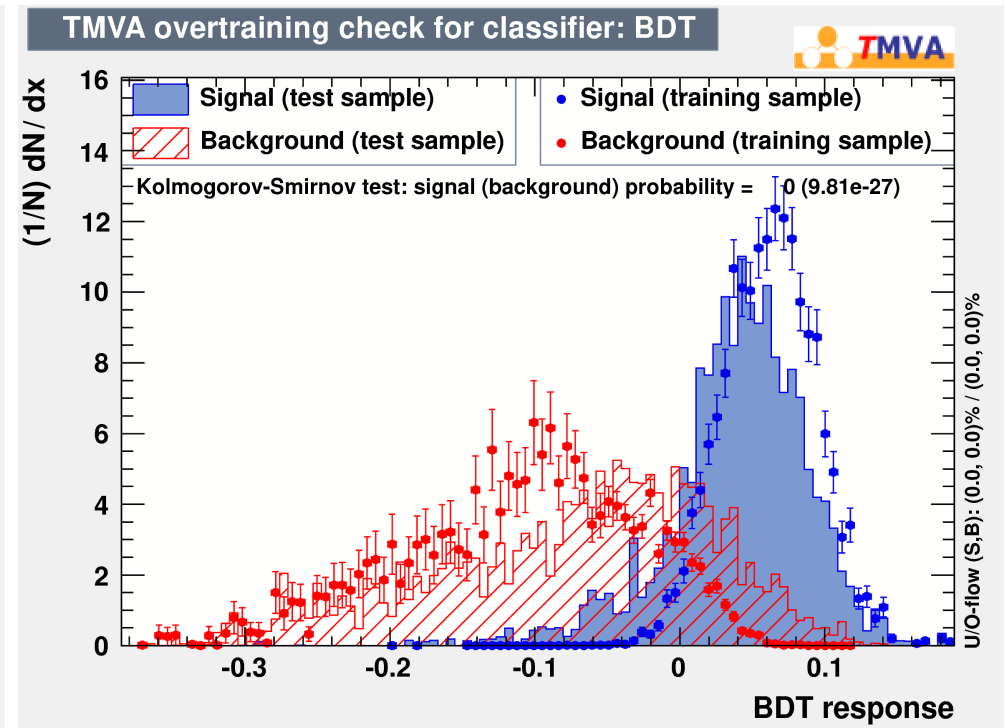
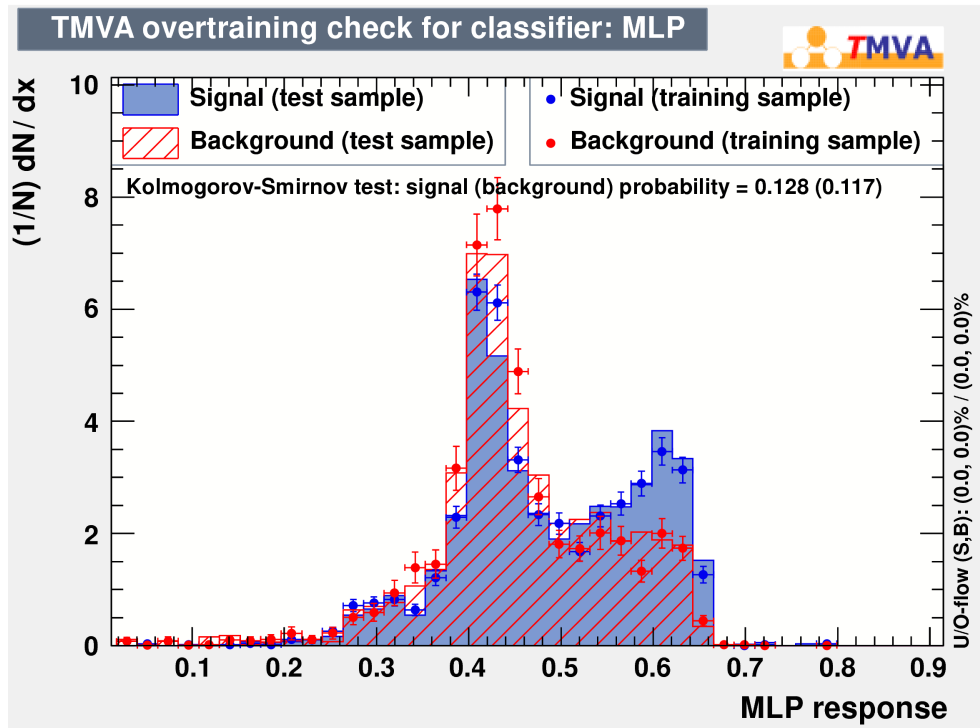


# 2Re $\pi$ Overtraining Check





# 2Re $\pi$ 1de Overtraining Check



# Thoughts

- Why is efficiency of  $2R\epsilon\pi$  sample being cut off at  $\sim 0.73$ ?
- Still looking at TMVA performance on “pre-baseline” events
  - nll2repi, nll2rpie, nll2ree
  - mrmom1, mrmom2
  - towall1, towall2
    - replaced direction and vertex of each ring with towall
      - use less RAM
  - mrpid1, mrpid2
- Studies ongoing